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GENETIC AND ENVIRONMENTAL EFFECTS ON SILAGE PRODUCTIVITY OF CORN (<u>ZEA</u> <u>MAYS</u> L.)

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ABSTRACT

A series of 5 experiments were conducted on silage corn production in Hawaii, with assessment of a variety of genetic and environmental factors. Two corn hybrids were planted bimonthly for 2 years using 6 different population densities, ranging from 50,000 to 200,000 plants/ha. The optimum population density for silage yield was 167,000 plants/ha, but for grain was much lower. Optimum populations for grain under unfavorable seasons (winter) were lower than those in favorable seasons (spring and summer). Significant population x season interaction for grain and stover yields would recommend lower population density in winter planting for silage production in Hawaii.

Increasing population resulted in reduction of yield components and plant characters such as height, stem diameter, and leaf area. Grain and stover yields showed seasonal cyclic variations throughout the years, with higher yields in spring and summer, and lower yields in fall and winter seasons. Plant characters and yield components showed similar seasonal variations to those of grain and stover yields. Minimum temperature and solar radiation were important determinant factors for corn production in Hawaii.

Brown midrib-3 mutant corn, low in lignin content and high in digestibility, was compared to normal counterpart corn to determine yield response and their components. Significant grain and stover yield reductions were observed in *bm3*, with average reductions of 20 % for grain yield and 17 % for stover yield. Several hybrids showed small reduction in total yield (6-7 %), indicating possible use of bm3 for high quality corn silage.

Mean squares of general combining ability (GCA) and specific combining ability (SCA) were highly significant for grain and stover yields. The GCA/SCA ratio for stover yield was much higher than that of grain yield, indicating that the GCA effect was more important than SCA in stover yields. The GCA/SCA ratio for filled ear length and number of kernels were much higher than those for grain yield. This result indicated that the GCA effect was more significant for yield components than for grain yield.

Corn genotypes were evaluated for yields and their characters, under normal daylength (average 12 hours) and extended daylength of additional 4 hours of light in Hawaii. Tasseling and silking were delayed under extended light for all genotypes. Plant characters, including plant height, ear height, number of stem nodes, LAI, and stem diameter increased significantly under extended light. The magnitude of increase for those characters depended on the sensitivity to photoperiod.

Significant grain yield reduction was observed, but stover yield increased significantly under extended light. The interval from tasseling to silking was much longer under extended light, creating poor condition for pollination. No difference of total dry matter yield was observed between normal and extended daylength conditions. The increase in stover yield was offset by the decrease in grain yield.

Tropical inbreds from wide genetic sources were evaluated for silage yield and plant characters with Hawaiian tester inbreds. Among the 217 hybrids studies, about 5 % of those were superior for silage yields to the Hawaiian superior check hybrid. CIMMYT, H632, and ICA inbreds revealed superiority for silage production. These inbreds also had high GCA effects for grain yield. In general, the superior hybrids selected were later in flowering and maturity. The late maturing hybrids were 10-15 days longer in maturity than early maturing hybrids. The superior hybrids had an advantage for silage production because of much higher yield even in the longer growing period.

A 7-entry diallel set based on the factorial experiment was evaluated for silage yield and genetic characters. In general, late maturing hybrids showed higher grain and silage production. Stover yield was correlated with most of the plant characters and rust rating was negatively correlated to grain and stover yields.

GCA and SCA were significant for both grain and stover yields. The GCA/SCA ratio indicated that additive genes were more important in the genetic variation. GCA x season and SCA x season interactions were significant for grain and stover yields, indicating that gene effects were not stable for grain and stover yield under dissimilar environment.

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1. INTRODUCTION

Corn silage is widely used for ruminant livestock feeding. In addition to high yield, a silage corn should also be of good quality, palatable and preferred by the animals. Increasing silage corn yield and quality can be achieved by improvement of cultivation, fertilization, planting date, plant population, cultivar, and maturity. Much work has been done on the effects of planting density on grain yield of corn. However, relatively little work has been published on silage yield. The available reports indicate that the use of high populations and narrow rows can increase total silage yields. It is necessary to know the interaction of season and population and its effect on silage corn production in the tropics.

Sensitivity to photoperiod limits the exchange of germplasm materials between temperate and tropical regions. Selection for photoperiod insensitive genotypes can result in increased exchange of cultivars between different latitudes. Another aspect of light is the intensity of radiation. Light intensity varies througout the year in Hawaii; it is much higher in the summer than in the winter. The silage yields of corn under tropical conditions are usually lower than those of temperate regions. Silage corn plantings in different seasons will provide information on genotype x environment interactions, as corn genotypes respond differently in different environmental conditions.

The quality of corn silage is an important factor for ruminant animals. Lignin is an important limiting factor in the digestibility and utilization of fibrous feeds by ruminants. Nutrient availability and utilization can be increased by chemical and genetic modification. Producing corn silage with a lowered lignin content is an important objective in improvement programs. The brown midrib genes of corn significantly reduce lignin contents. Maturity at harvest is recognized as an important factor in determining the quality of corn harvested for silage. Generally, late maturing genotypes produce higher silage yields than early maturing genotypes.

Selection for yield can be less effective compared to selecting for specific yield components because many genes are involved in controlling yields of corn. Correlation studies among plant characters and yield components have provided valuable information for increasing grain and silage production.

Several studies were conducted to investigate factors influencing silage production in relation to genetic and environmental effects, including population density, hybrid background, daylength, and annual variations in light and temperature. Plant characters and yield components and their relation to grain and stover yield were studied.

2. LITERATURE REVIEW

2.1. Effects of Population Density on Corn.

2.1.1. Yield response to population density.

Corn silage is a major feed component for all ruminant livestock in the Corn Belt area and is used widely in many countries. The yield of corn grain per unit land area is highly dependent upon population, plant distribution, fertility level, and growth characteristics of the hybrid adapted to that area. Rutger and Crowder (1967 a) obtained the highest yields of silage at 80,000 plants/ha in New York in a study with six hybrids at populations vayring from 40,000 to 80,000 plants/ha. Highest grain yields were obtained at 70,000 plants/ha. Their results indicate that higher planting rates can be used for producing silage than grain. Genter and Camper (1973) observed maximum grain yield at 54,300 plants/ha, but obtained maximum yield of dry matter at 64,200 plants/ha in Virginia. Alessi and Power (1975) reported that optimum population for corn grain ranged from 30,000 to 40,000 plants/ha in North Dakota.

Bryant and Blaser (1968) reported that the highest silage yield was obtained at 98,800 plants/ha in Virginia. They also found that the average yields of silage were higher and of grain smaller in the late than early hybrids. Grain yield increased significantly as plant population increased from 49,400 to 123,500 plants/ha, then dropped off at population above 148,000 plants/ha in Hawaii (Chung et al., 1982). They also reported that stover yields increased about 50 % as population increased from 49,000 to 123,500 plants/ha, with no further increase at higher populations. They suggested that optimal population densities for silage corn production in Hawaii were between 98,800 and 135,900 plants/ha. Knapp and Reid (1981) reported that grain yields were highest when populations were between 48,000 and 62,000 plants/ha in New York. They obtained highest silage yield at a population nearer 62,000 plants/ha.

In general, silage yields maximize at a higher population than grain yields. The optimal population for either, however, varies with climate, soil, hybrid, and differences in management. Grain yields were increased as the population increased from 34,500 to 51,750 plants/ha in North Dakota (Nunez and Kamprath, 1969). Phipps (1975) obtained the highest dry matter yield of ears and total dry matter yield at 167,000 plants/ha in England. Robinson and Murphy (1972) observed good yield of grain and silage at population up to 98,800 plants/ha when adequate fertility was provided. In Nebraska, Colville and Burnside (1963) obtained the highest grain yield at 58,000 plants/ha. Sotomayor-Rios et al. in Puerto Rico (1979) reported no yield advantage when densities were increased to 90,000 plants/ha, compared to 45,000 plants/ha.

Stivers et al. (1971) showed that a population of 69,000 plants/ha produced 4.0 % more dry matter than the 54,000 plants/ha in Indiana. Average grain yields of the 69,000 plant/ha were 2.3 % lower than at 54,000 plant/ha in 11 location-year trials. They also reported that average grain yields were increased 7.3 % with 51 cm row spacing, and 4.4 % with 76 cm row spacing in comparison to 102 cm row spacing.

Several researchers have found that corn yields increased with decreased row spacings (Hoff and Mederski, 1960; Lutz et al.,1971; Stickler, 1964). However, Bryan et al. (1940), Giesbrecht (1969), and Stickler and Laude (1960) reported no positive response of corn yields to narrow row spacings. Corn silage yield increased significantly as populations increased from 49,000 to 86,000 plants/ha in Georgia (Cummins and Dobson, 1973). Significantly higher silage yields were obtained in 51 than 102 cm rows. However, Rumawas et al. (1971) in Indiana found no difference in whole plant yield due to row spacing (50 and 75 cm) when harvesting stage at about 65 % moisture. Giebrecht (1969) reported maximum grain yield at 75,000 plants/ha in Canada, but row spacing did not affect grain yield. He also noted that varieties differed significantly in their yield response to increased plant population.

Rutger and Crowder (1967) observed population x location interactions for both silage and grain yields. They also found a hybrid x population interaction for grain yield. Sotomayor-Rios et al. (1979) found no population x hybrid interaction for yield, yield components, and plant characters. They observed that hybrid X304C had the highest yield among 12 hybrids used. Several researchers have noted that for early hybrids the optimal population was higher than for later hybrids (Brown et al., 1970; Colville, 1966; Duncan 1954; Hunter et al., 1970). This difference has been attributed to the smaller plant size and lower leaf area of most early hybrids. Moll and Kamprath (1977) in North Carolina found that increased population density resulted in greater yield per hectare in the improved genotypes with recurrent selection. Yield of the five and ten cycle selections, averaged over densities were 27 and 42 % greater, respectively, than the yield of the original genotype.

2.1.2 Plant Characters in Relation to Population Density.

As plant population increased, the weight of the individual plant constituents decreased proportionately (Bryant and Blaser, 1960). They found no difference in maturity of the plant, as indicated by the percent dry matter, by increasing the plant population. Increased plant densities usually result in a long interval between anthesis and silking (Buren et al., 1974; El-Lankany and Russell, 1977; Woolley et al., 1962) and genotypes classified as density tolerant have a shorter pollen-shed to silk interval than intolerant genotypes. Mason et al. (1976) observed delayed days to mid-silking with increasing population density.

Moll and Kamprath (1977) showed that ear height and plant height were significantly increased at higher populations. Giesbrecht (1969) observed increases in ear and plant heights with increases in population. Ear and plant heights at 75,000 plant/ha were 10 cm taller than those at 30,000 plants/ha. At high populations, ear height (but not plant height) was increased and stalk diameter decreased (Rutger and Crowder, 1967). As population increased, stalk diameter decreased significantly (Genter and Camper, 1973). They observed no difference in plant height but a slight increase in ear height with increasing population density. They also found significant reduction of ear weight as population increased. Chung et al. (1982) reported that lodging at silage stage increased as population density increased, reaching almost 50 % at 296,400 plants/ha.

As plant populations are increased, the yield of individual plants is reduced. However, the total yield per unit area may increase because the small decrease in yield per plant is compensated for by the increase in plant numbers. Grain yield per plant has been found to decrease with increased population and the rate of decrease is affected by factors such as fertility level and variety (Hoff and Mederski, 1960; Duncan, 1958). The reduced production of individual corn plants with increasing population is due to increased environmental stress resulting from greater competition among plants. Phipps (1975) showed that increasing density significantly decreased ear weight and there was a significant negative correlation between weight of ear and population. Prine and Schroder (1964) reported that weight per ear and number of ears per plant decreased with increasing population. They concluded that the poorer light environment resulting from increased shading at high populations was the principal factor decreasing yield components.

One of the major factors limiting high yield in corn grown at high population density is barrenness (Stinson and Moss, 1960; Woolley et al., 1962). As population increased, ear size decreased and barrenness increased (Colville and Burnside, 1963). Barren stalks increased from 3 % at 30,000 plants/ha to 15 % at 75,000 plants/ha (Giesbrecht, 1969). Mason et al. (1976) observed increased barren stalks with increasing population density. They also showed significant reductions of ear weight as population increased. Stivers et al. (1971) found increase in barren stalks with increasing population densities. They observed 25 % of barren stalks in a 54,000 population and 40 % in a 69,000 plants/ha population. The number of barren stalks was also significantly affected by population levels and hybrid used (Woolley et al., 1962). The barrenness was 2 % at 39,500 population, and 12 % at 60,000 plants/ha population. Number of barren stalks increased and ear weight decreased with increased population (Alessi and Power, 1974). Woolley et al. (1962) observed decreases of 100 seed weight as the population level increased but it was not significant.

Usually correlation among the yield components and of yield components with yield would be most useful to corn breeders for prediction purposes. Ordas and Stucker (1977) reported that phenotypic and genotypic correlation were of the same magnitude and tended to increase with increasing planting density. They concluded that ear length appeared to be a satisfactory selection criterion for yield progress at high densities. El-Lankany and Russell (1971), using test crosses of 20 inbred selections, found the number of significant correlations increased as the planting density increased, indicating a higher degree of relationship among the traits at the level of greater environmental stress to the individual plants. Collins et al. (1965) in Iowa found that prolific hybrids were more consistent than single eared hybrids in yield performance as related to population density. Russell (1968) reported that prolific hybrid produced better than non prolific hybrid at higher plant densities, because prolificacy seemed to give resistance to barrenness under stress conditions. Duvick (1974) showed that prolific corn was more resistant to barrenness in the higher population densities.

DeLoughery (1979), Fery and Janick (1971), and Genter and Camper, (1973) found a decrease of harvest index (HI) with increasing population density. HI, the ratio of the grain dry weight to the total above ground dry weight of a crop at maturity, is an index similar to grain/stover ratios used to evaluate a crop's partitioning efficiency. Early maturing hybrids had higher HI than late maturing hybrids (Bonciarelli and Monotti, 1975; Bryant and Blaser, 1968). A high grain/stover ratio in silage may be as important as total dry matter production. Many feeders grow productive hybrids to produce a silage with high grain and low stalk ratios.

2.1.3 Leaf area and leaf area index

<u>LAI and yields</u>:

The photosynthetic rate of a plant canopy per unit of land area is closely related to the area and orientation of its leaves. Canopy photosynthetic rates may range from 92 % of theoretical maximum at LAI 3.0 to 76 % at LAI 7.0 (Duncan, 1971). Duncan (1972) found a nearly linear increase of grain yield as LAI increased to 4.0, but no further increases above LAI of 4.7. Eik and Hanway (1966) showed a linear relationship between LAI at silking time and yield up to an LAI of 3.3, above which the linear relationship did not continue. Rutger et al. (1971) found that the relationship between grain yield and LAI varied appreciably among genotypes, such that the yield/LAI ratio showed wide differences. Hybrids with a high ratio were considered the most efficient types. Prior and Russell(1976) reported that the yield/LAI ratio decreased with increasing population density. This was due to the differences of increasing rates of yield and LAI with increasing population density. Optimum LAI should vary among hybrids depending upon the prolific potential of each hybrids.

In North Carolina Nunez and Kamprath (1969) found that a LAI of 3.5 was reached at about 50,000 plants/ha which gave maximum yields. The LAI increased linearly as plant population increased from 34,000 to 69,000 plants/ha. The leaf area per plant varies with hybrids, populations, and growth conditions. Long season hybrids usually have larger leaf area per plant than short season hybrids because the long season hybrids have more and larger leaves. Brown et al. (1970) found that at a given population the leaf area was 49 dm^2 per plant for D-XL65 and 65 dm^2 per plant for P-309B. Hicks and Stucker (1972) found that among 18 hybrids, width of the leaf above the ear varied from 8.6 to 11.2 cm and leaf length varied from 78 to 94 cm. For the two hybrids LAI varied from 2.7 at a population of 39,520 plants/ha to 5.5 at a population of 88,920 plants/ha. Mason (1976) reported that LAI was positively correlated with grain yield, grain weight/ear, and population density.

The photosynthetic capacity of crops expressed as LAI is much more variable in agricultural environments than the photosynthetic efficiency measured by net assimilation rate (NAR); for example, variation of nutrient supply by fertilizer application, and differences between seasons in weather conditions, affect dry matter yield mainly varying LAI (Watson, 1958). The extent to which the rate of dry matter production can be increased by increase in LAI will depend on how NAR is affected by change in LAI. As LAI increases, mutual shading of the leaves would be expected to decrease photosynthesis by part of the foliage, and so to decrease NAR.

According to Pendleton and Hammond (1969), the relative photosynthetic potential of the corn leaves in the top one-third of the canopy was twice as high as middle leaves and five times as high as leaves in the bottom one-third. At the low population density (4,942 plants/ha), the removal of the middle leaves has the greatest effect on grain yield. In all other plant populations, removal of the top leaves showed the greatest yield reduction. The NAR of corn was linear to the LAI when it was less than 2.7, but at higher LAI values it declined rapidly and showed a tendency to level off (Hoyt and Bradfield, 1962). They also reported that the dry matter produced per square meter of leaf surface from grain initiation to muturity, showed that the top leaves were much more productive than the bottom leaves. The dry matter produced per square meter of leaf area in a stand with a LAI of 3.3 by the top, middle, and bottom leaves was of the ratio 4:2.2:1. It is suggested that the low amount of dry matter produced in the bottom leaves was due to reduction in light intensity from shading by the above leaf canopy, and that reduced production in the bottom leaves caused the decreasing NAR at high LAI.

According to Scarsbrook and Doss (1973), the relationship between grain yield or stover yield and either LAI by segment or total LAI were quadratic rather than linear equations. There was an excess LAI with the 80,000 plants/ha population which was not associated with an increase in grain yield. Generally the lower populations had LAI values below those associated with maximum yield.

LAI was generally highest for the highest population and for the later maturing hybrids (Alessi and Power, 1975). Maximum LAI for high population ranged from 1.8 to 4.9. LAI per plant decreased with increasing population (Moll and Kamprath, 1977). Nunez and Kamprath (1969) observed that LAI increased and leaf area per plant decreased with increasing plant population. The reduction in leaf area per plant was at lower rate than the rate of increase in total leaf area as the population was increased. They found a linear relationship between yield of grain per plant and leaf area per plant. LAI increased with increasing population density (Williams et al., 1968). LAI ranged from 3.5 to 8.5 for densities 17,500 to 125,000 plants/ha. According to Williams et al.(1965), LAI was 20 at the 700,000 plant/ha population. They observed the highest dry matter yield at this population. This would certainly seem to indicate that excessive respiration in shaded leaves of corn with an LAI near 6 could not account for the yield decline at high populations.

2.2 Corn Silage

2.2.1. Maturity of Corn for silage.

Maturity at harvest is an important factor influencing the quality of corn harvested for silage. Total yield of forage and plant composition are important factors to consider in silage production. They could be appreciably influenced by maturity at harvest. Bryant et al. (1966) reported that corn ears at later harvests made up a considerably larger portion of the total silage yield than at earlier harvests. Leaves, stalks and husks were a smaller portion of the mature plant than of the immature corn plant. They found that the total digestible nutrient values were slightly higher for the corn cut at the dent stage.

The milk production of the cows fed mature (dent stage) silage was slightly higher than for those fed immature silage. Bryant et al. (1965) showed that persistency of milk production was higher on the mature than on immature corn silage. Average milk production on the immature corn silage was 32.3 lb compared to 33.1 lb per day for the mature corn silage. This increased milk production on the mature corn silage might have been due to higher consumption of mature corn silage than immature corn silage. They also found that the apparent dry matter digestibility of the immature and mature corn silage was 66.7 and 68.6 %, respectively.

It has been reported that corn silage quality increases with maturity up to the dent (dough) stage of the grain (Byers and Ormiston, 1964; Johnson and McClure, 1968). Gordon et al. (1968) found a decrease in dry matter intake, and Johnson and McClure (1968) observed a decrease in dry matter digestibility with late harvested silage as compared to an earlier dent (dough) stage harvest. Cummins (1970) observed that *in vitro* dry matter digestibility (IVDMD) of ears increased with maturity then leveled off.

Own (1967) reported that heavy fertilization of corn generally improves the nitrogen content of the resulting forage, but otherwise has little effects on nutritional quality. He found early maturing or high-grain varieties are usually equal or slightly superior in terms of daily lactation performance to late maturing silages of low-grain content. Rutger (1969) observed that fresh silage yields of late hybrids were considerably higher than those of early hybrids. However, dry matter yield of the early hybrid were nearly as high as those of late hybrids. Thus harvest and storage cost per unit of dry matter production would be higher for the late hybrids. He also found higher feeding value of silage made from late maturing hybrids, primarily because an animal can consume more dry silage per day than wet silage.

In areas where early maturity is a major consideration it is suggested that hybrids used for silage should be fully as early as the best adapted grain hybrids for that region. Thompson (1968) reported that late maturing tropical corn grown in North Carolina produced 13 to 41 % more dry matter and 4-28 % more estimated total digestible nutrients than check hybrids. He also found a decrease in protein content but increased fiber contents in late-maturing tropical corn. These data demonstrate the silage potential of late maturing tropical corn. However, increased production alone is not necessarily a convincing criterion for practical aspects. Tall growth is a major cause of the lodging problem. Thompson concluded that improving stalk strength by breeding would help to minimize but not eliminate the lodging hazard.

Bryant and Blaser (1968) reported that stalks were a significantly smaller proportion of the total dry matter in early than in late hybrids. However, Genter and Camper (1973) in Virginia reported that the early hybrids tended to be lower in grain yield and total dry matter than the later hybrids. The later maturing, taller hybrids were better adapted to competition in high populations than were the earlier hybrids (Giesbrecht, 1969).

Rutger and Crowder (1967) and Termunde et al. (1963) showed no consistent relationship between maturity and response to different populations. In general, later- maturing corn hybrids have been reported to produce the highest grain and silage yield (Colville, 1966; Knapp and Reid, 1981; Lutz et al., 1971; Lutz and Jones, 1969). Higher silage yield from late hybrids than from early and medium hybrids may be attributed to the longer period of time available for the corn to grow. Some studies have shown, however, that silage yield from different maturing hybrids were similar (Colville and McGill, 1962). Other researchers have noted that longer-season hybrids produced higher silage yields but early hybrids had higher grain yield (Alessi and Power, 1974; Andrew and Peek, 1971; Bryant and Blaser, 1968). According to Stivers et al. (1971), full season corn hybrids generally produced higher yields of grain than either early or late hybrids in Indiana.

The maximum whole plant dry matter yield of corn is normally attained several days prior to the maximum grain day weight (Daynard et al., 1969). Daynard and Hunter (1975) reported that whole plant dry matter digestibility of corn was relatively constant over a range of moisture contents from 75 % to 56 %, indicating that digestibility might not be a major factor in selecting a proper harvest stage for corn silage. Huber et al. (1965) and Chamberlain et al. (1971) observed reduced dry matter intake with ruminants when the moisture content of corn silage was higher than 65-58 %. Gordon et al. (1968) reported that the production of high quality silage from late harvesting was quite possible under good storage conditions, but the practice would be impractical because of high field losses. The mature corn silage was slightly superior to immature silage (Huffman and Duncan, 1956).

Maximum yield of digestible energy per hectare would be achieved by harvesting between the dough-dent and glaze stage of maturity (Johnson and McClure, 1968). They concluded that the later the maturity, the more attention must be given to proper protein supplementation. Leask and Daynard (1973) reported that hybrids differed significantly in the yield, feeding value, and moisture percent of the stover fraction. They mentioned that selection is possible for hybrids that combine high grain yield and early maturity with desirable stover characteristics.

Total dry matter production is of major importance in a forage feed program. However, composition of the dry matter as it affects palatability and digestibility may be even more important to feeders. A digestion study showed that calculated total digestible naturient (TDN) values increased with advancing maturity (Thorton et al., 1969). The calculated TDN values for ear corn at early milk, early dough, mid-dent and maturity stage were 80.7, 82.9, 90.2 and 91.7 %, respectively. Such calculations indicate that ear corn harvested at mid-dent stage compared favorably with mature ear corn and that there was considerable difference between ear corn of mid-dent and early dough stages of development.

White et al. (1976) reported that corn grown for silage in Canada was well below the desired level of 30-35 % dry matter at the time of frost. Yield losses occured although allowing immature corn to stand a long period after frost increased its dry matter content to the 30-35 % level. In addition to a loss in dry matter yield, the quality of the crop declined, with increasing losses of digestibility. They recommended that silage corn in Canada could be harvested prior to or immediately after being frozen to obtain maximum yield and quality.

Highest total dry matter yield was obtained between the dent and glaze stages (Johnson et al., 1966). No vegetative growth of the leaves and stalk occured during visible ear growth and maturation. These two components decreased in weight in the later stages of maturity when ear formation had completed. They explained this might be due to decreases in protein. It is common farm practice to judge the maturity of a field of corn by assessing the stage of maturity of the kernels, even though there is considerable variability between individual plants in the field.

2.2.2. Brown midrib mutant for low lignin corn silage.

Lignin is a limiting factor in the digestion and utilization of fibrous feed by ruminant animals. Improvement of corn silage quality for ruminant animals through the use of a low lignin brown midrib mutant has been reported by many researchers. The brown midrib mutant bm3 of corn produces lowered lignin contents of vegetative parts of corn (Colenbrander et al., 1972, 1973, 1975; Lechtenberg et al., 1972). Brown midrib mutant genotypes produced corn plants with nearly a 40 % reduction in lignin content in the whole plant comp red to normal corn (Muller et al., 1971).

El-Tekriti et al. (1976) observed that the lignin percentage in leaves averaged 5.8 and 7.1 % for bm3 and normal plants, respectively. Lechtenberg et al. (1972) reported that the bm3 was the most effective of 4 mutants tested (bm, bm2, bm3 and bm4) in reducing lignin and increasing *in vitro* dry matter disappearance (IVDMD).

Muller et al. (1972) reported that bm3 corn stover silage was 10 % higher in digestible dry matter than normal stover silage fed to sheep. Dry matter consumption was 29 % greater in bm3 stover silage than with normal stover silage. Colenbrander et al. (1972, 1973, 1975) and El-Tekriti (1976) reported significantly lower cell wall constituents, acid detergent fibers and lignin in bm3 stover silage. Apparent digestibility of bm3 silage with Holstein cattle was significantly higher for dry matter, cell wall constituents, acid detergent fiber, hemi-cellulose and cellulose. Frenchick et al. (1976) reported that bm3 silage increased milk production, decreased milk fat percentage and increased body weight of Holstein cows with bm3 silage. These effects may have resulted from improved utilization primarily due to lowered lignin content and higher digestibility.

Nutrient availability and utilization can be increased by chemical and genetic modification. Most studies of bm3 were with *in vitro* chemistry of digestion. Relatively little genetic work has been done. The bm3 hybrids produced less grain yields than normal conterparts and the differences were greater at higher populations (Tu and Bauman, 1977). The yield reductions ranged from 16 % to 33 %. Frenchick et al. (1976) also reported that bm3 of corn decreased yield. The bm3 corn produced 16.1 T/ha wheras the normal corn produced 19.3 T/ha. No information is available on bm3 of corn for yield components and genetic characters.

2.2.3. Quality of corn silage.

It has been reported that corn silage is superior to sorghum silage on ruminant animal feeding. Burris et al. (1981) noted that corn silage was better than sorghum silage for feeding steers. Schmid et al. (1976) observed lower acid detergent fiber in corn silage (29 %) than in sorghum silage (34%). They also noted that the high average daily gain of sheep fed corn silage (64.5 g compared to 18.1 g for sorghum silage) was primarily due to high daily dry matter intake and highly digestible dry matter compared to the sorghum silage. Schaffert et al. (1974) reported that tannins in sorghum grain resulted in decreased growth of ruminant animals. Harris et al. (1970) obtained a significant negative correlation between tannin content of sorghum grain and *in vitro* digestibility. They suggested that high tannin content reduces feed efficiency.

Cummins and McCullough (1971) found no significant percentage difference between male-sterile and male fertile corn in digestibility of dry matter, crude protein, crude fiber and cellulose. Perry and Compton (1977) found that percent crude protein of leaves was twice as large than that of stalk crude protein, indicating the importance of retention of leaf material when harvesting corn silage. They also observed that ears contributed much of the digestible material in corn silage, but a considerable amount also came from the digestible portions of leaves and stalks.

2.3 Environmental and Genetic Factors affecting Corn Yield.

2.3.1. Photoperiod response of corn.

Most tropical lines are too sensitive to photoperiod for effective use as parents in temperate climates, while many temperate lines are too sensitive for use in the tropics. They become extremely early and small in height. Insensitivity to photoperiod would be a available addition to the tools currently available to the corn breeder. It will facilitate crossing of divergent materials from widely different latitudes and would promote an easy exchange of lines among programs of improvement in different countries.

It has been reported that long photoperiods delay tassel initiation or flowering of plants (Garner and Allard, 1927; McClelland, 1928). Francis et al. (1970), Hunter et al. (1974), and Breuer et al. (1976) observed temperature and photoperiod both significantly affected the number of days from planting to tassel initiation. Long photoperiod (20 h) and low temperature (20 °C) independently increased the number of days between planting and tassel initiation. The interval between tassel initiation and silking was not affected by photoperiod. During the grain filling period, temperature had greater effects, but a photoperiod x temperature interaction occured. Hunter et al. (1974) showed a more detailed relationship between photoperiod and temperature. Their work suggested that at long photoperiod the delay in tassel initiation was less at 30 °C than at 20 °C or 25°C.

Francis et al. (1969) and Arnold (1969) reported that extending the daylength did not delay the maturity of the corn belt lines (adapted to long photoperiod). Coligado and Brown (1975) observed that photoperiod increased the time to tassel initiation and number of leaves at all temperature, however, the increases were more pronounced at low temperature (15 °C). They concluded that the increases in leaf number with increasing photoperiod resulted from the prolongation of the time to tassel initiation.

Francis et al. (1969) found insensitive inbred lines in a study under extended day length. They suggested that insensitivity could be incorporated into corn of different maturities and thus the developments of genotypes with very wide adaptation was possible. Brewbaker (1981) noted that hybrids could be bred with wide adaptability to daylength abd also to the incident light variation of tropic and temperate regions.

Most genotypes showed a delay in floral differentiation when grown in extended daylength (Francis et al., 1970). They also found that the magnitude of the delay in tassel initiation under long day conditions is related to the intensity of light used to lengthen a naturally short day. Several genotypes were quantitative in delay, but certain genotypes showed specific threshold intensity levels above which the delay was very pronounced, and below which there might be less delay or none at all. Some sensitive genotypes showed a substantial delay in development under light intensities greater than about 5 fc (54 lux), and a significantly less pronounced delay at intensities between 1 to 2 fc (11 to 22 lux) and 5 fc (54 lux).

Moss and Heslop-Harrison (1968) reported reduced leaf number on the principle axis, fewer tassel branches, and reduced pollen fertility under the short day (8 hour) in comparison with long day (18 hour). All of these effects were reduced by night interuption by light at low intensity level indicating direct or indirect effects of true photoperiodic reactions. Ragland et al. (1966) observed that supplementary light treatment increased number of kernel rows. However, they found that there were fewer kernels per row and less grain weight per ear under the supplementary light treatment. The addition of artificial light to the corn field showed increased corn yield (Graham et al., 1972). The results show that the increase in yield was directly proportional to the amount of light added to the leaf area.

With longer photoperiod, there was an increase in the amount of vegetative growth and development prior to tassel initiation (Hunter et al., 1974). It was ovserved that total leaf number, total stem length, and total plant dry weight were increased with longer photoperiod. The response was not consistent for each genotype. Pioneer X306 which is a subtropical hybrid showed much larger responses than Guelph GX122 which is adapted to Ontario, Canada. Stem length of Pioneer X306 at tassel initiation were 3.8 and 38.9 cm when grown under 10 and 20 hour photoperiod, respectively.

In contrast, for the hybrid Guelph GX 122, increasing the photoperiod comparably resulted in less than doubling of stem length. Bonaparte (1975) reported that fewer leaves were developed in 12 h than in 16 h daylength in the same temperature regime. This could largely be attributed to higher leaf area per plant and greater average daily dry matter production. Leaf area and leaf number were increased with longer photoperiod under both high and low temperature treatments. However, 1000 kernels weight and number of kernel rows at maturity were increased only under low temperature conditions.

2.3.2. Solar Radiation.

Theoretically, with adequate fertility and population the next growth limiting factors of importance would be light penetration related to leaf area and photosynthesis rate. Increasing plant population is a method for maximizing interception of incoming solar energy in crop species. Colville (1968) reported that the quantity of light reaching the soil through the leaf canopy was diminished with increasing plant population but remained stable at populations of 49,400 or more plants/ha. He concluded that light was the only factor influenced significantly by planting patterns.

Yao and Shaw (1964) reported greater light interception by plants grown in 53 cm rows than in 107 cm rows. Denmead et al. (1962) suggested that spacing rows narrower than 102 cm could increase the energy available for photosynthesis by 15 to 20 %. They observed that after maximum leaf area development, the net radiation at the ground constituted only 25 % of the total net radiation measured above the crop. According to Williams et al. (1965), crop growth rate was increased with increasing amounts of light intercepted and light intercepted was increased as LAI increased. The LAI value at 95 % light interception was 8. Plant populations and row widths affected the amount of energy absorbed by the corn plant and by the soil (Aubertin and Peters, 1961). Greater amounts of energy were absorbed by the plants under narrow rows and high population combinations. Conversely, greater amounts of energy were absorbed by the soil under wide rows and low population combinations resulting in greater evaporation and higher soil temperatures.

Hybrids tolerant of thick planting were also tolerant of shading, while hybrids less tolerant of thick planting were less tolerant of shading (Stinson and Moss, 1969). It is apparent that different yield response of various hybrids at high planting rates is in part a differential response to shading. Grain production of corn hybrids was reduced significantly by 60 % or higher shading treatment in all stages (Early et al., 1967). Their results showed that shading during the reproductive stage was most detrimental. Plants shaded during the reproductive stage had a full complement of normal leaves, but initiated and developed only a limited number of kernels and had reduced kernel weight. It was concluded that in the absence of a "sink" (kernels or ears) the leaves of these plants were essentially nonoperative although exposed fully to light.

Moss (1962) reported reduction of CO_2 assimilation rate (40 to 60 % of control plants) upon removal of ears or prevention of ear fertilization. Photosynthetic rate in crop plants is highly correlated with light intensity from a low intensity to light saturation of the leaves (Hesketh and Musgrave, 1962; Moss et al., 1961). Moss et al. (1961) observed serious grain yield reduction of hybrids intolerant to dense planting because they failed to silk normally.

Increased grain yields were observed under a high light environment (Pendleton et al., 1967). Grain yield was 26 % higher in the reflector areas than in normal sunlight and plants with extra light were shorter and had larger stalks. These results suggested that under field condition all leaves on a corn plant are not light saturated, therefore, light appears to be the primary factor limiting grain yield of corn when grown under highly productive conditions. Jong et al. (1982) in Hawaii observed that the cyclical change of grain yield and its components closely followed cyclical changes in climatic conditions. Grain yields were generally greatest for March to August plantings, and minimal yields were observed for November to January plantings. They found that the most influencial climatic factor affecting the yield component was solar radiation.

2.3.3. Temperature and dry matter accumulation.

The maturity of corn is frequently measured by recording the number of days from planting to silking. Such a method for comparing material grown at different locations and years is limited because the number of days from planting to silking varies widely with changes in environmental conditions. One of the needs confronting corn breeders and producers is a means of classifying corn hybrids with respect to maturity. Classifying hybrids according to the number of days elapsed between planting or emergence and maturity lacks precision because environmental variations between years and locations may influence the number of days between planting and grain 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). Moisture percentage as a basis for the prediction of maturity was shown to be unreliable by Shaw and Thom (1951). They reported that large differences in moisture percentage at the time of physiologic maturity existed among hybrids in any one year. Hillson and Penny (1964) reported that 95 % of physiologic maturity was more accurately determined than 100 %. They found that moisture percentage at the time of physiologic maturity have no indication of the rate of drying.

Accumulated temperature is in index which has been used to determine physiological stages of plant maturity and climatically suited areas for corn production. Andrew et al. (1956) used accumulated thermal units to compare stages of maturity of two corn hybrids at two different locations. They concluded that accumulated thermal units above a base of 10 °C were nearly equal in both locations for predicting maturity. Gilmore and Rogers (1958) reported that the use of temperatures taken at 3-hour intervals was slightly superior to daily maximum and minimum readings. It was concluded that the degree days method was more reliable than calendar days for predicting flowering dates for different planting dates.

Cross and Zuber (1972) used 22 different methods of computing thermal units to test their ability to account for variation in flowering dates. They observed that daily measurements were approximately as accurate as the hourly measurements. It was concluded that the best equation for predicting flowering dates on the basis of thermal units utilized a base temperature of 10 °C and an optimum of 30 °C. The excess temperature above 30 °C was subtracted to account for high temperature stress. Daynard (1972) in Canada observed that delayed planting resulted in an increased number of accumulated heat units from planting to midsilking and decreased heat accumulation from midsilking to maturity. As a result, the number of accumulated heat units from planting to maturity was only slightly reduced by delayed planting date. He concluded that accumulated heat units were superior to the number of days in determining the length of the interval from planting to midsilking, but not from midsilking to maturity.

Gunn and Christensen (1963) showed that the number of accumulated heat units from planting to silking remained relatively constant for corn grown in different environments, while calendar days varied widely. Their study indicated that the time interval from silking to physiologic maturity was not constant but appeared to vary with climate and hybrid. They suggested that evaluation of the accumulated heat unit classification of hybrids should extend from planting to maturity rather than planting to silking. Mederski et al. (1973) reported that the accumulated heat unit methods were about half as variable as the calendar day method showing that growing degree day methods of classifying corn hybrids was superior to calendar days.

Dry matter accumulation:

Analysis of dry matter accumulation showed that, as grain development progressed, the rate of grain fill began to exceed the rate of dry matter accumulation, indicating a net redistribution of stored assimilates (Jurgens et al., 1978). Johnson and Tanner (1972) reported that the growth of individual corn kernels starts immediately after fertilization as a non-linear period followed by a linear growth phase. Up to 90 % of the maximum kernel dry weight may accumulate during the linear phase. Dry weight accumulation continues after the linear phase, but at a continuously reduced rate until the kernel reaches physiological maturity. Tip kernels on an ear of corn have a shorter period of grain filling than base kernels, but the rate of growth is the same for individual kernels in either position (Tollenaar and Daynard, 1978).

Poneleit and Egli (1979) observed that kernel dry weight accumulation rate was not affected by population density, however, effective filling period was 2.5 days less at the high population density. They also showed that yield per plant and per unit area in response to changes in population density were changed more by kernel number per plant than by kernel size. Hanway and Russell (1969) reported that the rate of dry matter accumulation in the grain was similar for all hybrids and plant populations, but length of time during which dry matter accumulated in the grain at the rapid rate varied among the hybrids, resulting in markedly different final grain yields. Dry matter accumulation in many non-grain parts of the plants after silking and was later translocated to the grain. They observed that the average rate of dry matter accumulation was slightly higher, and the period of dry matter accumulation in the grain was silghtly shorter at the higher than at the lower population density. It was reported that photosynthesis throughout the upper two-thirds of the leaf area of corn supplied the dry matter that filled the grain (Allison, 1966). The estimated contributions of the top 5, the middle 4, and the bottom 6 leaves to dry matter production after flowering were about 40 %, 35-50 %, and 5-25 %, respectively. The decrease in stem weight caused by defoliation suggests that previously stored dry matter was moved to the grain. He noted that dry matter production after flowering was more than sufficient for grain growth, and previous photosynthsis probably contributed little to the grain.

Egharevba et al. (1976) observed that defoliation within 30 days after silking significantly reduced total accumulated dry matter. More severe yield reductions (6.2 to 82 %) were observed by complete defoliation than partial defoliation (1.5 to 32.7 % yield reduction). The effect of removing all leaves above the ear was not significantly different from that obtained by removing all leaves below the ear. They showed that the number of kernels produced per unit area was strongly influenced by defoliation. However, at 10 days after midsilking, the weight of kernels was affected more than number of kernels when leaves were removed at 20 or 30 days after midsilking. These results suggest that stress at silking or up to 10 to 15 days may reduce yield significantly because of a decrease in the number of kernels produced. Thereafter, yield losses are largely due to a decline in kernel weight.

2.3.4 Yield Components of Corn

Yield components have not been used extensively as selection criteria by plant breeders for improvement of yield. However, selection for the components may be effective during corn inbred development. If such inbreds had greater GCA for yield, the yield components would be useful selection criteria. El-Lankany and Russell (1971) observed relatively high phenotypic correlations between yield and three yield components, kernel depth, ear length, and ears per plant among test crosses of 20 inbred lines. Andrew and Peek (1971) found averaged highest coefficient of variability fot the unfavorable and lowest for the favorable environments. Bigger (1919) observed no relationship between number of kernel rows and grain yield, or between shelling percentage and grain yield. He found positive correlations between ear length, weight and yields but correlation coefficients were not large. It was concluded that there was no well marked basis for using ear characteristics to indicate yield possibilities.

Hartfield et al. (1965) in Kentucky observed significant correlations between ear components and grain yield in 6 environmental conditions. They observed that the correlation of ear components with grain yield and was drastically affected by the environment, suggesting that the genetic yield potential of varieties cannot be evaluated by component correlations except as these varieties react to a specific environment. Mass selection for increased and decreased ear length was conducted by Cortez-Mendoza (1979) in Illinois. Selection response for increase ear length was not accompanied by a correlated response in grain yield per plant. Selection response for decreased ear length, however, was accompanied by a significant reduction in grain yield per plant. Other correlated responses to selection for increased ear length were taller plants, later silking, and decreased ear diameter. On the other hand, selection for decreased ear length resulted in shorter plants, but there was no change in days to flowering, and ear diameter.

Cross and Zuber (1973) obtained a significant correlation between plant height and number of leaves for most genotypes. They also found that the relationship between number of leaves at naturity and number of days from planting to anthesis was even lower than that for plant height and number of days from planting to anthesis. Significant positive correlations between the average number of leaves per plant and the number of days to mid-silking were observed (Chase and Nanda, 1965). They (1967) also observed that there was a significant positive correlation between the number of leaves and number of days to anthesis. They reported that there were fewer leaves per plant in winter planting, and concluded that the number of leaves per hybrid was a highly reliable index to maturity classification. Geadelmann and Peterson (1978) reported that yield components selection programs did not increase yield in the highest yielding hybrid background, nor modified hybrids respond well to increased population density.

These results did not support wide use of backcross-selection for increased yield component expression as a general procedure to increase yield of corn hybrids.

Resistance to stalk bending was affected by internode diameter, environmental conditions, and stage of development (Pickett et al., 1969). Thompson (1972) observed increased lodging resistance after 7 cycles of recurrent selection for resistance to lodgings. The percentage of erect plant had increased from 40.3 to 91.9, and rind thickness from 1.00 to 1.16 mm, while ear height and yield decreased. Considerable lodging occurs in many high eared corn hybrids when grown under modern corn production practices. Understanding of the ear height and associated characters is needed to determine the most effective breeding procedures necessary for selection of these characters.

2.3.5 Environmental Interaction and Genetics of Corn

Genotype x environment interaction has been widely observed to play a significant role in the expression of phenotypes. An alternative is to develop varieties which can more efficiently exploit favorable environments and at the same time are buffered against unfavorable genotype x environment interaction. The ideal corn genotype would produce high yields regardless of environmental conditions. In general, genotypes do not perform equally well in all environments, but some tend to be closer to ideal than others. Genotype response to differing environments can be measured statistically as genotype x environment interaction while those with large interaction would be called unstable.

Genotype x environment interactions were examined by Eberhart et al. (1973) in East Africa using 23 genotypes of corn. A large proportion of the genotype x environment interaction could be explained by differential responses among varieties to altitude and to environments. They concluded that varieties that originated or were selected at high altitudes were more responsive to altitude than were their low altitude counterparts. Darrah and Penny (1974) studied genotype x environment interaction using 15 varieties at 50 sites in East Africa and Nigeria. They reported that varieties that had been selected at high elevation showed higher responses that those from low altitudes. Differences among varieties were small at low altitudes and in poor environments, but they widened rapidly as either altitude or environmental index increased. Increased response was related to adaptability and to the need for inclusion of high altitude germplash in breeding populations.

Stability of yield is important in corn hybrids, especially for those grown in fringe areas of production. Eberhart and Russell (1966) indicated that stability of performance differed among inbred lines tested in hybrid combinations. According to Scott (1967), a stable hybrid was defined as: (a) a hybrid that exhibits the least yield variation over all environments, and (b) a hybrid that does not change its relative performance with other entries in many environments. Both types of stability have merit for selection in a desirable corn hybrid. However, these two types tend to be mutually exclusive. Corn breeders should decide which type of stability is more important in each program. If the origin is the fringe areas of production, the type of stability defined in (a) would be more important. Where environmental conditions are generally favorable, the type of stability defined in (b) should be more important. Eberhart and Russell (1966) modified and applied their method to estimate stability of corn. The regression coefficients and deviations from regression were used as parameters. They concluded that reliable estimates of deviations from regression would require testing over a number of environments, while estimates of the less important regression coefficient would require fewer but widely different environment.

Dhillon and Singh (1977) found that GCA was more important than SCA in the expression of mean yield. Generally, inbreds with high GCA effects for kernel depth and kernel rows per ear had high GCA effects for yield (Cross, 1977). He found significant interactions of GCA with environments for yield, ear length, and kernel rows. Significant SCA interactions with environments were for ear length. It was indicated that the absence of environmental interactions with GCA or SCA effects for ear traits might be important for development of high yielding hybrids from these inbreds. Corn breeders have devoted considerable effort and expense to the development of inbred lines with superior combining ability for grain yield. GCA of the original and modified lines was evaluated by testing their top-crosses to the synthetic variety in two environments in Minnesota by Geadelmann and Peterson (1970). Average GCA for grain yield for modified ear per plant exceeded the original inbreds by 10 and 5 %, respectively. GCA of the modified lines, as measured by their average top-cross grain yield, was higher than their original inbreds for some but not all inbreds.

Harville et al. (1978) reported that the GCA effect was larger than SCA effects for ear height. They concluded that the inheritance of ear height was controlled primarily by additive gene effects. Significant changes of the estimate of the GCA effects were less with each succeeding cycle of generations, indicating less progress in lowering ear height with each succeeding cycle. Flowering-time and accumulated heat unit to flowering were largely determined by GCA effects and, thus, GCA estimates were higher than those of SCA (Rood and Major, 1980). They observed that GCA effects for flowering-time and accumulated heat unit to flowering were generally consistent across years and environments.

Gamble (1962) reported that the dominance gene effects were the most important contributors to the inheritance of plant height, ear length, ear diameter, and kernel weight. He also observed that additive gene effects were more important for plant and ear characters than for yield. They were relatively more important for the number of kernel rows, ear diameter, and kernel weight than for plant height and ear length. In other study, Gamble (1962), found that additive gene effects are relatively more important in the inheritance of plant and ear characters than for yield performance. Robinson et al. (1949) have also obtained results which indicate that additive genetic variation is greater in those characters. Giesbrecht (1961) observed that heritability estimates averaged 65.5, 38.3, and 82.4 % for number of internodes, internode length, and ear height, respectively. The comparatively high heritability estimate obtained for ear height suggested that it would be easier to select desired genotypes on the basis of ear height than on the number of internodes or internode length.

Most of the studies on the inheritance of maturity have used the date of pollen shedding or silking as their basis of maturity. Giesbrecht (1960) reported that more than two genes were involved with some evidence of partial to complete dominance and epistasis. In a later study, Giesbrecht (1960) reported that 5 genes were involved for days to pollen shedding and 4 or 5 genes for days to silking. Mohamed (1959) obtained similar results in that the days from planting to pollen shedding and silking were controlled by 2 and 3 major gene pairs, respectively. Jones (1955) reported that 2 to 11 genes were involved with heritability values of 22 to 83 % for maturity. The heritability estimates in a broad and narrow sense were higher for flowering-time (Rood and Major, 1980). The average heritability estimate of narrow and broad sense over two years were 71 and 90 %, respectively. The high estimate of narrow-sense heritability suggests that selection for early flowering should be effective.

3 MATERIALS AND METHODS

3.1 Effects of Population Density and Seasonal Changes on Grain and Stover Yields

The objective of this study was to determine the responses of grain and silage yields and their yield components to increasing population densities in different seasons. Two corn hybrids were planted bimonthly using six different population densities at the Waimanalo Research Station of the University of Hawaii. The Research Station is located at 21°N latitude in Oahu, Hawaii, and its soil type is a Typic Haplustoll with pH of around 6.5.

Population densities used were 50,000, 75,000, 100,000, 125,000, 150,000, and 200,000 plants/ha. The hybrids used were H763 (Hawaiian singlecross hybrid) and X304C (Pioneer tropical singlecross). A total of 12 plantings were made over the 2 year period (Table 1). The spacings adopted were 76 cm between rows and 26, 18, 13, 11, 9, and 6.5 cm between plants. Marked nylon strings were used to keep correct planting distance during plantings. At higher population densities (150,000 and 200,000 plants/ha), plantings were done in paired rows, spaced 25 cm apart, retaining the 76 cm between pairs. Two border rows were planted around the experimental planting. Each experimental plot consisted of 2 rows of 5 m length.

The experiment was conducted in a split plot design with 4 replications. Genotypes were treated as mainplots with population densities in subplots. Two seeds were planted per hill and were

Table 1. Planting and harvesting dates of bimonthly plantings.

Planting number	Planting month	Planting date	Harvesting date
1	January	Jan. 15, '80	May 20, '80
2	March	Mar. 15, '80	Jul. 24, '80
3	May	May 17, '80	Sep. 4, '80
4	July	Jul. 15, '80	Oct. 28, '80
5	September	Sep. 18, '80	Jan. 18, '81
6	November	Nov. 14, '80	Feb. 26, '81
7	January	Jan. 15, '81	May 5, '81
8	March	Mar. 16, '81	Jul. 2, '81
9	May	May 15, '81	Aug. 31, '81
10	July	Jul. 16, '81	Nov. 9, '81
11	September	Sep. 15, '81	Jan. 5, '82
12	November	Nov. 15, '81	Mar. 9, '82

thinned to one plant after 4 weeks. A preplant fertilizer application equivalent to $N-P_2O_5-K_2O$ = 130-130-100 kg/ha was made and corn plants were sidedressed with 70 kg/ha of nitrogen as urea after thinning. The herbicide was incorporated to control weeds. Overhead sprinkler irrigation was used on a 5-day interval.

Data on the following plant and ear characters were collected·

1) Days to tasseling, as the time in days from planting to the day of tassel emergence.
2) Plant height, as the height in cm from ground to the tip of central axis of the tassel.
3) Ear height, as the height in cm from the ground to the base of the upper most ear.
4) Filled ear length, as the length in cm with fully developed kernels.
5) Number of kernel rows.
6) Number of kernels per row.
7) Leaf area index (LAI) as the ratio of total leaf area to the area of planting space, using method of pearce et al. (1975).
8) Stalk diameter, as the diameter of stalk in mm above the first node from the ground.
9) Fusarium infection, as the percentage of fusarium infected kernels per ear.
10) Grain yield, as the grain weight in metric tons per hectare adjusted to 15.5 % moisture content.
11) Stover yield, as the stover weight in metric tons per hectare adjusted to oven dry moisture content.

Ten plants per plot were recorded for each plant character, and 6 to 7 ears were sampled after harvesting for measuring yield components. The size of harvested plot was 2 rows x 4 m. Grain ears were harvested by hand picking, and then stover was cut by sickle. After harvesting, 2-3 corn stalks were sampled and shredded at the field. These shredded stalk samples were dried in a forced air dryer (60-65 °C) to determine moisture content. Grain ears were shelled and tested for moisture content using a digital moisture tester.

3.2 Effects of Brown Midrib Mutant (bm3) of Corn on Yields and Yield Components

Fifteen hybrids from a 6-entry diallel were grown to assess the effects of bm3 on yields and yield components. Three of the inbreds -- Ant2, Hi27 and Hi 28 -- were tropical in origin, while B37, Mo17, and Oh545 were temperate. All inbreds used were University of Hawaii conversions to Mv (resistance to Maize Mosaic Virus), Rp-d (resistance to *Puccinia sorghi*) and Ht (resistance to *Helminthosporium turcicum*). Two trials were planted at the Waimanalo Research Station of the University of Hawaii on August 12, 1980, and May 21, 1981. Four replicates were planted in a split-plot design, with hybrids as main plots and type (normal vs. bm3) as subplots. The population density was 60,000 plants/ha, with 76 cm between rows. Each plot consisted of a single 7 m row with 30 plants. Two seeds were planted per hill and thinned to a perfect stand. Other management factors including field preparation, fertilization, herbicide application, and irrigation, were the same as those of population density experiments.

Data were recorded for days to tasseling, plant height, leaf area index, number of stem nodes, stem diameter, filled ear length, number of kernel rows, number of kernels per row, grain and stover yield. The whole plot was harvested for grain and stover yields. Ten plants per plot were recorded for each plant characters, 6 or 7 harvested ears were observed for grain yield components. Leaf area measured using the rapid method (Pearce et al., 1975). Grain yields were adjusted to 15.5 % moisture and two corn stalks were sampled for stover moisture content. These stalk samples were shredded and dried in a forced air dryer (60-65 °C) to determine moisture content. Griffing's diallel method 4 was used for the combining ability test.

3.3 Effect of Extended Daylength on Yields and Yield Components of Corn.

The objectives of this study was to determine increase in total dry matter and grain yields, and their components, under 4-hour extended daylength conditions. Ten hybrids from a 5-entry diallel cross (Ant2, Hi28, Hi29, Hi31, and Mo17) together with control hybrids -- B37 x Hi25, B37 x Mo17, Pi3369A, and X304C -- were planted on September 18, 1980 and May 21, 1981, under the normal and extended light conditions at the Waimanalo Research Station. Population density was 60,000 plants/ha, with 76 cm between rows and 22 cm within rows. The plot size was 2.8 m x 2 rows with 24 plants.

For the supplementary lighting system, 150 watt incandescent flood lamps were used at night. Lights were turned on after sunset

(September: 6 PM, May: 6:30 PM) for 4 hours. Lamps were spaced 4.6 m apart on a line at a height of 3.4 m above the ground. A clock timer was used to turn the lamps on and off. Average light intensity was about 161.5 lux (15 fc-c) (Lee, 1978). A randomized complete block design with 4 replications was used. Other management practices were the same as those of the population density experiments.

Observations were recorded on the following characters: days to tasseling, days to silking, plant height, ear height, LAI, number of stem nodes, filled ear length, number of kernel rows, number of kernels/row, stalk diameter, kernel fusarium, grain yield, and stover yield.

3.4 Selection of the Superior Hybrid Corn from a 31 x 7 Factorial.

The objective of this experiment was to identify superior hybrids for silage production, their plant characters and yield components. This experiment was conducted at the Waimanalo Research Station in 3 different seasons. Plantings were made on March 24, May 29, and November 9, 1981. The total number of hybrids was 225, including 217 from the factorial combinations of 31 tropical inbreds with 7 tester inbreds, and 8 check hybrids (Tabel 2). The 31 tropical inbreds were used as female parents and 7 tester inbreds as male parents.

Two seeds were planted per hill and thinned to one plant after 4 weeks. The population density was 60,000 plants/ha, with 76 cm between rows and 22 cm within rows. Plot size was 3.5 m long x 2 rows, with 30 plants. Experimental design was a simple lattice design (15 x 15). Soil preparation, fertilizer application,

Table 2. Pedigrees of inbreds used in silage yield trials.

Female parents:

Number	Inbred	Source	Number	Inbred	Source
1	CIMMYT-A21	CIMMYT	16	INV443	Texas
2	CIMMYT-T11ES	CIMMYT	17	INV534	Texas
3	Fla.2AT-112	Florida	18	MIT11 DMR	Thailand
4	Fla.2AT-114	Florida	19	Pi4243	U.H.
5	Fla.2BT-54	Florida	20	Pi4257	U.H.
6	H632A	Kenya	21	Pi4283	U.H.
7	H632F	Kenya	22	Pi4287	U.H.
8	H632G	Kenya	23	SR52-F	Zimbabwe
9	ICA L25	Colombia	24	SR52-M	Zimbabwe
10	ICA L27	Colombia	25	Tuxpeno	Thailand
11	ICA L210	Colombia	26	Tx602	Texas
12	ICA L221	Colombia	27	77-4407	U.H.
13	ICA L223	Colombia	28	77-4412	U.H.
14	INV138	Texas	29	77-4441	U.H.
15	INV302	Texas	30	77-4449	U.H.
			31	77-4544	U.H.

Male parents:

1	Hi26
2	Hi28
3	Hi29
4	Hi31
5	Hi33
6	Hi34
7	Tx601

Check hybrids:

1	H636 (Hi29 x Hi33)
2	H650 (Hi28 x Hi33)
3	H763 (Hi34 x Hi31)
4	H767 (Hi29 x Hi31)
5	H823 (Hi28 x Hi34)
6	H824 (Hi29 x Hi34)
7	X105A
8	X304C

erbicide incorporation, irrigation, and other management practices were the same as those for the previous experiments.

Several characters were observed over 3 plantings, including grain yield, stover yield, days to tasseling, plant height, and ear height. However, yield components data, including filled ear length, number of kernel rows, number of kernels/row, and 100 kernel weights were recorded only in the March and May plantings. LAI, number of stem nodes, and stem diameters were measured only in March planting. Harvesting and sampling methods were described in population density experiments.

3.5 Silage Yield Trial of 7-Entry Diallel.

The objective of this experiment was to determine silage yields and their combining ability among a 7-entry diallel cross, utilizing male parent inbreds from the 31 x 7 factorial experiment. The 21 hybrids (7-entry diallel) were planted in 3 different seasons at the Waimanalo Research Station. Planting dates were November 16, 1981, February 2, 1982, and May 5, 1982. Parent inbreds used were Hi26, Hi28, Hi29, Hi31, Hi33, Hi34, and Tx601. Plot size was 3.5 m x 2 rows, with 30 plants. The experimental design was a randomized complete block design with 4 replications. Cultivation and management were the same as previous experiments.

The following characters were observed: grain yield, stover yield, days to tasseling, plant height, ear height, filled ear length, number of kernel rows, number of kernels per row, 100 kernel weight, and rust. Data on barren stalks were collected in the November planting and LAI was observed in the May plantings. Harvesting and sampling methods were the same as those of the previous experiments.

RESULTS AND DISCUSSION.

4.1 Effects of Population Density and Seasonal Variations on Corn

4.1.1 Yield response to population density

The highest average total dry matter (TDM) yields over 12 plantings were observed at 150,000 plants/ha for both H763 and X304C. The highest TDM yields of H763 and X304C were 14.8 and 17.4 T/ha, respectively, indicating that X304C was superior to H763 for silage production. The response of TDM to population density fitted well to 2nd degree polynomial equation (Figure 1), with coefficient of determination was 0.99 for both H763 and X304C. Optimum population densities for maximum TDM yield from the 2nd degree polynomial equations were 169,100 and 166,700 plants/ha for H763 and X304C, respectively.

Second degree polynomial equation for overall average over 12 plantings showed that optimum population densities for maximum grain yield was 126,000 on H763 and 141,000 plants/ha for X304C (Figure 2). The highest grain yield of H763 was 6.8 T/ha at 125,000, while for X304C it was 8.4 T/ha at 150,000 plants/ha, showing that X304C had significantly higher grain yield than H763. At the lower population densities (50,000 - 75,000 plants/ha), the grain yield differences were 0.6-0.7 T/ha, while it was 1.3-1.8 T/ha at the higher population densities (125,000-200,000 plants/ha). This result indicated that the two hybrids were different in response to different population densities.

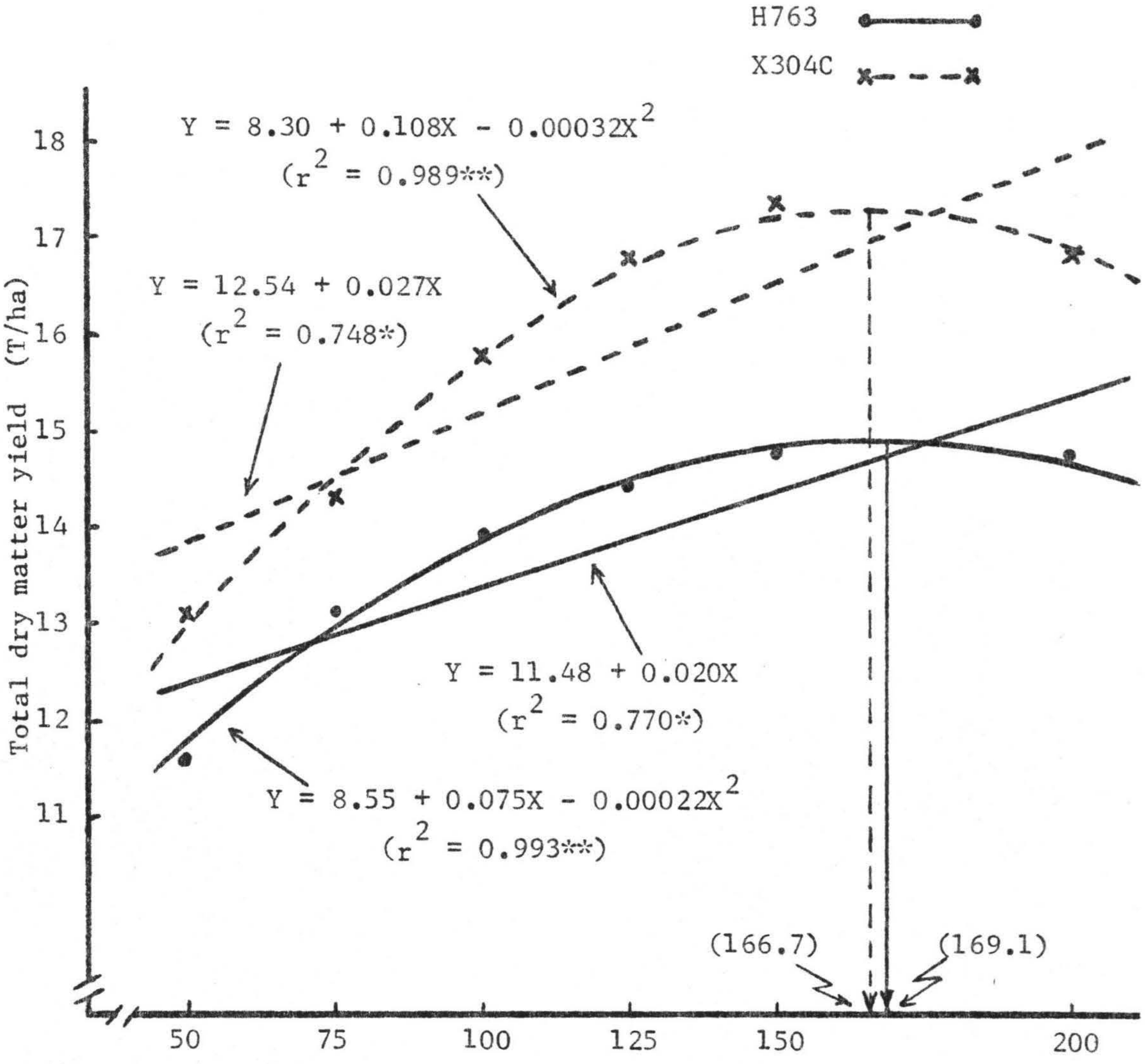


Figure 1. Response of total dry matter yield to population density.

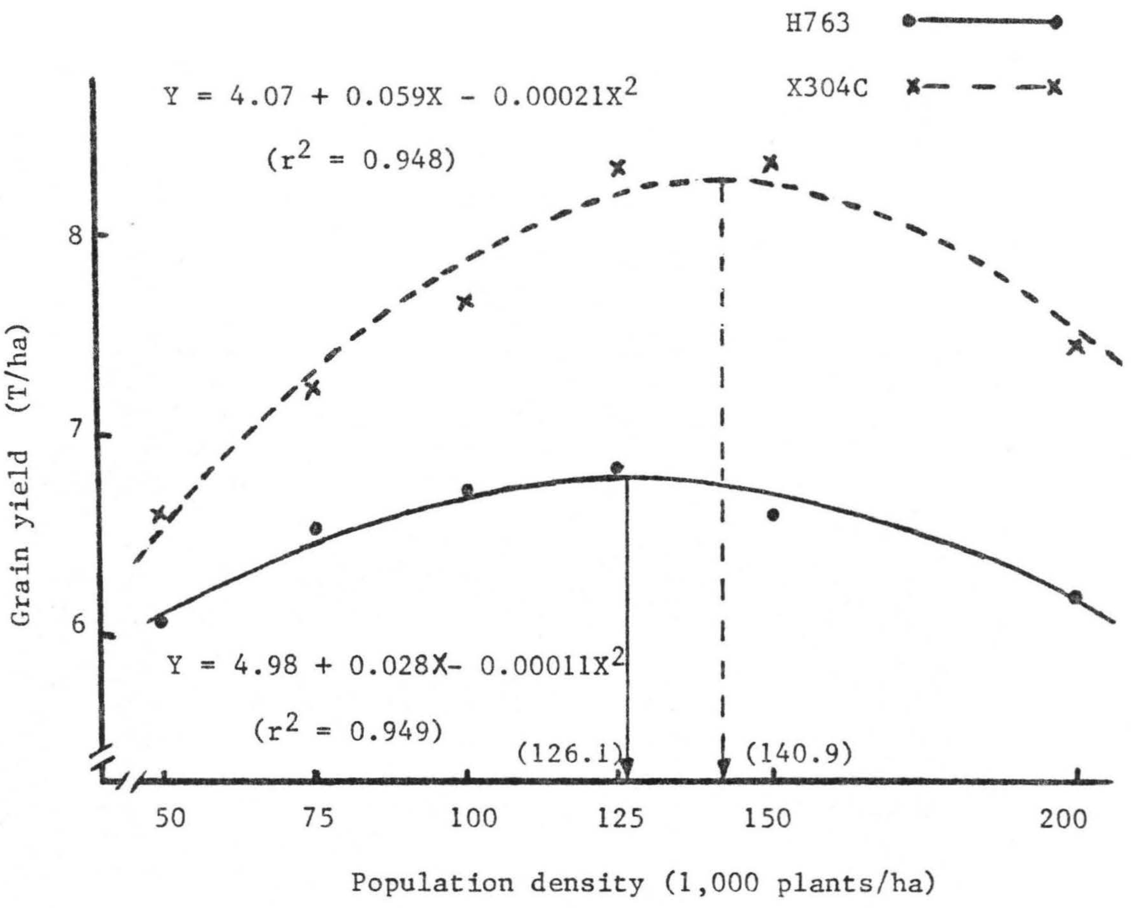


Figure 2. Response of grain yield to population density.

Responses of grain yields to population densities were different in different seasons (Figures 3, 4). The population densities for maximum grain yields in spring (January, March) and summer (May, July) were higher than those in fall (September) and winter (November) seasons except in one case. These differences might be due to the stressed environments in winter seasons; i.e. strong winds and concentrated rainfall that resulted in severe lodging.

Optimum population densities for maximum grain yields in different plantings are presented in Table 3. In September plantings, optimum population densities were not observed on both hybrids. This indicated that grain yield decreased as population increased.

Stover yield increased significantly with increasing population density up to 200,000 plants/ha for both hybrids (Figure 5). At the highest population density (200,000 plants/ha), stover yields of H763 and X304C were 8.6 and 9.4 T/ha, respectively. X304C was 0.5-0.8 T/ha higher than H763 in all different populations. Theoretical optimum population densities for maximum stover yields were observed at 212,700 on H763, and 215,100 plants/ha on X304C. Coefficients of determination of the quadratic regression equations were highly significant for both hybrids. Linear regressions also were highly significant for H763 (r^2=0.93) and X304C (r^2=0.92).

The responses of stover yields to population densities in different seasons were more consistent than those of grain yields for both hybrids (Figures 6, 7). In the September and November plantings, yield responses to population densities were similar to those in other plantings. Table 4 presents theoretical population densities

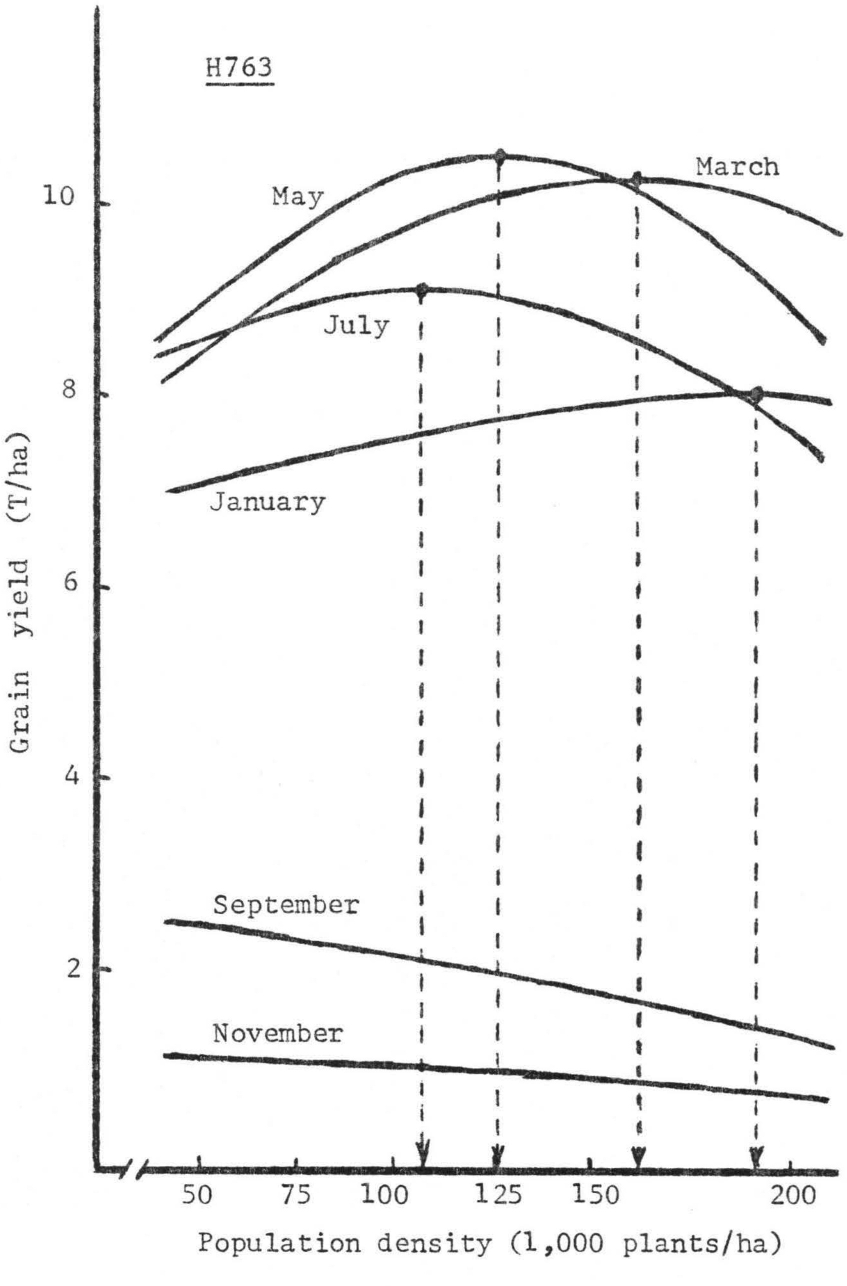


Figure 3. Responses of grain yields to population density in different seasons.

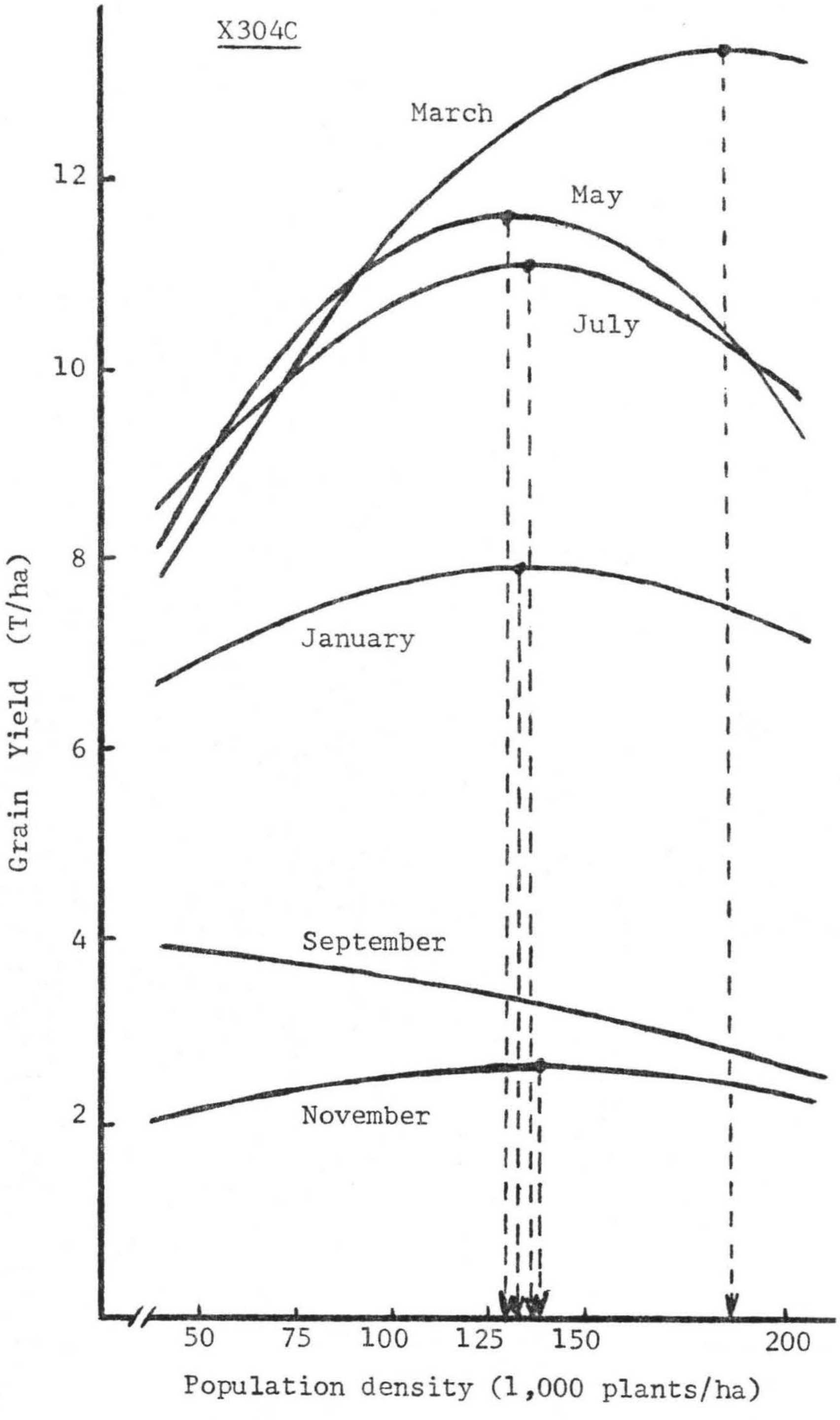


Figure 4. Responses of grain yields to population density in different seasons.

Table 3. Second degree polynomial equation of grain yield with population density.

Hybrid	Month	Equation	r^2	Optimum pop. density for max. yield
H763	Jan	$Y= 6.34 + 0.018x - 0.000048X^2$	0.75	189.3
	Mar	$Y= 6.33 + 0.050X - 0.00016\ X^2$	0.87^{*}	157.2
	May	$Y= 6.17 + 0.070X - 0.00028X^2$	0.83	125.4
	Jul	$Y= 7.28 + 0.035X - 0.00016X^2$	0.98^{**}	106.8
	Sep.	$Y= 2.66 - 0.0033X - 0.000015X^2$	0.88^{*}	-
	Nov	$Y= 1.12 + 0.00015X - 0.0000101X^2$	0.77	7.4
X304C	Jan	$Y= 5.42 + 0.038X - 0.00014X^2$	0.85	133.3
	Mar	$Y= 3.96 + 0.102X - 0.00028X^2$	0.93^{*}	185.5
	May	$Y= 4.62 + 0.108X - 0.00042X^2$	0.80	129.8
	Jul	$Y= 5.14 + 0.091X - 0.00034X^2$	0.98^{**}	134.8
	Sep	$Y= 3.91 - 0.00046X - 0.000027X^2$	0.78	-
	Nov	$Y= 1.43 + 0.018X - 0.000066X^2$	0.93^{*}	137.7

* Significant at 5 % level. - indicates negative value.

** Significant at 1 % level.

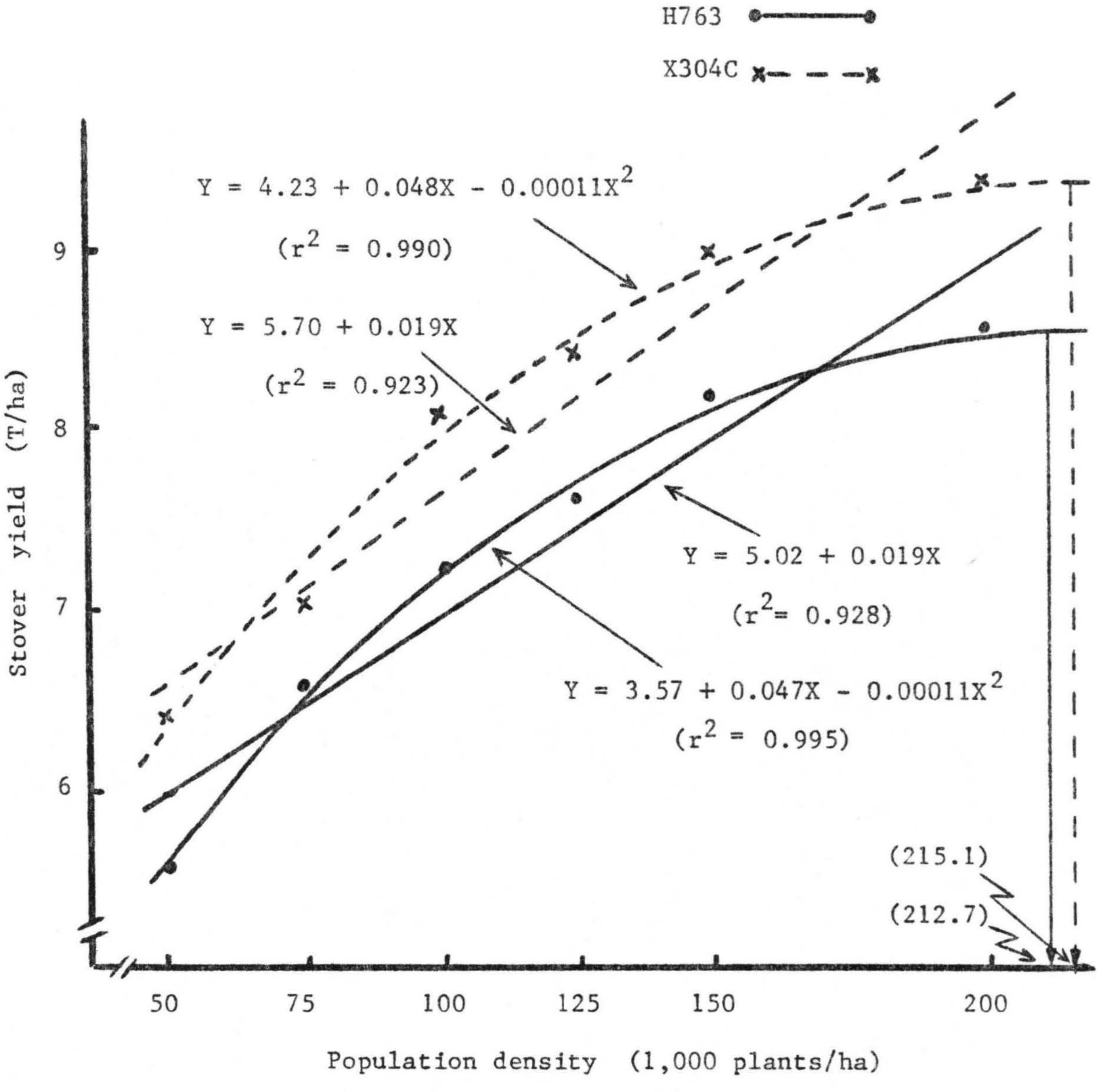


Figure 5. Response of stover yield to population density.

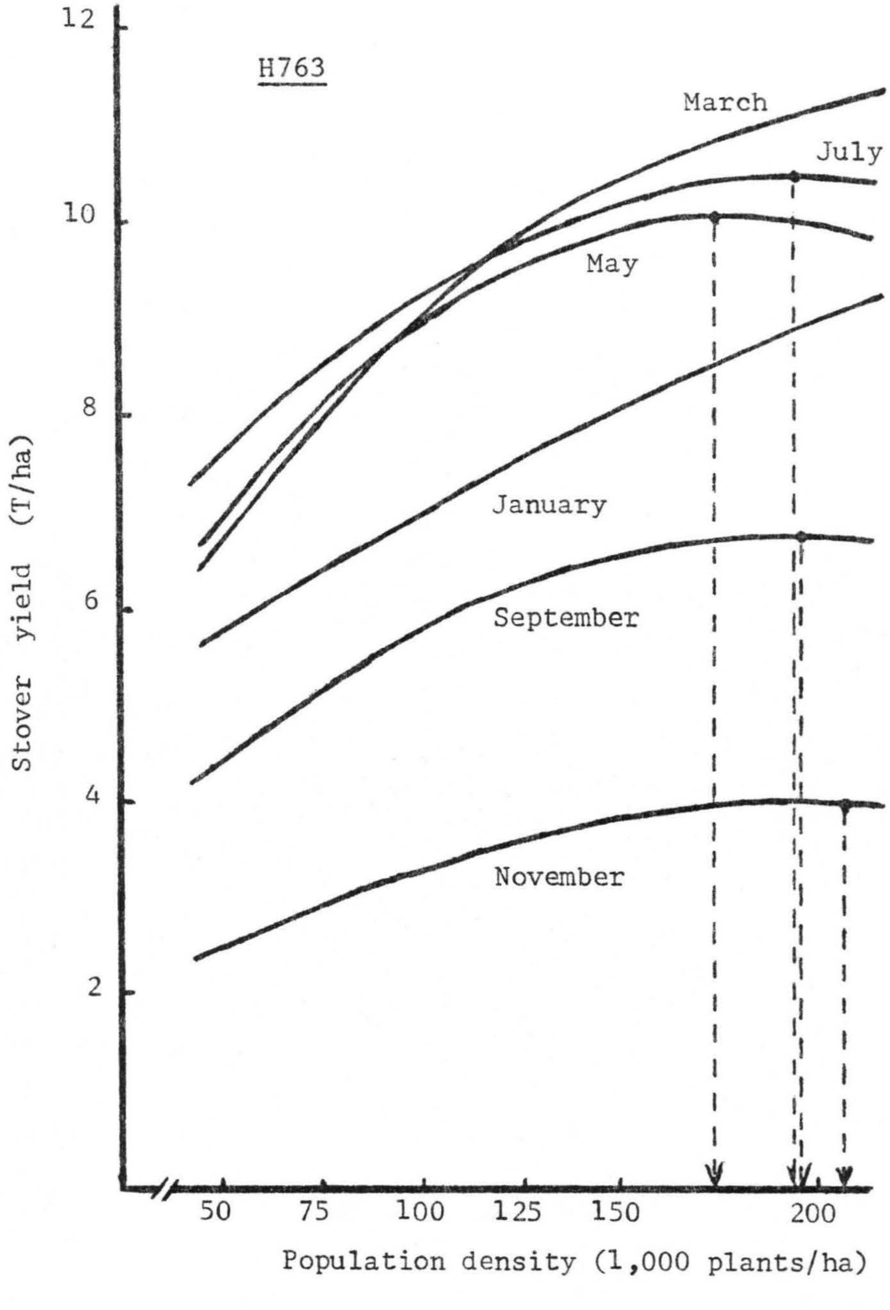


Figure 6. Responses of stover yields to population density in different seasons.

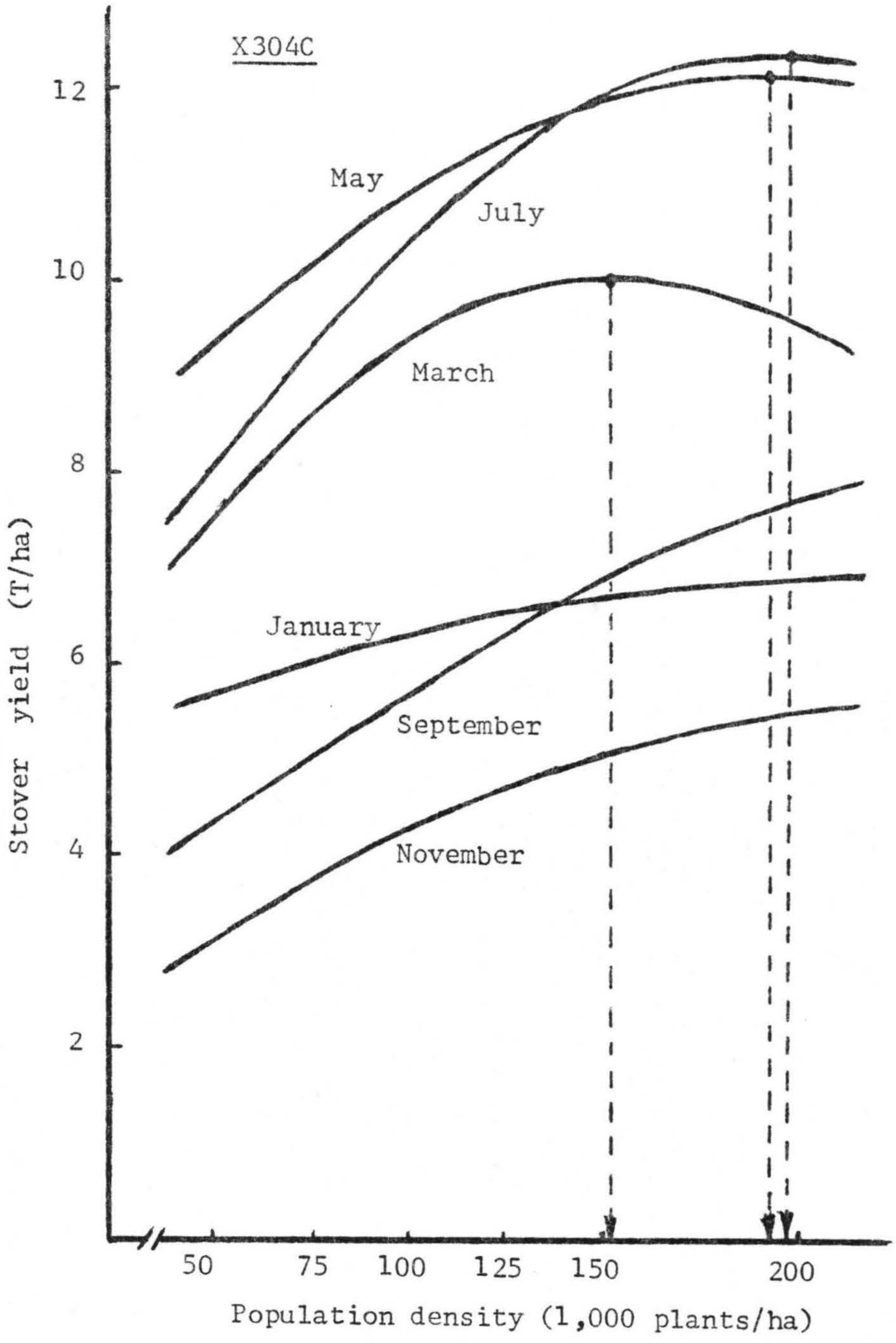


Figure 7. Responses of stover yields to population density in different seasons.

Table 4. Second degree polynomial equation of stover yield with population densities.

Hybrid	Month	Equation	r^2	Optimum pop. density for max. yield (1000 plants/ha)
H763	Jan	$Y= 4.71 + 0.023X - 0.0000089X^2$	0.98^{**}	1297.9
	Mar	$Y= 3.71 + 0.067X - 0.00015X^2$	0.99^{**}	277.9
	May	$Y= 3.81 + 0.072X - 0.000204X^2$	0.97^{**}	176.0
	Jul	$Y= 5.19 + 0.054X - 0.00014X^2$	0.99^{**}	195.3
	Sep	$Y= 2.62 + 0.042X -0.00011X^2$	0.82	196.7
	Nov	$Y= 1.37 + 0.025X - 0.000060X^2$	0.99^{**}	207.0
X304C	Jan	$Y= 4.99 + 0.015X - 0.000026X^2$	0.99^{**}	286.5
	Mar	$Y= 4.35 + 0.075X - 0.00025X^2$	0.93^{*}	152.9
	May	$Y= 6.84 + 0.056X - 0.00014X^2$	0.96^{**}	193.1
	Jul	$Y= 4.65 + 0.078X - 0.00020X^2$	0.93^{*}	198.7
	Sep	$Y= 2.93 + 0.032X - 0.000040X^2$	0.88^{*}	403.8
	Nov Y	$Y= 1.57 + 0.035X - 0.00077X2$	0.99^{**}	439.2

* Significant at 5 % level.

** Significant at 1 % level.

for maximum stover yields in different plantings. Seasonal plantings except January showed similar optimum population densities for H763. However, September and November plantings had higher optimum population densities than other seasons. Coefficients of determination for all plantings for both hybrids were either highly significant or significant except that for the September planting of H763.

Combined analysis of variance for grain yield showed that population, population x hybrid, population x season, and population x season x hybrid interactions were highly significant (Table 5). These results suggested that hybrids were different in response to population density, and population densities were different in different seasons. Population and population x season interaction were highly significant for stover yield, however, population x hybrid interaction was not significant, indicating that 2 hybrids were similar in response to population densities.

4.1.2 Plant Characters related to Population Density

Days to tasseling was delayed about 1 day for both hybrids as population increased (Figure 8). Days to tasseling for H763 was 55 days at lower populations (50,000 plants/ha), and 56 days at the highest population (200,000 plants/ha). Days to tasseling for X304C was 1-2 days longer than for H763.

Plant height was significantly different in population densities. Plant height decreased with increase of population. Plant height of H763 was 248 cm at 50,000 plants/ha and 236 cm at 200,000 plants/ha.

Table 5. Analysis of variance of grain and stover yields over 12 plantings.

Source	df	Mean squares	
		Grain yield	Stover yield
Season (S)	11	713.08	279.99
Reps in S	36	1.18	0.75
Hybrid (H)	1	187.11**	84.35**
H x S	11	11.04**	11.40**
Error (b)	36	0.64	0.81
Population (P)	5	20.26**	118.28**
P x S	55	3.77**	2.74**
P x H	5	5.32**	0.49
P x S x H	55	1.33**	1.22*
Error (c)	360	0.55	0.72

* Significant at 5 % level.
** Significant at 1 % level.

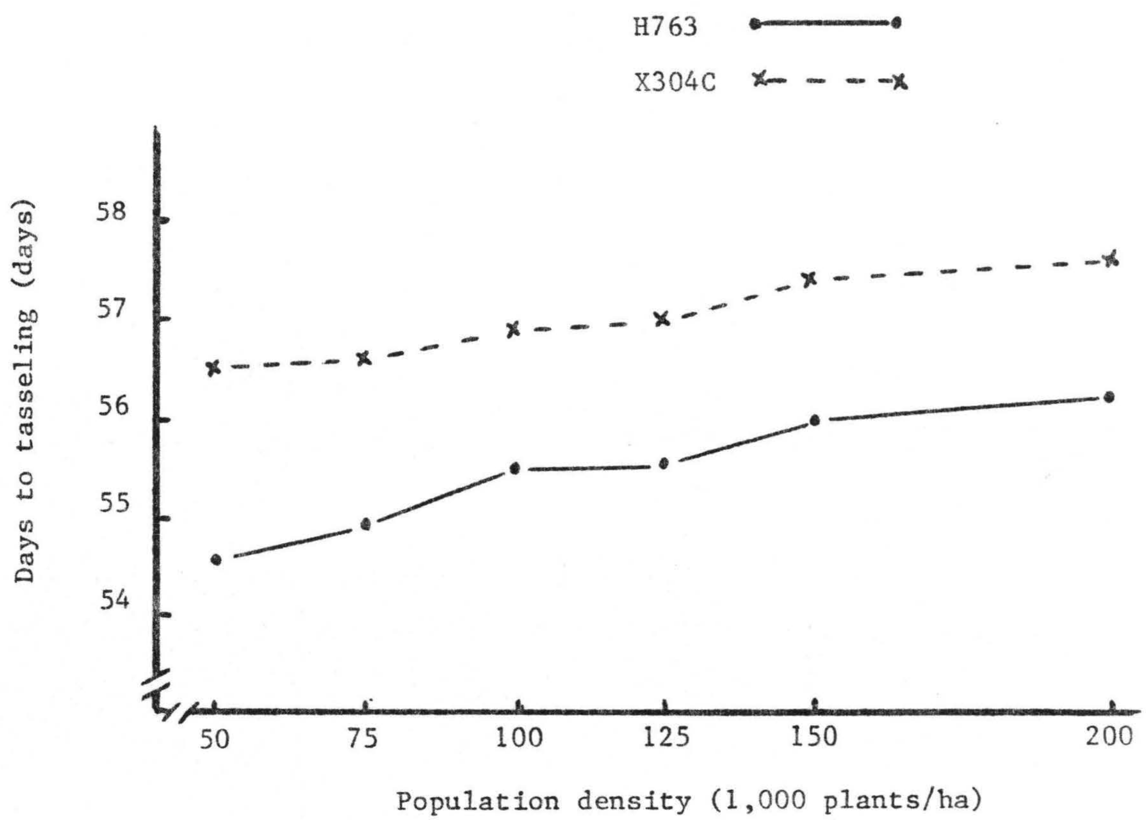


Figure 8. Days to tasseling in response to population density.

X304C was 6-10 cm taller than H763. These taller plants may be one of the factors responsible for the higher stover yield of X304C. Highly significant negative correlations were observed between population densities and plant heights (Figure 9). Correlation coefficients of H763 and X304C were -0.98 and -0.93. respectively. The slopes of the linear regressions of the 2 hybrids were similar, showing similar response of the 2 hybrids to population densities for plant height.

Ear height increased with an increase in population density for H763 and X304C (Figure 10). Ear heights at higher populations were 6 cm higher than those at lower populations for the both H763 and X304C. Ear height of X304C was 4-6 cm higher than for H763 in all populations.

Combined analysis of variance showed highly significant differences between hybrids and populations for days to tasseling, plant height, and ear height (Table 6). Population x hybrid interactions were not significant for those characters, indicating that the two hybrids were not different in response to population density, however, the population x season interaction was significant.

Leaf area per plant was measured using a rapid method (Pearce et al., 1975). Leaf area was not taken in the winter season (September and November plantings) due to severe lodging. Leaf area per plant decreased significantly with increasing population density. Leaf area at the lowest population (50,000 plants/ha) was 6383 cm^2 and 4472 cm^2 at higher population (200,000 plants/ha) indicating a 30 % reduction of leaf area at high population. X304C showed

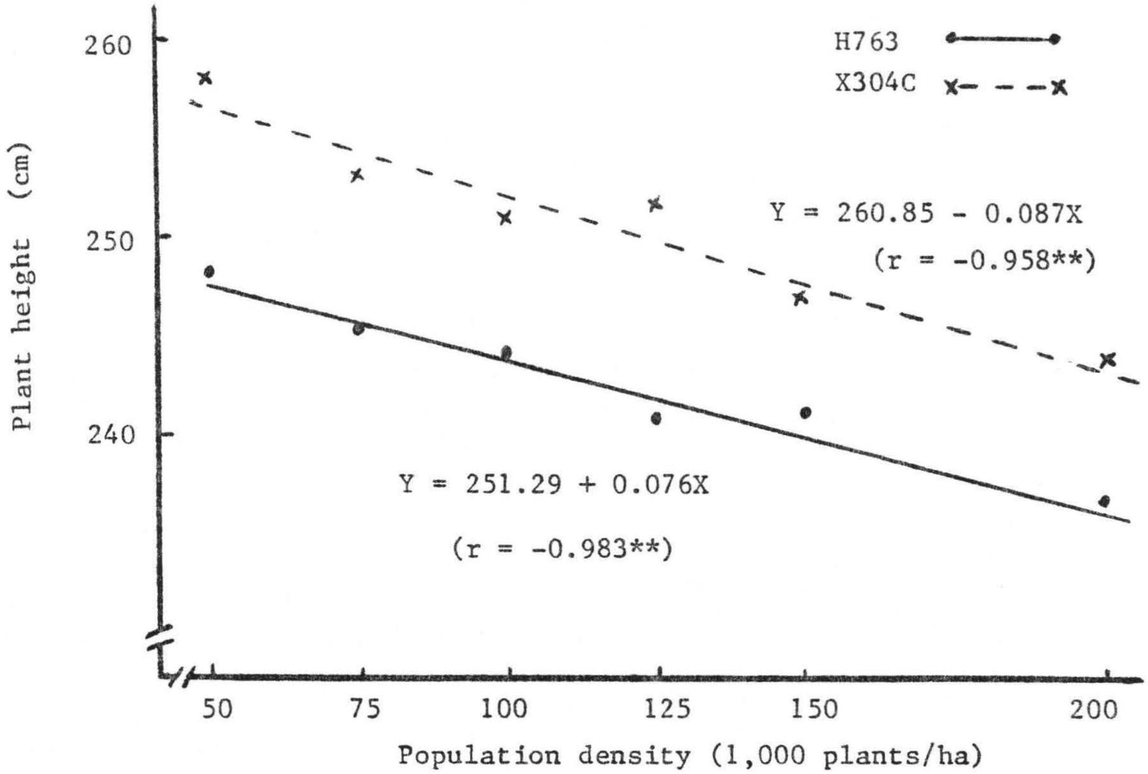


Figure 9. Relationship between population density and plant height.

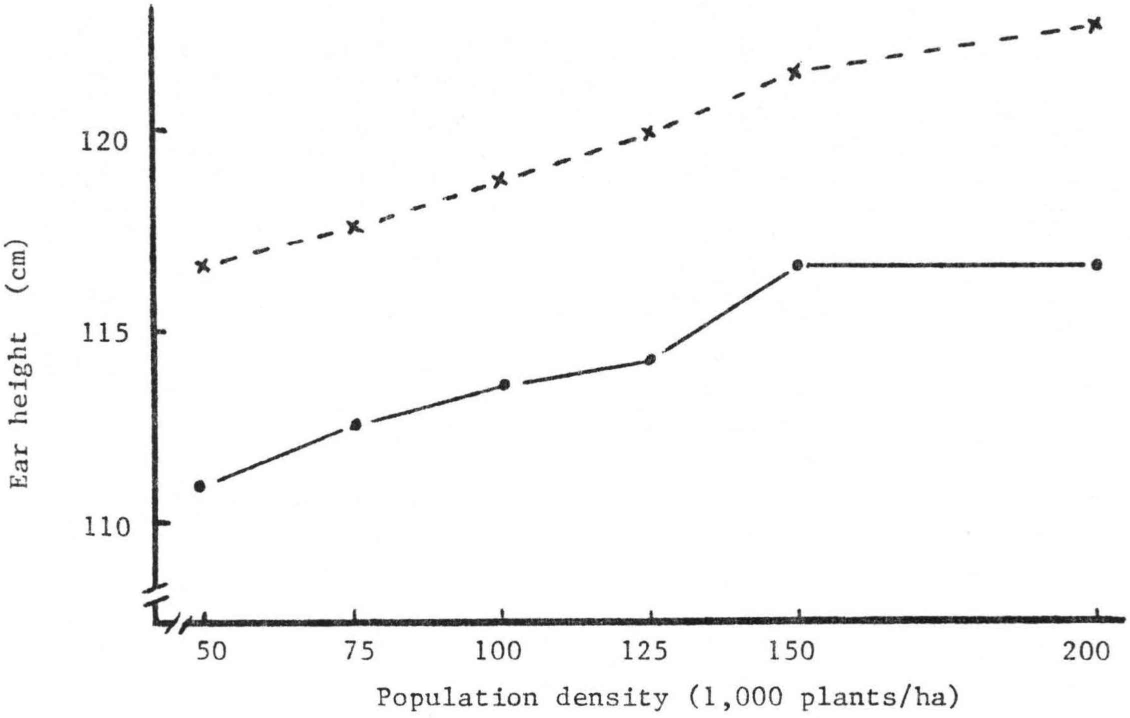


Figure 10. Ear height in response to population density.

Table 6. Analysis of variance of days to tasseling and plant characters over 12 bimonthly plantings.

Source	df	Mean squares		
		Days to tasseling	Plant height	Ear height
Season (S)	11	1815.85	125681.25	49626.51
Reps in S	36	4.48	291.58	191.28
Hybrid (H)	1	346.89**	9726.89**	4367.01**
H x S	11	30.61**	1373.94**	881.78**
Error (b)	36	0.88	114.45	76.90
Population (P)	5	25.24**	1889.87**	2407.89**
P x S	55	0.57*	123.16*	73.47*
P x H	5	0.75	95.32	6.32
P x S x H	55	0.27	121.83	52.81
Error (c)	360	0.37	80.31	40.05

* Significant at 5 % level.

** Significant at 1 % level.

similar reduction of leaf area per plant with increasing population and 3-6 % less than H763. However, LAI increased significantly as population increased. The rate of LAI increase was much higher than the rate of leaf area reduction. LAI of H763 was 3.22 and 9.03 at the lowest and highest population, respectively, showing almost a three-fold increase.

Stem diameter was measured at the first node from the ground. As the population increased, stem diameter decreased significantly. Highly significant negative correlations were obtained between population density and stem diameter for both H763 and X304C (Figure 11). Correlation coefficients of H763 and X304C were -0.97 and -0.98, respectively. Stem diameter was 2.1-2.3 cm at low population, while it was 1.4-1.5 cm at high population, showing about 30 % reduction at the high population density. This result suggested that reduction of stem diameter might be one factor for reduced stover yield. Stem diameter of X304C was 0.1-0.2 cm larger than H763. This could be one of the causes of the higher stover yield of X304C than H763.

4.1.3 Response of yield components to population density

Several yield components, including filled ear length, number of kernel rows, number of kernels/row, and 100 kernel weight, were measured after harvesting. Filled ear length was reduced significantly for both hybrids, with an increase in population density. Filled ear length of H763 was 13.2 cm at 50,000 plants/ha, while it was 8.5 cm

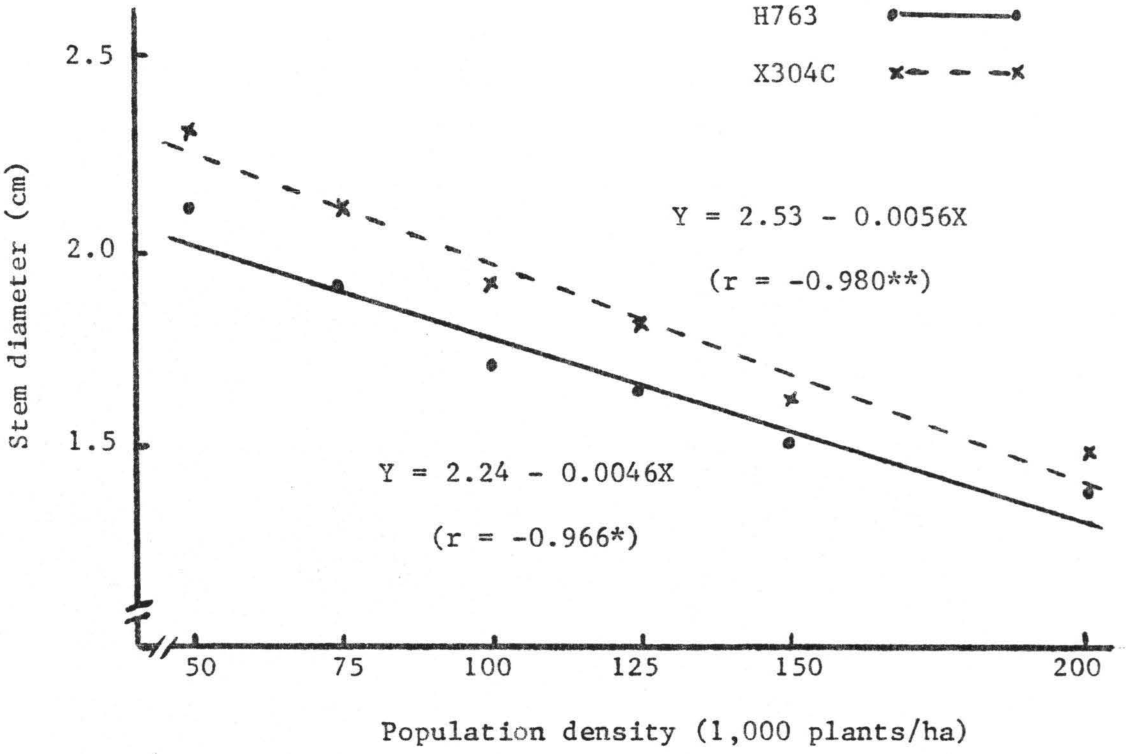


Figure 11. Relationship between population density and stem diameter.

at 200,000 plants/ha indicating a 36 % reduction. X304C showed a similar decreasing rate, but was 1-2 cm larger than H763. There were highly significant negative correlations between populations and filled ear length (Figure 12). The slopes of linear regressions of both hybrids were similar to each other, indicating similar response to population for filled ear length.

Number of kernel rows decreased significantly as the population increased, but the rate of reduction (8-16 %) at the higher population was much less than that of filled ear length (36 %). Number of kernels/row was significantly different between population densities. It was 28 and 16 at 50,000 and 200,000 plants/ha respectively for H763. The reduction rates were 43 % for H763 and 42 % for X304C. The reduced number of kernels/row could be the reason for low grain yield at higher population densities. H763 had 4-6 fewer kernels/row than X304C, and this could be the reason for low grain yield in H763. A linear relationship was observed between population density and number of kernels/row on both H763 and X304C, with highly significant negative correlations (Figure 13).

Combined analysis of variance over 12 plantings indicated highly significant hybrid and population effects for yield components, including filled ear length, number of kernel rows, and number of kernels/row (Table 7). The population x hybrid interaction was significant only for number of kernel rows, while population x season interactions were significant for filled ear length and number of kernels/row. These results suggest that population responses for filled ear length and number of kernels/row were different in

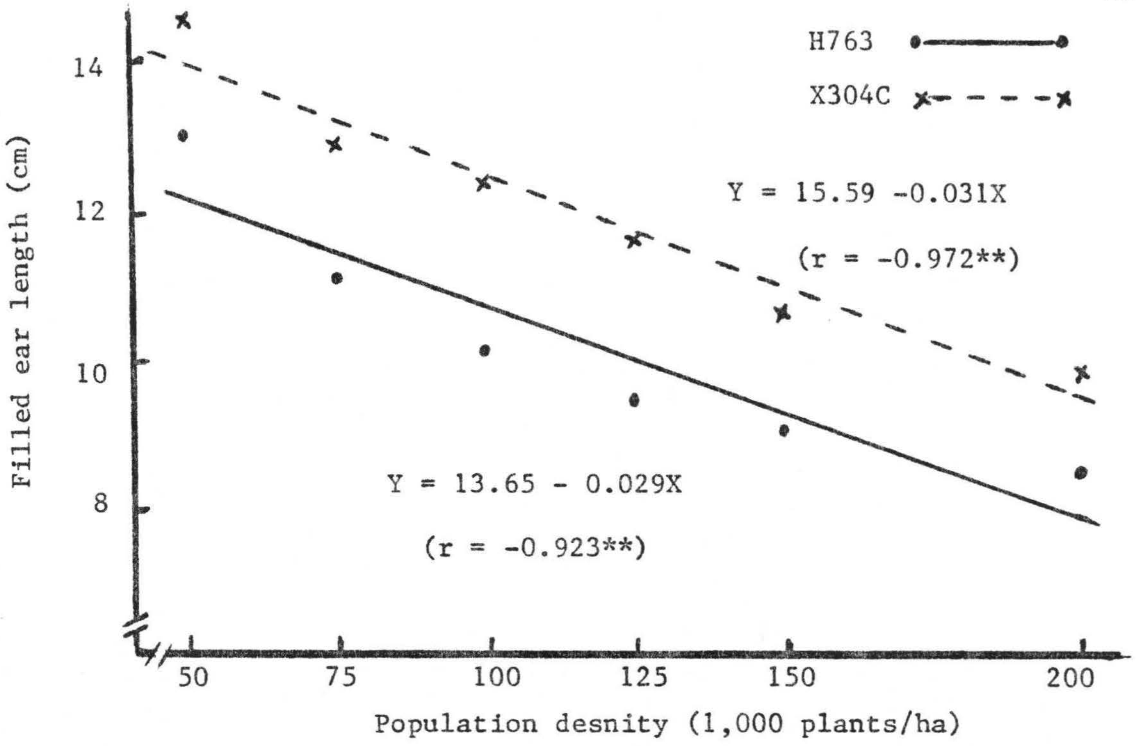


Figure 12. Relationship between population density and filled ear length.

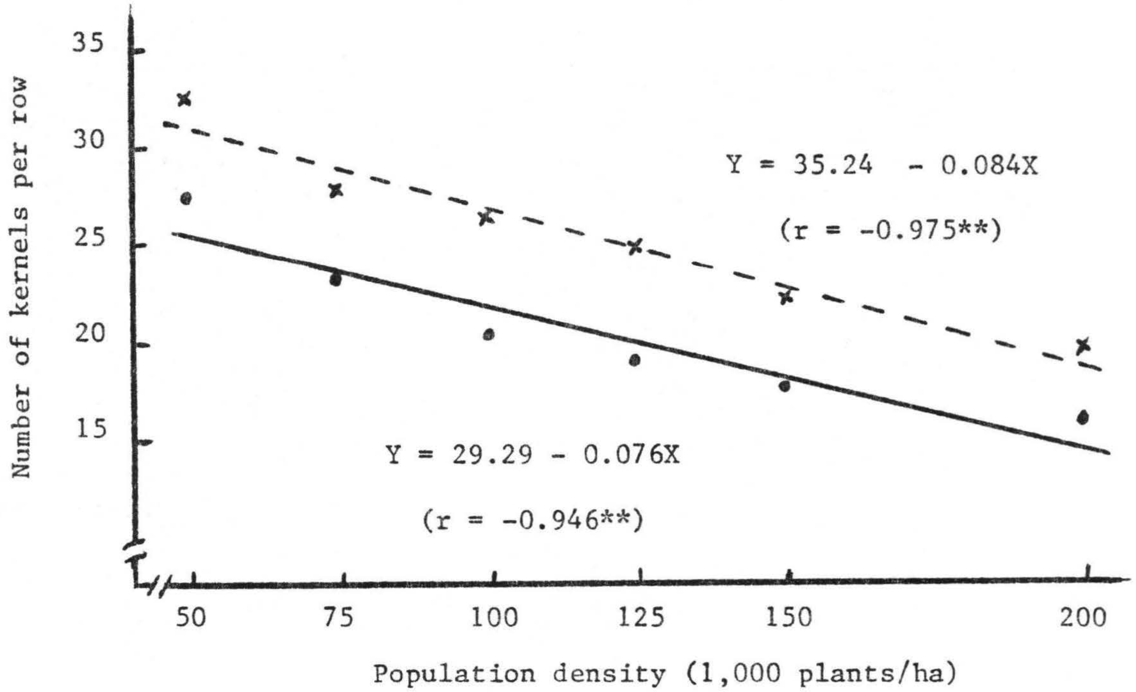


Figure 13. Relationship between population density and number of kernels per row.

Table 7. Analysis of variance of yield components over 12 plantings.

Source	df	Mean squares		
		Filled ear Length	Number of kernel rows	Number of kernels per row
Season (S)	11	148.55	48.83	799.65
Reps in S	12	1.72	0.62	10.14
Hybrid (H)	1	227.38**	51.85**	1802.50**
H x S	11	4.49**	17.58**	17.21*
Error (b)	12	0.91	0.76	4.71
Population (P)	5	138.65**	15.17**	968.36**
P x S	55	2.35**	0.71	14.25**
P x H	5	1.62	1.98**	10.05
P x H x S	55	1.06	0.46	8.41
Error (c)	120	0.76	0.46	5.84

* Significant at 5 % level.
** Significant at 1 % level.

different seasons.

Fusarium infection on kernels was found to be higher as the population increased in both hybrids. The response of fusarium infection to population density was different between hybrids. Fusarium infection was about 1.4% at 50,000 plants/ha for H763, while it was 4.2 % at 200,000 plants/ha. X304C showed much less kernel fusarium than H763. It ranged from 0.6 % at low to 1.5 % at high population for X304C.

Lodging and Barrenness:

In spring and summer plantings, 20-30 % lodging was observed at higher population (150,000-20,000 plants/ha) for H763. Stem diameter of H763 was 0.1-0.2 cm less than that of X304C. This smaller stem diameter might be the cause of more lodging of H763. However, severe lodging (more than 70 %) was noted at all population densities on both hybrids in the winter seasons. Lodging was the main factor for high barrenness resulting in reduction of grain yield in the winter seasons.

High percentages of barren stalks were recorded for both H763 and X304C in September and November plantings. The barrenness was found to be higher as the population increased. The barrenness of H763 and X304C were 9 and 2 %,respectively at 50,000 plants/ha, but increased to 37 and 21 % at 200,000 plants/ha. Highly significant correlations were observed between populations and barrenness percentage for both hybrids (Figure 14).

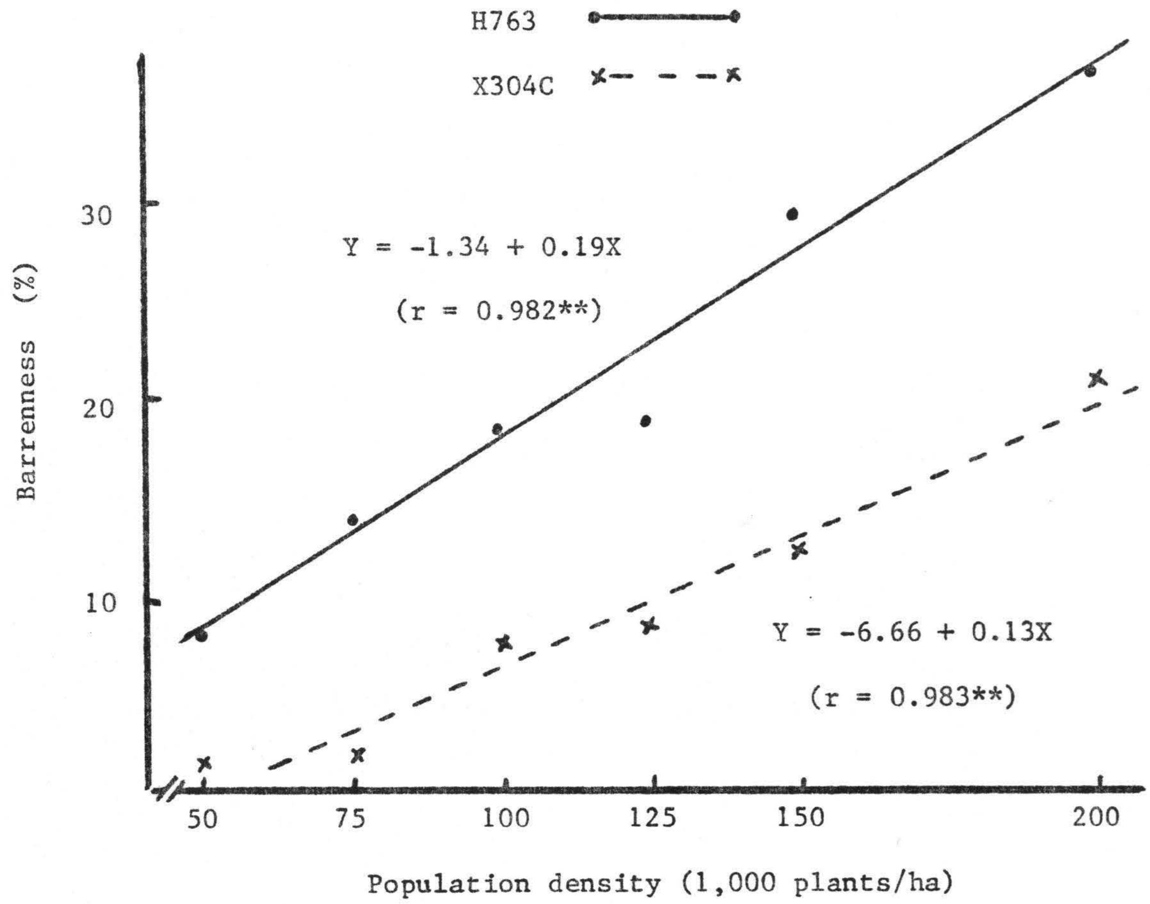


Figure 14. Relationship between population density and barrenness.

4.1.4 Seasonal changes of yields and their components

Climatic conditions at the Waimanalo Research Station:

Maximum and minimum temperature and daily solar radiation data were recorded during the experimental period. Figure 15 shows the monthly average climatic data. The average maximum temperature ranged from 24 to 30 °C, with higher temperature in June, July, August, and September, and lower temperature in November, December, and January. Minimum temperature ranged from 18 to 23 °C, showing similar cyclic change as maximum temperature. The average daily solar radiation showed the cyclic changes similar to that of maximum and minimum temperature. The cyclic change of solar radiation was approximately 2 months earlier than those of temperatures. Higher solar radiation began around May and continued to September, then decreased sharply in October in both years (1980 and 1981). In summer reasons, the average daily solar radiation was about 400-500 cal. $cm^{-2} \cdot day^{-1}$, and in the winter it was 150-250 cal. $cm^{-2} \cdot day^{-1}$. The highest average daily solar radiation was 527 cal. $cm^{-2} \cdot day^{-1}$ in July, 1981 and the lowest value was 153 cal. $cm^{-2} \cdot day^{-1}$ in November, 1981.

Figure 16 shows the average maximum and minimum temperature and average daily solar radiation during the growing period over 12 bimonthly plantings. Temperature was higher in the May, July, and September plantings in both 1980 and 1981, while it was low in the January, March, and November plantings. The seasonal changes were

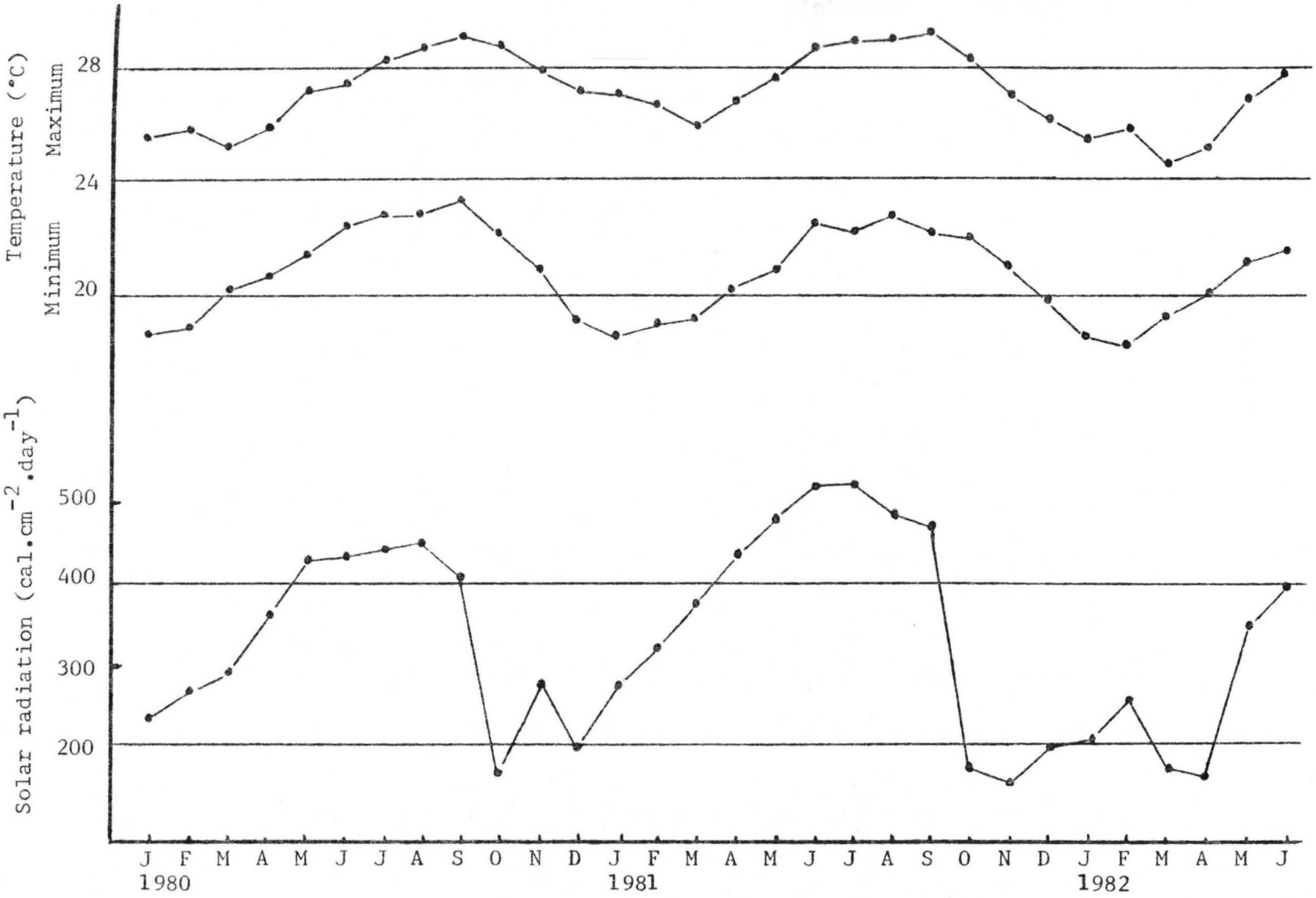


Figure 15. Monthly average maximum and minimum temperature, and average daily solar radiation during experiment period.

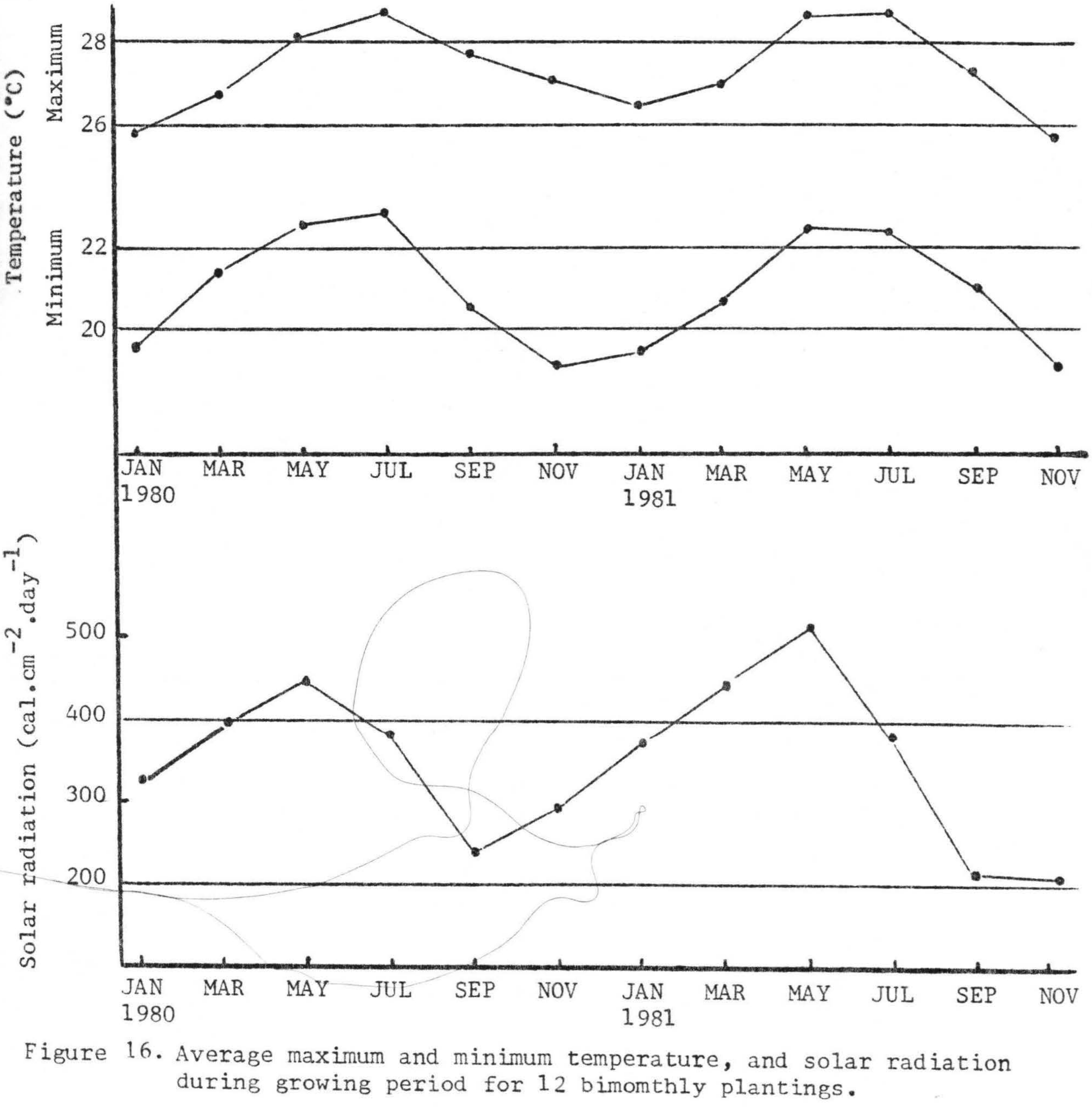


Figure 16. Average maximum and minimum temperature, and solar radiation during growing period for 12 bimomthly plantings.

different for solar radiation, i.e. it was higher in January, March, May, and July, and lower in September and November plantings for both years. Therefore March, May, and July plantings were found to be favorable conditions, and September and November plantings were unfavorable seasons. Rainfall was generally higher in winter seasons and lower in summer, but it was quite variable from month to month and did not show cyclic change throughout the years. Rainfall is not disscussed in this study as an overhead sprinkler system was used in all experiments.

Seasonal variation of yields and their components

Seasonal variation of grain yield showed cyclic changes throughout both years with higher yields in March, May, and July plantings, and lower yields in September and November plantings (Figure 17). The monthly average grain yield of H763 over 6 different population densities ranged from 6 to 12 T/ha in favorable seasons, and ranged from 1 to 3 T/ha in unfavorable seasons (September and November plantings). X304C showed a response similar to that of H763. Grain yield ranged from 6 - 13 T/ha in January, March, May, and July plantings, and 2 - 4 T/ha in September and November plantings. The reduced grain yield in September and November could be attributed to lower solar radiation and severe lodging. Severe lodging was observed in September and November plantings for both the hybrids. There were highly significant correlations between average daily solar radiation during the growing period and grain yield over 12 bimonthly plantings (Figure 18). Correlation coefficients for H763 and X304C were 0.82

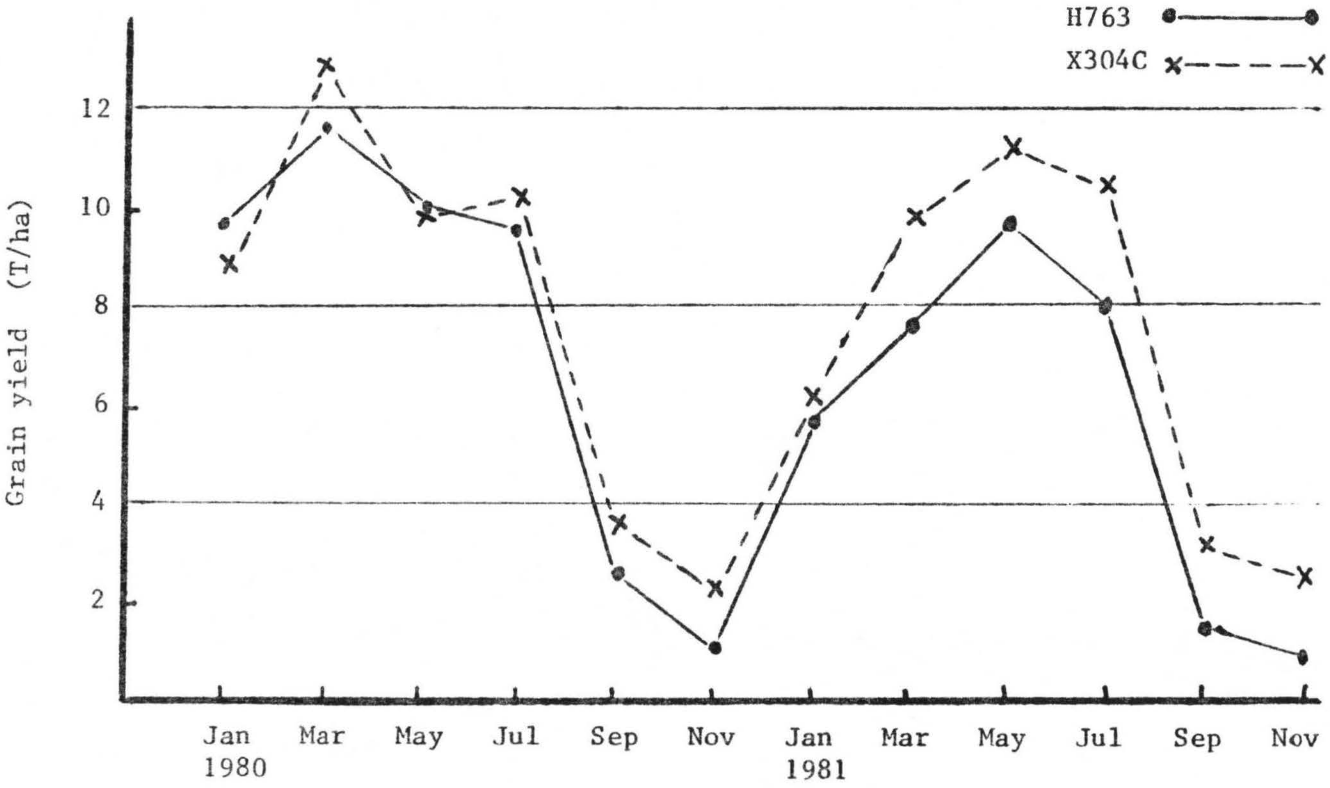


Figure 17. Seasonal changes of grain yields.

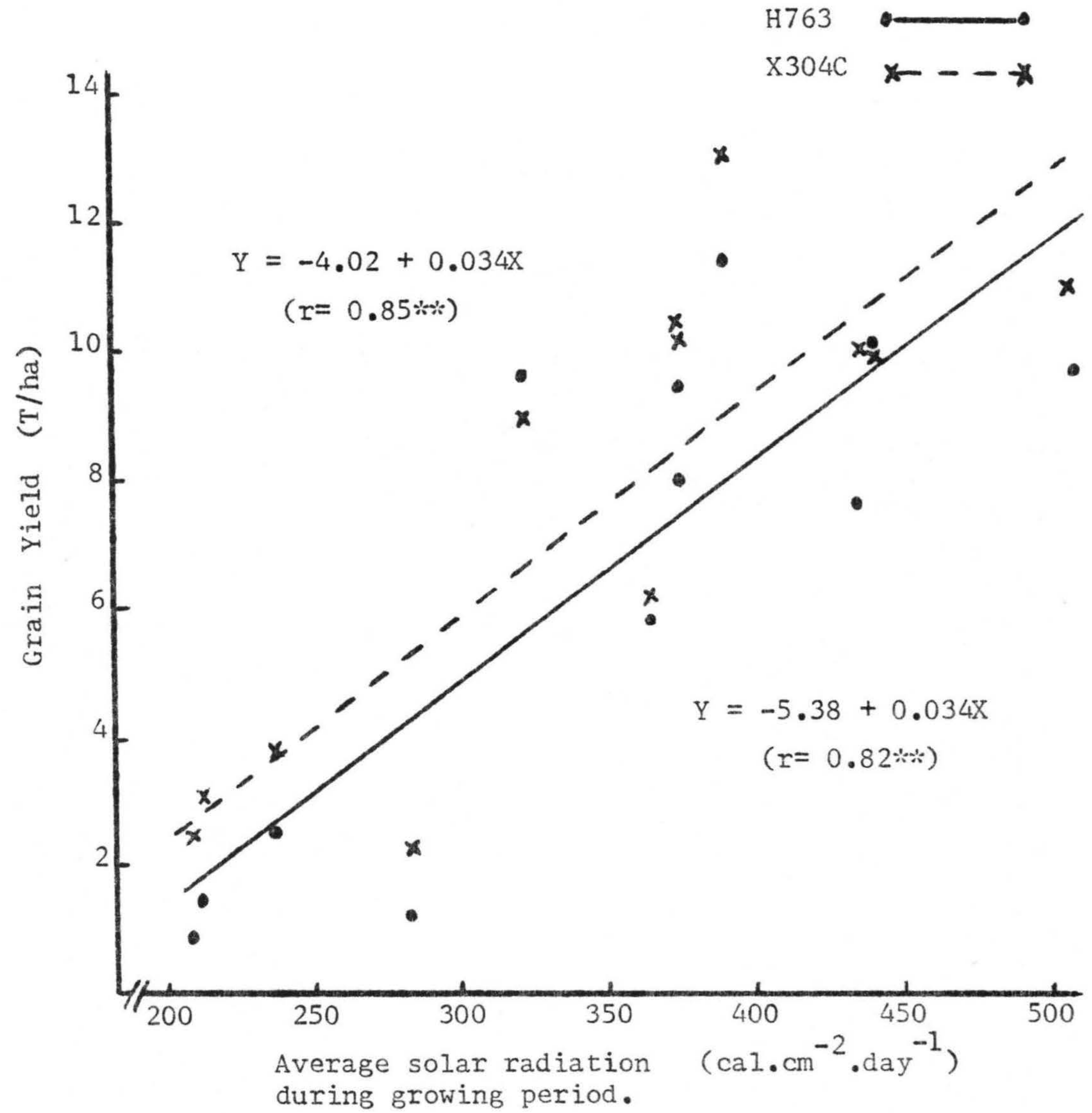


Figure 18. Relationship between average solar radiation during growing period and grain yield.

and 0.85, respectively. The slopes of linear regressions for both H763 and X304C were the same, indicating the responses of grain yield of two hybrids to solar radiation were similar.

Seasonal variation of stover yield averaged over populations was similar to that of grain yield (Figure 19). In March, May, and July plantings, stover yield ranged from 8 to 12 T/ha, whereas it ranged from 3 to 8 T/ha in other plantings. The reduction in stover yield under unfavorable seasons was smaller than those for grain yield for both H763 and X304C. This was because barren stalks in winter seasons produced no grain, but had stover yields. Highly significant correlations between average daily solar radiation during the growing period over 12 plantings and stover yields were obtained for both hybrids (Figure 20). The slopes of linear regression were larger for X340C than for H763, showing that X304C was more efficient in utilizing the solar radiation for producing higher stover yield under high solar radiation conditions.

Yield components, including filled ear length, number of kernels per row, showed cyclic changes over 12 plantings (Figures 21, 22). Filled ear length in the spring and summer planting was about 2 times larger than that in winter seasons due to favorable seasonal effects. Filled ear length of X304C was 1 - 3 cm larger than H763 in all the plantings. The respose of number of kernels/row to different seasons was similar to that of filled ear length. In winter seasons, the number of kernels/row was about half of those under favorable seasons. X304C had 2-7 more kernels/row than H763 in all plantings. These reductions in yield components could explain the reduction in

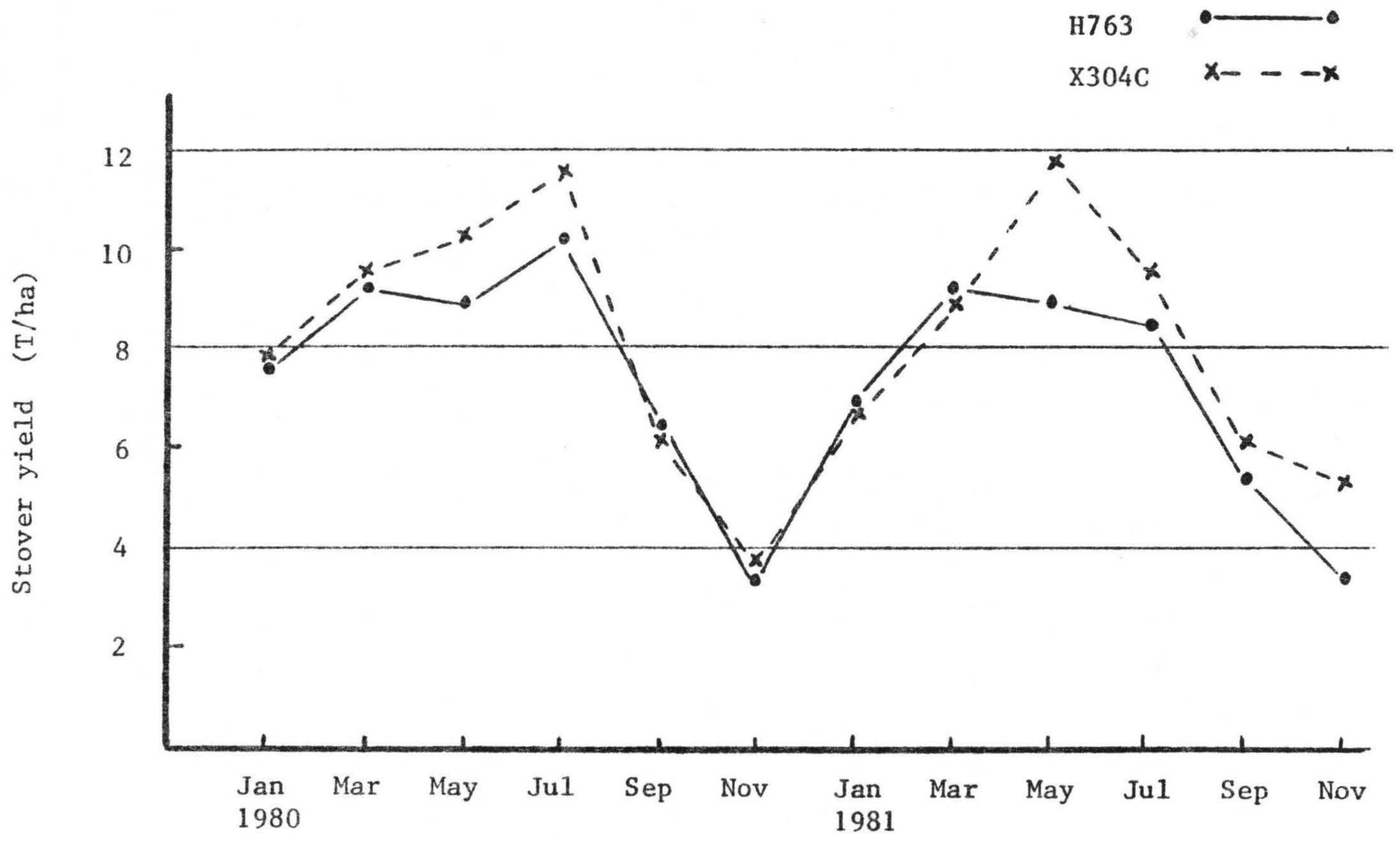


Figure 19. Seasonal changes of stover yields.

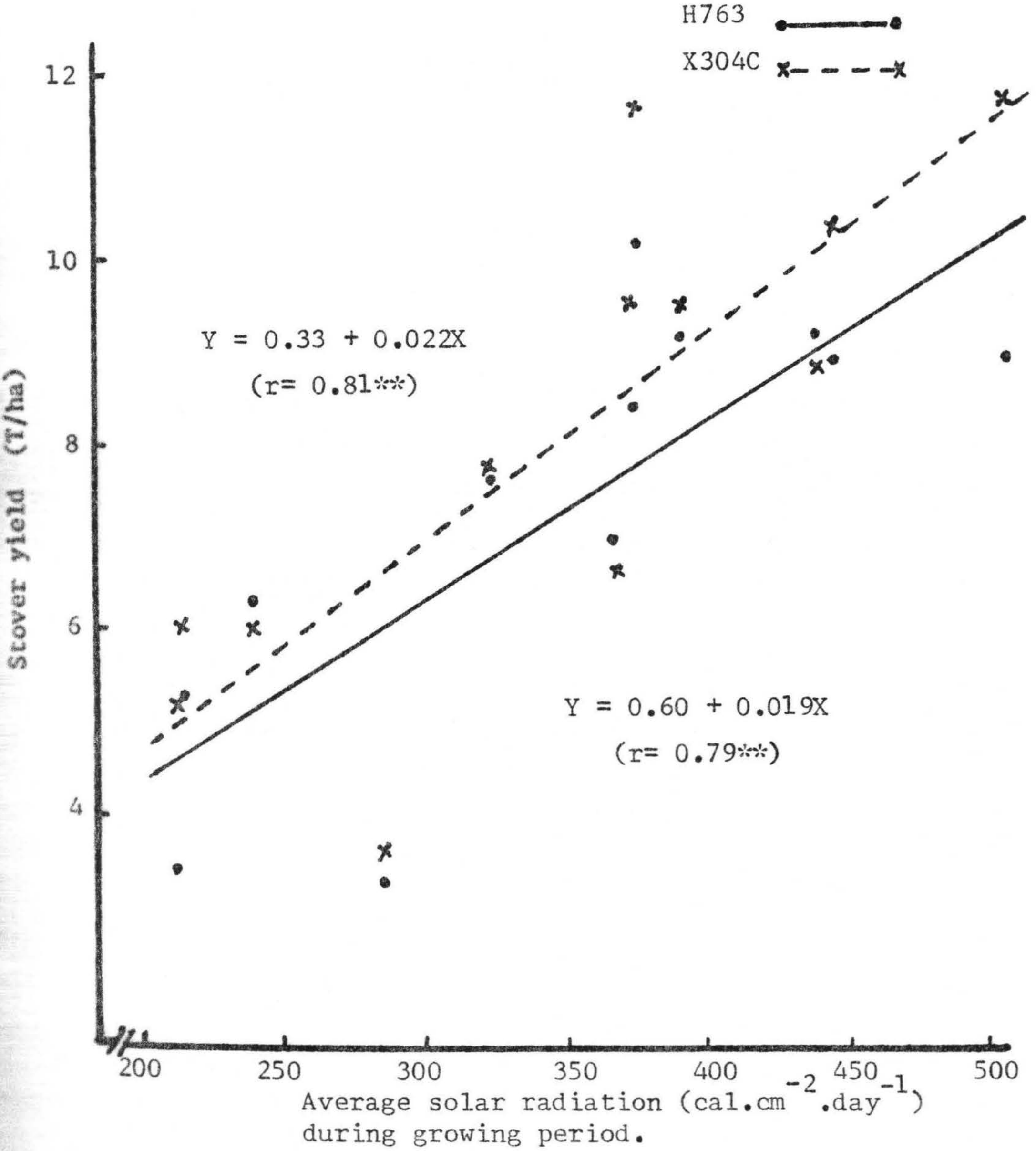


Figure 20. Relationship between average solar radiation during growing period and stover yield.

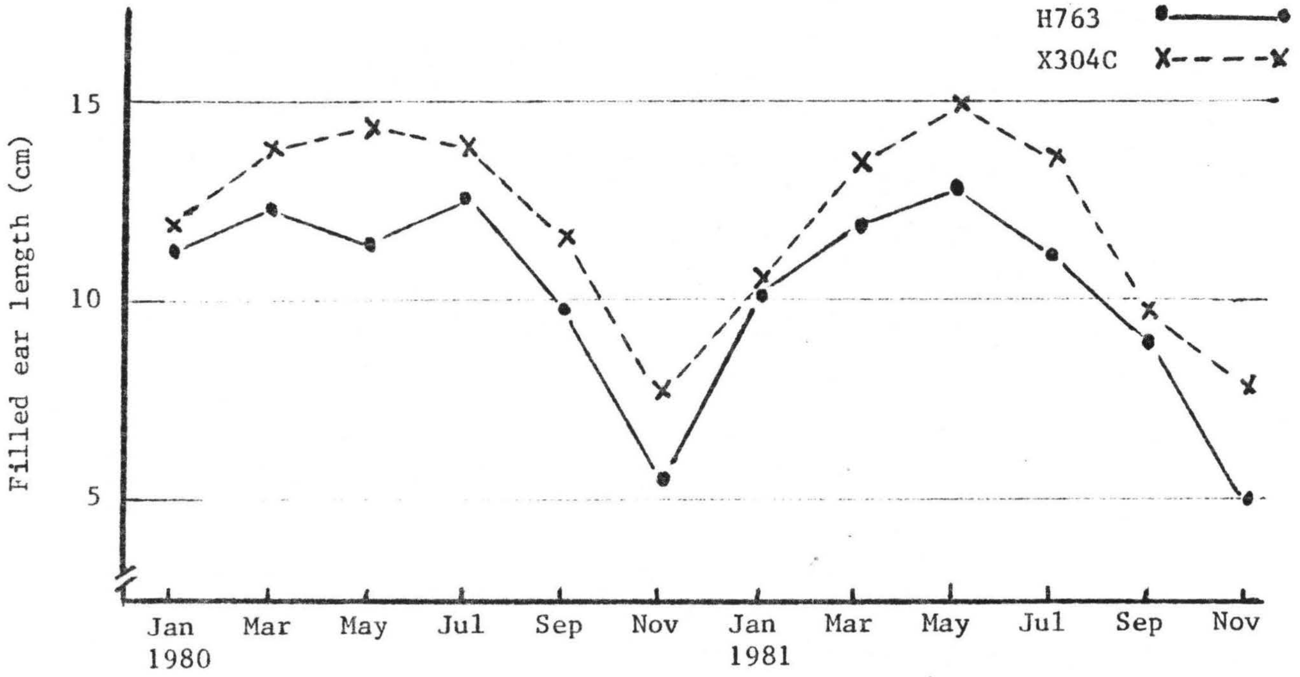


Figure 21. Seasonal changes of filled ear length.

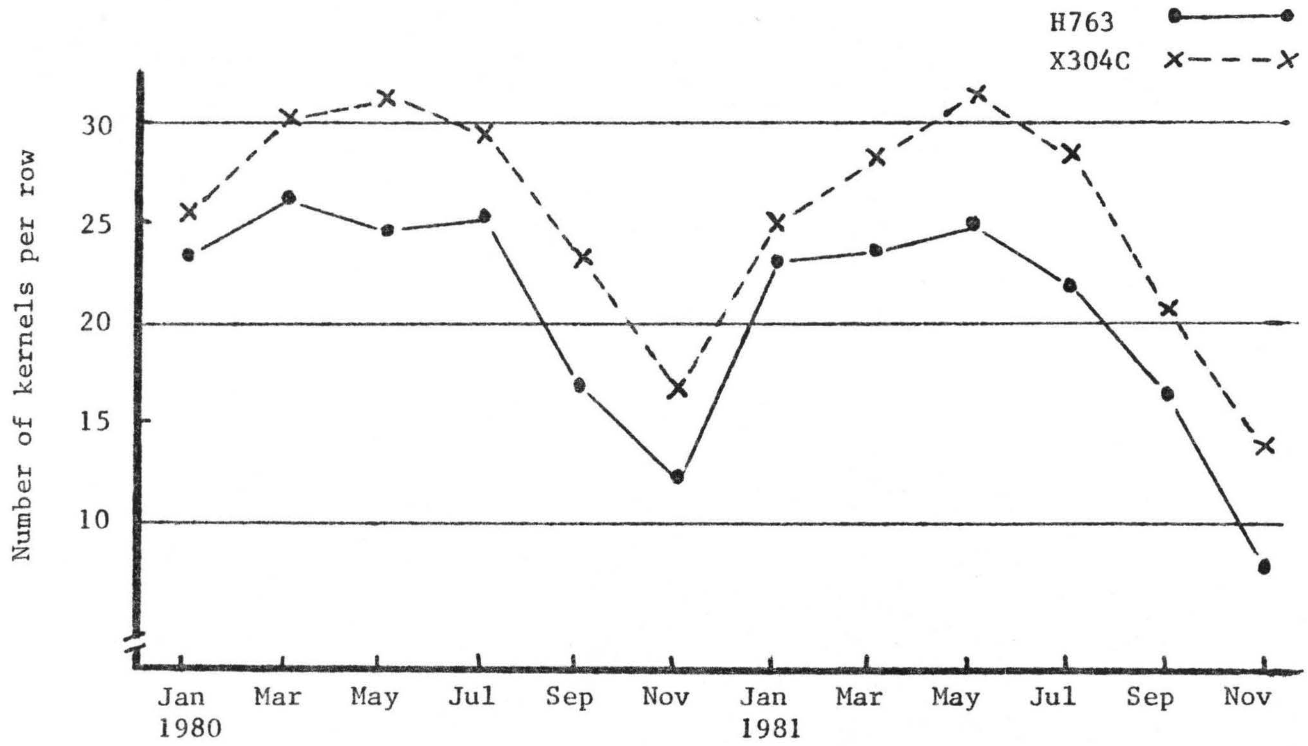


Figure 22. Seasonal changes in number of kernels per row.

grain yield in unfavorable conditions. Number of kernel rows reduced in winter plantings but the seasonal variations were rather noncyclic than that of other yield components.

Table 8 shows highly significant correlations between yields and yield components, including filled ear length, number of kernel rows, and number of kernels/row for both H763 and X304C. The average correlation coefficients for two hybrids for filled ear length, number of kernel rows, and number of kernels/row were 0.89, 0.85, and 0.92, respectively. This result suggests that number of kernels/row was the most important yield component.

Plant Characters:

Days to tasseling, plant height, and ear height showed cyclic changes throughout the years. Days to tasseling in November, January. and March were much longer than those in May, July, and September plantings. It ranged from 58 to 65 days in winter and spring, while it ranged from 45 to 55 days in summer seasons (Figure 23). Significant negative correlations were found between days to tasseling and average maximum and minimum temperature, but no correlation was observed with solar radiation.

Plant and ear height showed similar seasonal changes to those of grain and stover yields (Figures 24, 25). Plant and ear height in winter seasons almost half of those in summer plantings. These reduced plant height might be the factor of reduced stover yields in winter plantings.

Table 8. Correlations among yields, plant characters, ans yield components over 12 bimonthly plantings.

Characters	Stover yield	Total dry matter	Plant height	Ear height	Filled ear length	Number of kernel row	Number of kernel/row
Grain yield	0.91** 0.90**	0.99** 0.98**	0.59* 0.67*	0.66* 0.64*	0.88** 0.89**	0.86** 0.84**	0.92** 0.92**
Stover yield		0.96** 0.96**	0.81** 0.80**	0.84** 0.80**	0.97** 0.89**	0.89** 0.74**	0.95** 0.91**
Total dry matter yield			0.69* 0.74**	0.74** 0.73**	0.93** 0.91**	0.89** 0.83**	0.95** 0.94**
Plant height				0.93** 0.98**	0.86** 0.84**	0.79** 0.78**	0.77** 0.86**
Ear height					0.86** 0.83**	0.76** 0.70*	0.76** 0.81**
Filled ear length						0.93** 0.83**	0.96** 0.91**
Number of kernel rows							0.97** 0.93**

Upper and lower values are H763 and X304C, respectively.

* Significant at 5 % level.
** Significant at 1 % level.

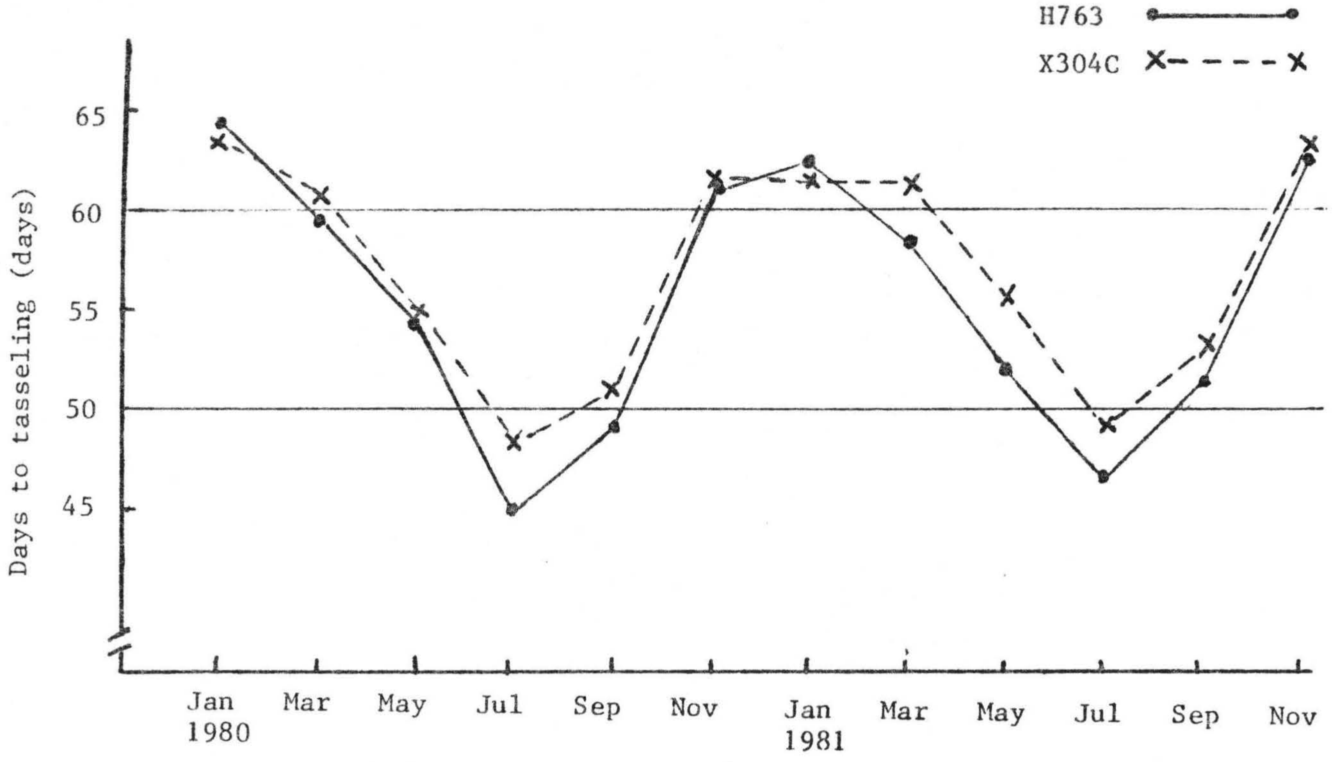


Figure 23. Seasonal changes in days to tasseling.

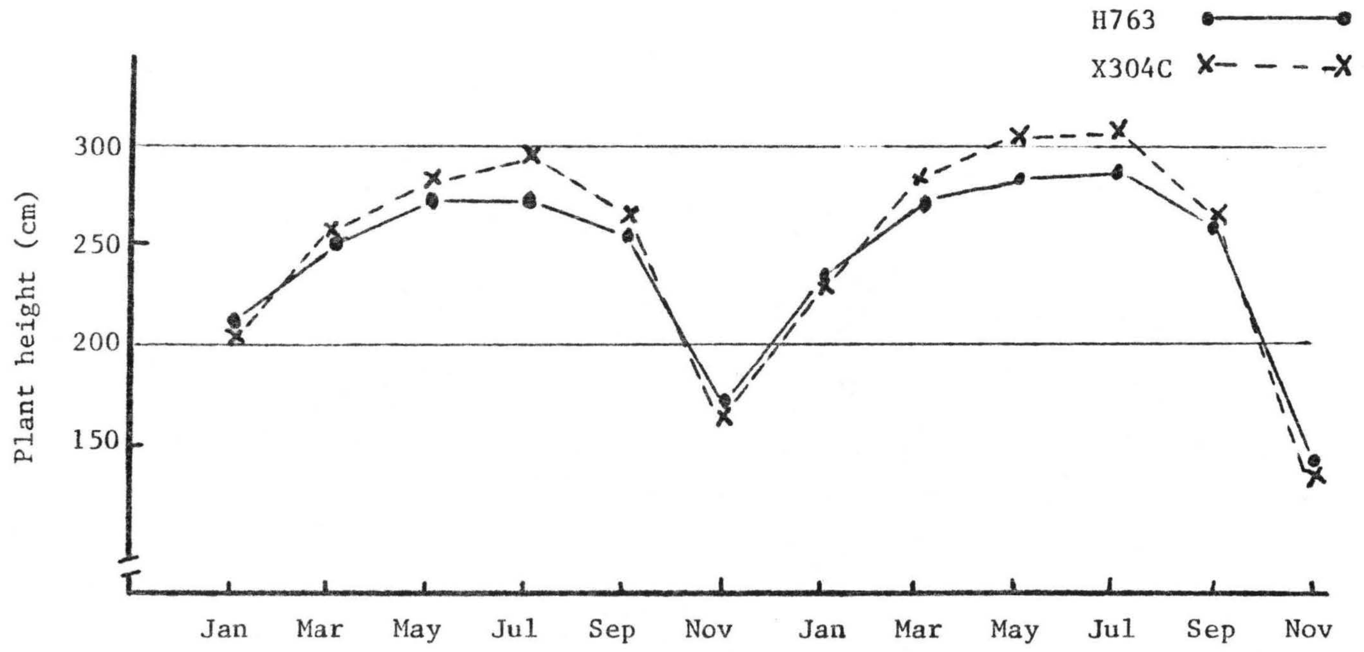


Figure 24. Seasonal changes in plant height.

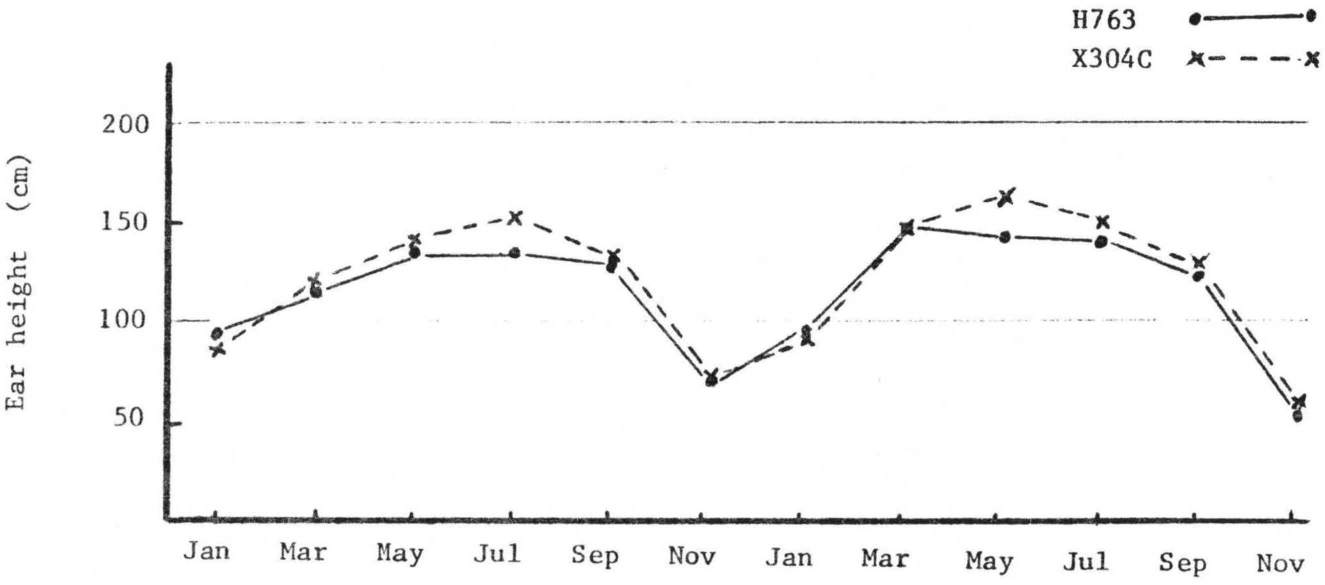


Figure 25. Seasonal changes of ear height.

Relationship between yields and climatic factors:

Correlations between yields and their components, and climatic factors are presented in Table 9. TDM, grain, and stover yields were significantly correlated with average solar radiation from planting to tasseling and to harvesting for both H763 and X304C. However, average maximum temperature was not correlated with yields except in stover yield of X304C. Average minimum temperature during the growing period was significantly correlated with total dry matter, grain, and stover yields. This indicated that minimum temperature was a more important factor than maximum temperature for corn yields at Waimanalo. Plant characters, including plant height and ear height, and yield components were correlated with average solar radiation from planting to tasseling and to harvesting. In all cases, minimum temperature was more highly correlated with yields and their components than maximumtemperature. This result suggests that minimum temperature might be more important than maximum temperature for those characters as well as yields.

Growing degree days (GDD) was calculated as follows:

GDD = (Maximum temperature + Minimum temperature) / 2 - 10°C.

There were significant correlations between GDD during the growing period and yields and the yield components excepting number of kernel rows. Multiple regression analysis was carried out using yields and their components as dependent variables, and average maximum and minimum temperature, and average solar radiation as independent variables. Table 10 shows multiple regression equations for yields and several characters with climatic factors, including average

Table 9. Correlations between yields and their components and climatic factors.

		From planting to tasseling				From planting to harvesting			
Characters	Hybrids	Average max. temp.	Average min. temp.	Average solar radiation	Growing degree days	Average max. temp.	Average min. temp.	Average solar radiation	Growing degree days
Grain yield	H763	0.04	0.26	0.74**	0.04	0.29	0.62*	0.82**	0.60**
	X304C	0.09	0.32	0.82**	0.19	0.36	0.68*	0.85**	0.59*
Stover yield	H763	0.26	0.47	0.84**	-0.32	0.50	0.76**	0.80**	0.66*
	X304C	0.34	0.60*	0.90**	0.06	0.60*	0.87**	0.81**	0.66*
Total dry matter yield	H763	0.12	0.34	0.79**	-0.10	0.37	0.69*	0.83**	0.63*
	X304C	0.20	0.45	0.88**	0.14	0.47	0.78**	0.85**	0.64*
Plant height	H763	0.63*	0.71*	0.80**	-0.52	0.74**	0.83**	0.61*	0.71*
	X304C	0.66*	0.74**	0.84**	-0.22	0.79**	0.87**	0.63*	0.70*
Ear height	H763	0.48	0.64*	0.74**	-0.42	0.63*	0.80**	0.61*	0.78**
	X304C	0.69*	0.79**	0.85**	-0.15	0.83**	0.90**	0.62*	0.71**
Filled ear length	H763	0.33	0.46	0.79**	-0.27	0.48	0.72**	0.75**	0.71**
	X304C	0.37	0.51	0.85**	0.03	0.54	0.73**	0.75**	0.70*
Number of kernel rows	H763	0.26	0.30	0.75**	-0.18	0.45	0.60*	0.78**	0.54
	X304C	0.26	0.30	0.75**	-0.01	0.45	0.60*	0.78**	0.54
Number of kernels/row	H763	0.16	0.30	0.74**	-0.12	0.38	0.63*	0.81**	0.59*
	X304C	0.31	0.49	0.86**	0.04	0.56	0.78**	0.85**	0.70*

* Significant at 5 % level.

** Significant at 1 % level.

Table 10. Multiple regression of yields and their components with average temperature and solar radiation from planting to tasseling

Characters	Hybrids	Equation	r^2
Grain yield	H763	$Y = 40.99 - 2.15X_1 + 0.69X_2 + 0.029X_3$	0.66^{*}
	X304C	$Y = 37.29 - 2.00X_1 + 0.71X_2 + 0.030X_3$	0.78^{**}
Stover yield	H763	$Y = 15.82 - 0.94X_1 + 0.55X_2 + 0.017X_3$	0.74^{**}
	X304C	$Y = 17.56 - 1.46X_1 + 1.17X_2 + 0.018X_3$	0.89^{**}
Total dry matter yield	H763	$Y = 56.81 - 3.09X_1 + 1.24X_2 + 0.046X_3$	0.71^{*}
	X304C	$Y = 55.10 - 3.48X_1 + 1.90X_2 + 0.048X_3$	0.85^{**}
Plant height	H763	$Y = -231.76 + 10.39X_1 + 4.77X_2 + 0.25X_3$	0.73^{*}
	X304C	$Y = -347.95 + 12.82X_1 + 6.40X_2 + 0.32X_3$	0.81^{**}
Filled ear length	H763	$Y = 7.16 - 0.22X_1 + 0.14X_2 + 0.018X_3$	0.63^{*}
	X304C	$Y = 5.45 - 0.037X_1 + 0.059X_2 + 0.017X_3$	0.72^{*}
Number of kernels/row	H763	$Y = 33.76 - 0.76X_1 - 0.39X_2 + 0.045X_3$	0.59
	X304C	$Y = 29.19 - 1.26X_1 - 0.76X_2 + 0.043X_3$	0.75^{**}

* X_1, X_2, and X_3 are average maximum, minimum temperature, and average solar radiation, respectively, from planting to tasseling.

maximum and minimum temperature, and solar radiation from planting to tasseling. All of the regression equations were significant except number of kernels/row for H763.

Effects of each climatic factors were calculated based on the standard partial regression coefficients. Standard partial regression coefficients could be calculated by the standard deviation and slope of each independent variable from the multiple regression equations. Effects of maximum and minimum temperature, and solar radiation from planting to tasseling on yields and their components are presented in Table 11. Average solar radiation had a higher effect than temperature on all the characters, indicating that solar radiation was more important than temperature in determining yields and their components. Average maximum temperature had negative effects on all characters except plant height. This suggests that maximum temperature was less important than minimum temperature for yields and their components.

Also, multiple regression analysis of yields and their components with climatic factors during the growing period indicated significant r^2 for all characters studied (Table 12). However, the effect of each climatic factor was different for those factors from planting to tasseling. Effects of minimum temperature were larger than those of solar radiation for all characters for both H763 and X304C (Table 13). For grain yield, the effect of minimum temperature was 0.87-0.89, while the effect of solar radiation was 0.62-0.63, indicating that minimum temperature might be more important than solar radiation in determining grain yield. Maximum temperature showed

Table 11. Effects of temperature and solar radiation from planting to tasseling on yields and their components.

Characters	Hybrids	Average maximum temp.	Average minimum temp.	Average solar radiation
Grain yield	H763	-0.55	0.25	0.82
	X304C	-0.53	0.28	0.89
Stover yield	H763	-0.41	0.35	0.83
	X304C	-0.56	0.65	0.78
Total dry matter yield	H763	-0.51	0.30	0.84
	X304C	-0.56	0.44	0.87
Plant height	H763	0.22	0.15	0.61
	X304C	0.23	0.17	0.64
Filled ear length	H763	-0.09	0.08	0.78
	X304C	-0.02	0.04	0.82
Number of kernels/row	H763	-0.13	0.10	0.86
	X304C	-0.22	0.19	0.85

Table 12. Multiple regression of yields and their components with average temperature and solar radiation during growing period.

Characters	Hybrids	Equation	r^2
Grain yield	H763	$Y = 20.79 - 2.78X_1 + 2.52X_2 + 0.026X_3$	0.85^{**}
	X304C	$Y = 13.13 - 2.30X_1 + 2.34X_2 + 0.025X_3$	0.88^{**}
Stover yield	H763	$Y = -0.099 - 0.94X_1 + 1.39X_2 + 0.012X_3$	0.81^{**}
	X304C	$Y = -6.41 - 0.10X_1 + 1.81X_2 + 0.012X_3$	0.94^{**}
Total dry matter yield	H763	$Y = 20.69 - 3.73X_1 + 3.91X_2 + 0.038X_3$	0.86^{**}
	X304C	$Y = 6.70 - 3.31X_1 + 4.15X_2 + 0.036X_3$	0.93^{**}
Plant height	H763	$Y = -387.34 + 7.40X_1 + 18.91X_2 + 0.094X_3$	0.71^{*}
	X304C	$Y = -581.17 + 12.26X_1 + 21.86X_2 + 0.19X_3$	0.79^{**}
Filled ear length	H763	$Y = 1.43 - 0.93X_1 + 1.42X_2 + 0.013X_3$	0.72^{*}
	X304C	$Y = -1.78 - 0.47X_1 + 1.07X_2 + 0.011X_3$	0.70^{*}
Number of kernels/row	H763	$Y = 17.05 - 2.34X_1 + 2.57X_2 + 0.039X_3$	0.73^{*}
	X304C	$Y = -4.20 - 1.50X_1 + 2.81X_2 + 0.034X_3$	0.86^{**}

* X_1, X_2, and X_3 are average maximum, minimum temperature, and average solar radiation, respectively, during growing period.

Table 13. Effects of temperature and solar radiation during growing period on yields and their components.

Characters	Hybrids	Average maximum temp.	Average minimum temp.	Average solar radiation
Grain yield	H763	-0.75	0.89	0.62
	X304C	-0.65	0.87	0.63
Stover yield	H763	-0.44	0.84	0.50
	X304C	-0.41	0.97	0.44
Total dry matter yield	H763	-0.65	0.89	0.59
	X304C	-0.57	0.93	0.55
Plant height	H763	0.17	0.57	0.19
	X304C	0.24	0.55	0.20
Filled ear length	H763	-0.38	0.77	0.48
	X304C	-0.22	0.64	0.46
Number of kernels/row	H763	-0.42	0.61	0.63
	X304C	-0.28	0.68	0.56

negative effects for most characters except plant height, suggesting that maximum temperature might be a less important factor in determining yields.

Multiple regressions of yields and their components with GDD from planting to tasseling and to harvesting were not significant for yields, including TDM, grain, and stover yield, whereas they were significant for plant height and yield components. GDD from planting to harvesting had higher effects on all characters than GDD calculated from planting to tasseling. This result suggests that GDD during the growing period was more important than GDD from planting to tasseling.

4.1.5 Discussion

The average TDM yield of corn over 12 bimonthly planting increased significantly with increasing population density for both genotypes used. The population density for maximum TDM yield estimated from the curvilinear regression equations were 166,700 for X304C and 169,100 plants/ha for H763. Phipps (1975) obtained the highest TDM yield at 167,000 plants/ha in England. Azih (1978) obtained the highest TDM yield at 114,813 plants/ha in Hawaii. Chung et al. (1982) reported that the optimum population density for silage corn production in Hawaii ranged from 98,000 to 135,000 plants/ha.

In this study, the optimum population density for silage yield was higher than that for grain yield. Population densities for grain yields ranged from 126,000 (H763) to 141,000 plants/ha (X304C). Rutger and Crowder (1967 a) and Genter and Camper (1973) reported that population density for silage was higher than those of grain yield. Knapp and Reid (1981) also obtained similar results as those of other workers.

The response of grain yield to population density was different under different seasons. The optimum population densities in favorable growing seasons (spring and summer) were higher than those in unfavorable seasons (fall and winter). It was postulated that population density for maximum grain yield in unfavorable growing seasons would be higher than under favorable seasons, because poor environmental conditions such as short day length, and low solar radiation might be compensated for by the higher population density. However, in winter seasons, heavy rainfall and strong winds caused severe lodging of plants at all population densities. This severe lodging resulted in high barren stalk, especially at higher population.

Azih (1978) in Hawaii reported different response of grain yield to population density in different plantings. He observed that the population density for maximum yield was higher in the March than in the August planting. However, stover yield increased significantly up to 200,000 plants/ha in both genotypes. This difference could be due to high barrenness at higher population density. In this study, high barrenness was observed at high population density in winter seasons. Increased barrenness was reported as population increased (Colville and Burnside, 1963; Mason et al., 1976; Woolley et al., 1962). Stivers et al. (1971) observed 25 % barrenness at 54,000 plants/ha, and 40 % at 68,000 plants/ha.

The grain/stover ratio is an important factor to be considered in corn silage production, as this indicates the quality of the corn silage. The grain/stover ratio decreased with increases in population density in this experiment. The result indicated that quality of the silage from the higher population was lower than those from the lower population density, even if the total silage production increased with increasing population. The optimum population density for maximum silage yield should be lower in practical farming than the optimum population obtained in this experiment if quality of corn silage is considered. The higher percentage of barren stalks in the winter season suggests that the quality of silage was poorer in winter than in the spring or summer seasons.

Days to tasseling was delayed with increase in population. Mason et al. (1977) found a similar delay of tasseling with increasing population. Giesbrecht (1969), and Moll and Kamprath (1977) observed increased plant and ear height at higher population. In this study, ear height increased, while plant height was reduced significantly with increasing population density. The population densities used here were much higher than those used by other workers. Higher population densities in this experiment could cause more competition among plants. Azih (1978) in Hawaii reported decreased plant height as population increased. Rutger and Crowder (1967),and Genter and Camper (1973) found no difference in plant height but ear height increased slightly with increase of population density.

Stalk diameter decreased significantly as population increased in this study. Similar reduction of stem diameter with increase in population was reported by Rutger and Crowder (1967), Genter and

Camper (1973), and Azih (1978). The reduced stem diameter as well as decreased plant height might be one of the factors for reduction of individual plant size. Stem diameter was reduced by about 30 % at the highest population compared to the lower population, but this reduction was calculated as 60 % reduction of cross-section area of the stem. Therefore, individual plant size decreased primarily due to reduction in stem diameter rather than decrease in plant height as population increased.

Increasing population density is also known to increase the LAI (Duncan, 1971, 1972; Mason, 1976). LAI increased almost linearly, while leaf area/plant was reduced significantly as population increased. The increasing population increased LAI which is the main source of photosynthesis, but photosynthesis rate is reduced. Duncan (1971) reported that photosynthsis rate was 92 % of theoretical maximum at LAI 3.0 and 76 % at LAI 7.0. The reduced photosynthesis rate could be attributed to mutual shading, which resulted in less light penetration into the crop canopy. Excessive LAI with high population density was not associated with increasing grain yield. LAI at the highest population (200,000 plants/ha) was nearly 3 times larger than that at the lower population (50,000 plants/ha).

Leaf angle was not recorded in this experiment, but it was found that X304C had a more vertical leaf angle than H763. It was reported that vertical leaf orientation was more efficient in producing grain yield than horizontal leaf orientation (Pepper et al., 1977; Winter and Ohlrogge, 1973; Whigham and Woolley, 1974). X304C outyielded

H763 in all population densities, but LAI was slightly less than H763. The superior yield of X304C with less LAI might be attributed to the better leaf orientation.

Plant-lodging increased with increase in population. In the winter season severe lodging was observed at all populations. This was due to strong wind followed by concentrated heavy rainfall. Under favorable spring or summer seasons, 20-30 % lodging was common at the higher populations (150,000-200,000 plants/ha). This high lodging might be due to weak plant structure such as reduced stem diameter.

Yield components, such as filled ear length, number of kernel rows, number of kernels/row, and 100 kernel weight, decreased as population increased. These reductions of yield components might be due to increased environmental stress resulting from higher competition among plants. Phipps (1975) observed decreased ear weight with population increase. Prine and Schroder (1964), Mason et al. (1976), and Alessi and Power (1974) also reported reduction of ear weight as population increased. Woolley et al. (1962) observed a decrease of 100 seed weight as population increased. The reduction rates of filled ear length and number of kernels/row were 30-40 %. These reductions were higher than those of other yield components such as number of kernel rows and 100 kernel weight. There were negative correlations between population density and yield components studied for H763 and X304C. X304C had superior yield components to those of H763, explaining its higher yield than H763.

Kernel fusarium infection increased with the increase in population. The response to fusarium infection of the two genotypes under different population densities was different. At a lower population (50,000 plants/ha) there was little difference between the two genotypes, while at a higher population (200,000 plants/ha) H763 had higher infection than X304C. This result suggested that X304C was more resistant to kernel fusarium than H763.

Year-round production of corn is possible in tropical regions. Bimonthly plantings under different population densities can provide information on the optimum population density for grain and stover yields of corn under different environmental conditions. Grain and stover yields showed cyclic seasonal variations througout the years with higher yield in the spring and summer, and lower yield in the autumn and winter seasons. Lee (1978) and Jong (1980) in Hawaii reported that grain yield of corn in winter was less than half of those in summer. This was confirmed by the results of this experiment. However, the seasonal variation of stover yield was less than that of grain yield. This was due to the high percentage of barrenness in winter plantings.

Lee (1978) found that temperature was the main factor in determining days to tasseling, and grain yield was more affected by solar radiation than other climatic factors. Jong (1980) reported that solar radiation was the main limiting factor for corn production in Hawaii. In this study, days to tasseling were greater in the winter planting than in the spring and summer. Significant correlations between days to tasseling and maximum and minimum temperature, but not solar radiation, were observed. This relationship suggested that temperature could be more important factor for days to tasseling than solar radiation.

The longer period for tasseling might have resulted in similar accumulation of heat unit under lower temperature conditions. The accumulated heat unit was expressed as growing degree (GDD). GDD during the growing period was more important than that from planting to tasseling. Gunn and Cristensen (1963) and Daynard (1972) reported that the accumulated heat unit was superior to number of days in determining the flowering time. Mederski et al. (1973) observed that accumulated heat unit methods were less variable than the calendar day method for determining growth stages. GDD from planting to tasseling was less variable than calendar days for days to tasseling over 12 bimonthly plantings in this study. Days from planting to maturity were more variable than that from planting to tasseling through the years. In winter plantings, harvesting date was rather dependent on weather conditions. As mentioned earlier, severe lodging was observed during the winter. Lodged corn plants should be harvested earlier than in the summer planting. Therefore, it was difficult to correctly estimate the days from planting to maturity in winter plantings.

Standard partial regression coefficients from multiple regression analysis showed that among the climatic factors from planting to tasseling, solar radiation was the most important factor determining yield and other characters. However, among the climatic factors during the growing period the minimum temperature was the most important determinant factor for corn production. Plant characters and yield components showed cyclic variations following those of grain and stover yields. All of these components were highly correlated with yields, indicating that these characters could explain the yield variation.

4.2 Effects of brown-midrib-3 Mutant of Corn

4.2.1 Yields and yield components

Grain yields of brown midrib mutants were significantly below their normal counterparts (Figure 26). The grain yield reduction was consistent for all 15 hybrids in both trials, averaging a highly significant 20 % decrease overall. Stover yields of the bm3 were also less than the normal counterparts in both August and May plantings for all hybrids (Figure 27). Yield reductions ranged from 9 to 26 % and averaged 17 %. The rates of grain yield reductions were quite different between hybrids. Some hybrids (Ant2 x Mo17, B37 x Oh545) showed only 6 - 7 % reduction, however, other hybrids had grain yield decreases up to 29 % compared to normal counterparts.

Average grain and stover yields of the 2 plantings are presented in Table 13. No significant differences were observed in days to tasseling between bm3 and normal in August planting, while there were highly significant differences among hybrids. The average days to tasseling was 46 days in August planting and 48 days in May.

The overall average plant height over 2 seasons showed that normal corn was 12 cm taller than bm3 (Table 14). Plant height of normal corn was 10 and 14 cm taller than bm3 in August and May planting, respectively.

LAI was not significantly different between bm3 and normal, although it differed significantly among hybrids. The overall average LAI was 4.08 and 4.17 for bm3 and normal, respectively. No differences were observed in number of stem nodes between normal vs.

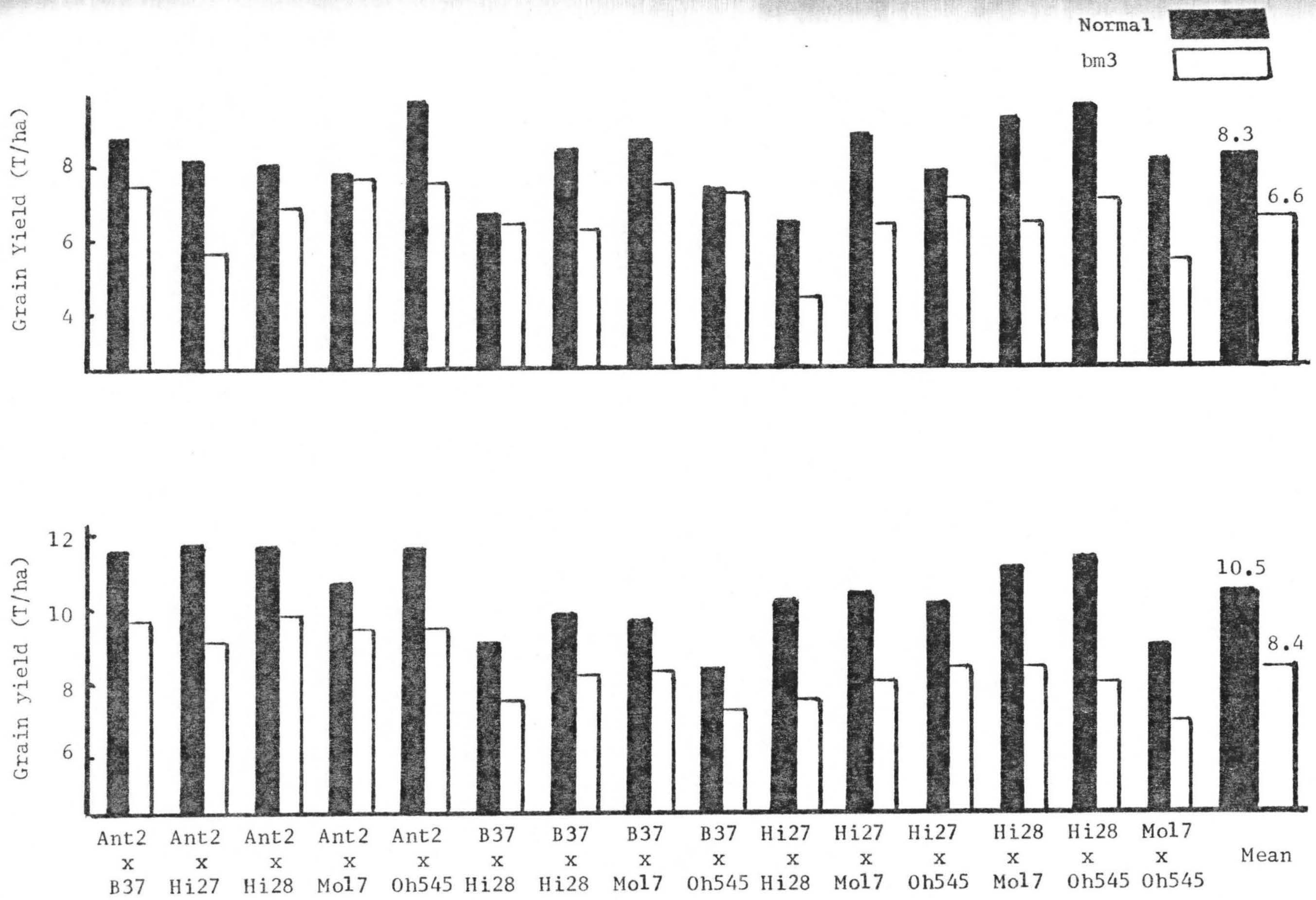


Figure 26. Comparison of normal and bm3 corn for grain yield in different seasons.

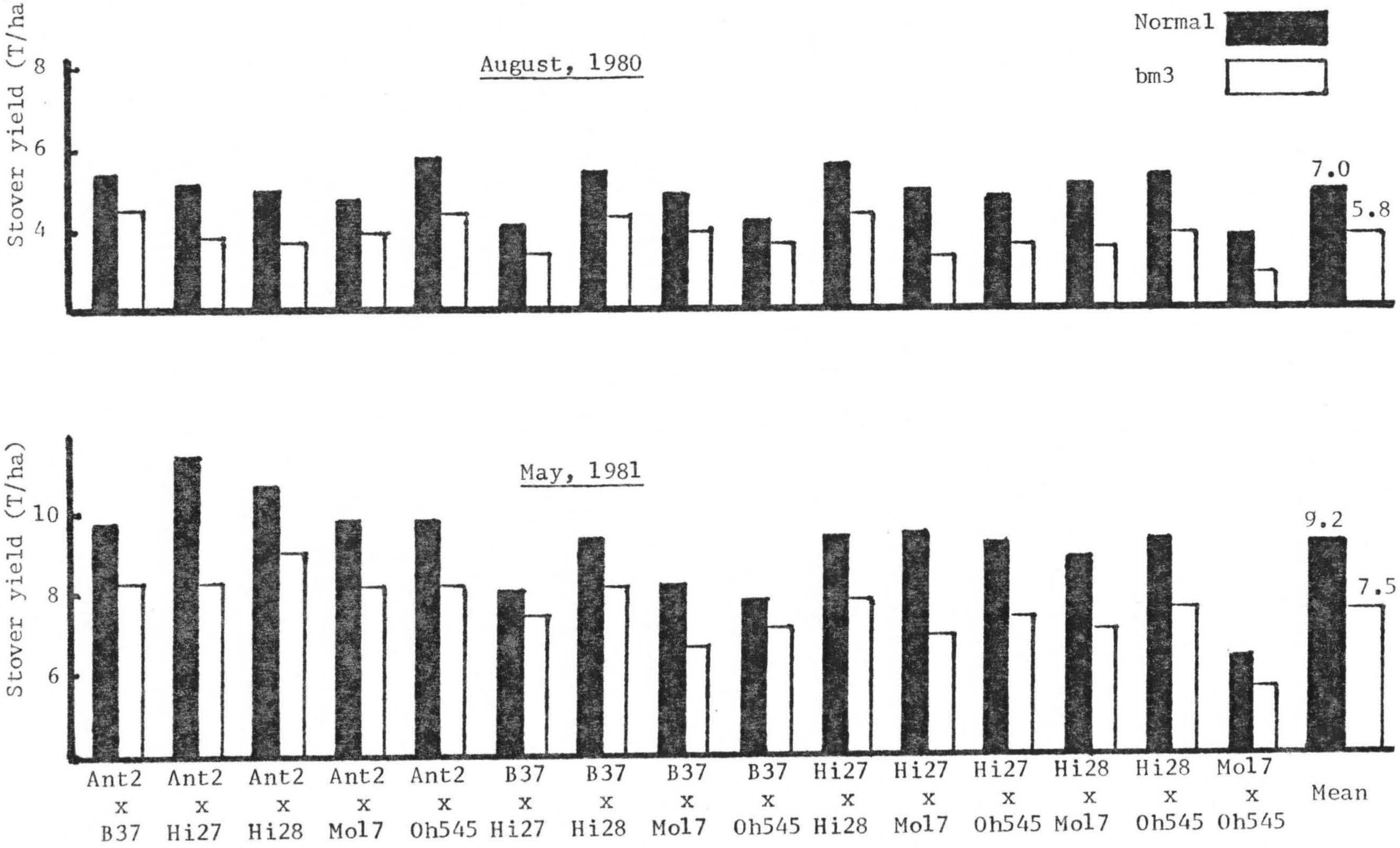


Figure 27. Comparison of normal and bm3 corn for stover yield in different seasons.

Table 14. Average yields, plant height and filled ear length of normal and bm3 mutant corn over 2 seasons.

Hybrids	Grain yield(T/ha)		Stover yield (T/ha)		Plant height (cm)		Filled ear length (cm)	
	Normal	bm3	Normal	bm3	Normal	bm3	Normal	bm3
Ant2 x B37	10.29	8.61	8.63	7.31	274	273	17.0	14.7
Ant2 x Hi27	10.03	7.41	9.34	7.02	278	263	16.0	14.1
Ant2 x Hi28	9.88	8.32	8.85	7.36	274	264	16.7	15.6
Ant2 x Mo17	9.27	8.58	8.30	7.06	265	256	18.9	16.5
Ant2 x Oh545	10.76	8.41	8.88	7.26	278	259	18.2	18.3
B37 x Hi27	7.91	7.00	7.09	6.49	269	263	15.1	13.5
B37 x Hi28	9.23	7.22	8.43	7.19	282	273	16.8	14.2
B37 x Mo17	9.21	7.91	7.56	6.28	266	251	18.2	15.9
B37 x Oh545	7.87	7.22	7.00	6.35	261	250	17.7	16.2
Hi27 x Hi28	8.39	6.02	8.49	7.13	280	268	15.4	13.6
Hi27 x Mo17	9.74	7.21	8.19	6.07	265	250	17.3	14.2
Hi27 x Oh545	9.03	7.81	8.03	6.46	275	257	17.8	17.8
Hi28 x Mo17	10.30	7.42	8.01	6.27	274	262	17.5	15.8
Hi28 x Oh545	10.62	7.54	8.37	6.71	277	267	19.8	16.5
Mo17 x Oh545	8.55	6.19	6.17	5.19	262	243	20.2	20.4
Mean	9.41	7.52	8.09	6.68	272	260	17.5	15.8

bm3, and between plantings. Filled ear length and number of kernels per row were significantly different between bm3 and normal corn, and among hybrids. The overall reduction of filled ear length was 10 % in bm3. The overall number of kernels per row was 37 in normal and 32 in bm3, indicating a 12 % decrease in bm3. Reduced filled ear length and number of kernels per row would be therefore the main reasons for grain yield reductions in bm3. No significant difference was observed in number of kernel rows, but bm3 had slightly fewer kernel rows than normal corn.

Combined analysis showed significant interactions between hybrids and season, and between types (bm3 vs. normal) and seasons in both grain and stover yields (Table 15). The mean square values of types were much larger than those of interactions in all characters tested.

Correlation coefficients among yields, plant characters, and yield components of normal and bm3 are presented in Table 16. There were highly significant positive correlations between days to tasseling and grain yields, stover yields, ear height, and LAI in both normal and bm3. This indicated that late maturing hybrids generally had higher grain and stover yields. Combined data showed no significant correlations between plant height and stover yields in both types, however, separate analysis for each planting showed significant correlation except for normal corn in May (Figure 28). This difference resulted from the different response of plant height and stover yield to different seasons. Plant height was taller in the August planting than May, while stover yield was higher in the

Table 15. Combined analysis of variance for several characters over two seasons

Source	df	Mean squares				df	Mean squares	
		Grain Yield	Stover Yield	Plant Height	LAI		Ear Length	No. of kernels
Seasons (S)	1	244.62	223.17	3473.20	1.58	1	134.00	1484.03
Reps in S	6	0.74	2.67	220.74	0.12	2	6.00	6.12
Hybrid (H)	14	9.31**	2.48**	887.17**	0.67**	14	20.78**	65.38**
H x S	14	3.49**	2.45**	197.28	0.05	14	0.86	11.07*
Error (a)	84	0.68	0.67	149.37	0.05	28	1.18	4.54
Type (T)	1	212.21**	119.53**	8676.04**	0.44**	1	86.36**	615.63**
T x S	1	2.65*	3.79**	230.10**	0.09	1	13.07**	21.51
T x H	14	2.54**	0.88*	101.58**	0.17**	14	2.38*	7.41
T x H x S	14	0.39	0.25	83.99**	2.57**	14	0.46	3.00
Error (b)	90	0.39	0.40	29.84	0.03	30	1.15	6.11

* Significant at 5 % probability level.
** Significant at 1 % probability level.

Table 16. Correlation matrix of 10 characters in normal and bm3 hybrids.

Above diagonal: Normal
Below diagonal: bm3

Charactors	Grain yield	Stover yield	Plant height	Ear height	LAI	Filled ear length	No. of kernels per row	Days to tassel	No.of stem nodes	Stem diameter
Grain yield		0.87**	-0.14	0.33	0.49**	0.62**	0.69**	0.59**	0.74**	0.71**
Stover yield	0.79**		-0.16	0.54**	0.61**	0.40*	0.56**	0.81**	0.84**	0.76**
Plant height	-0.22	-0.01		0.53**	0.20	-0.44*	-0.33	-0.03	0.25	-0.19
Ear height	0.20	0.44*	0.62**		0.50**	-0.30	0.03	0.69**	0.74**	0.14
Leaf area index	0.29	0.58**	0.23	0.66**		0.04	0.31	0.66**	0.63**	0.35
Filled ear length	0.56**	0.41*	-0.66*	-0.42*	-0.12		0.85**	0.11	0.20	0.66**
Number of kernels per row	0.71**	0.56**	-0.53**	-0.24	-0.11	0.90**		0.33	0.45*	0.61**
Days to tasseling	0.51**	0.75**	0.05	0.71**	0.76**	0.07	0.20		0.72**	0.63**
Number of stem nodes	0.39*	0.67**	0.56**	0,85**	0.63**	-0.17	0.02	0.66**		0.53**
Stem diameter	0.49**	0.68**	-0.27	0.11	0.58**	0.46*	0.45*	0.65**	0.29	

* Significant at 5 % probability level.

** Significant at 1 % probability level.

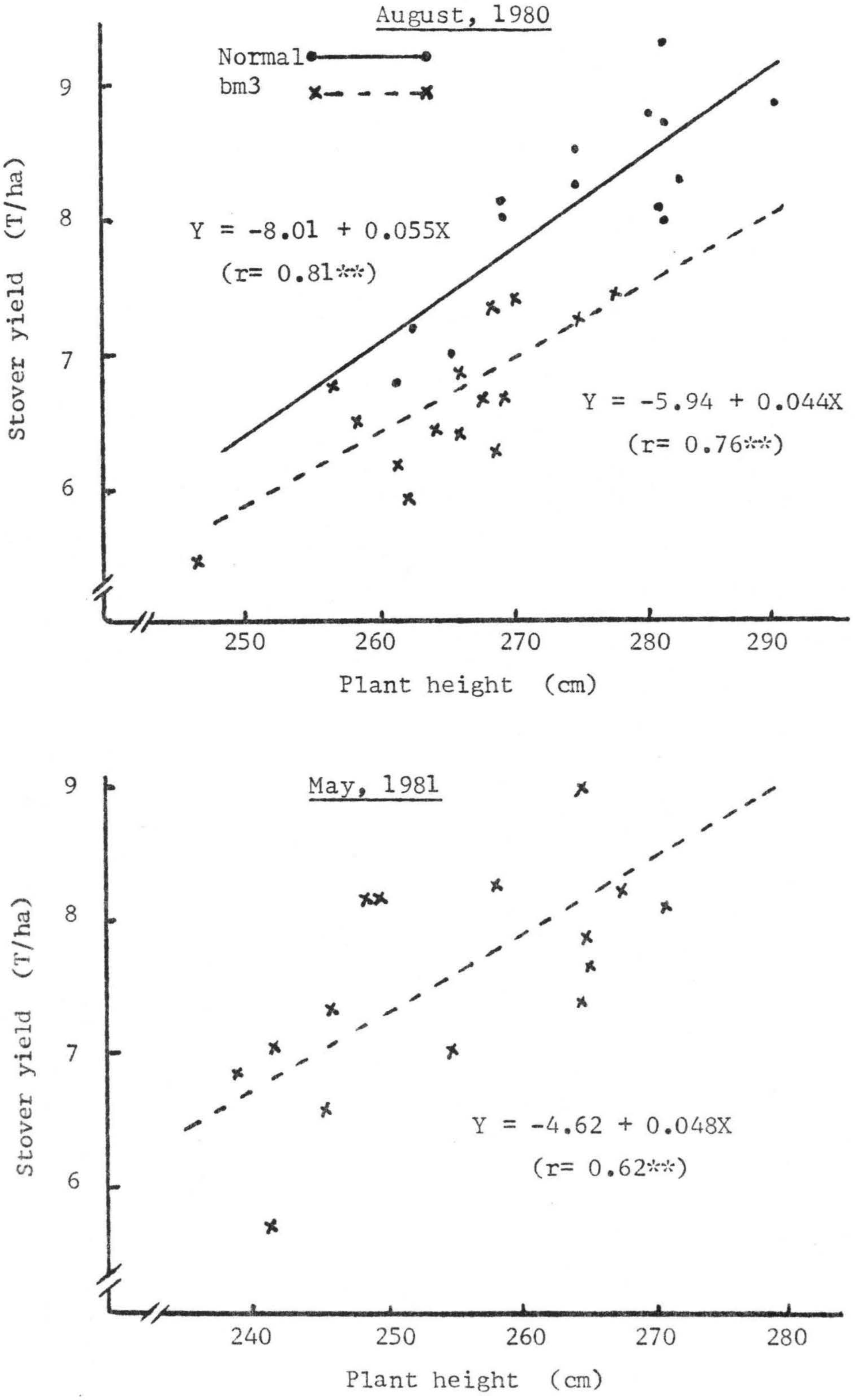


Figure 28. Relationship between plant height and stover yield.

May than in the August planting. This increase in stover yield in the May planting with its shorter plant height might be attributed to the increased stem diameter. The stem diameter of the August planting was 22 mm, whereas it was 25 mm in May. Highly significant correlations were observed between the number of stem nodes and several characters, including grain yield, stover yield, days to tasseling, plant height, and LAI in bm3 and normal corn, except one in normal plant height. LAI was correlated with grain yield of normal in May (Figure 29). Figure 30 shows the relationship between LAI and stover yield. Highly significant correlations were observed in both plantings except bm3 in August.

There were highly significant correlations between grain yield, filled ear length, and number of kernels per row, but number of kernel rows was not correlated to grain yield. The average correlation coefficients of bm3 and normal corn for filled ear length, number of kernel rows, and number of kernels per row were 0.588**, 0.015, and 0.701**, respectively. This indicated that the number of kernels per row was the most significant component for grain yield and number of kernel rows was less significant.

4.2.2 Diallel analysis

Combined analysis for gerneral combining ability (GCA) and specific combining ability (SCA) showed highly significant mean squares for grain and stover yields in both normal and bm3 (Table 17). Plant height, filled ear length, and number of kernels per row were highly significant in GCA for both types, however SCA was

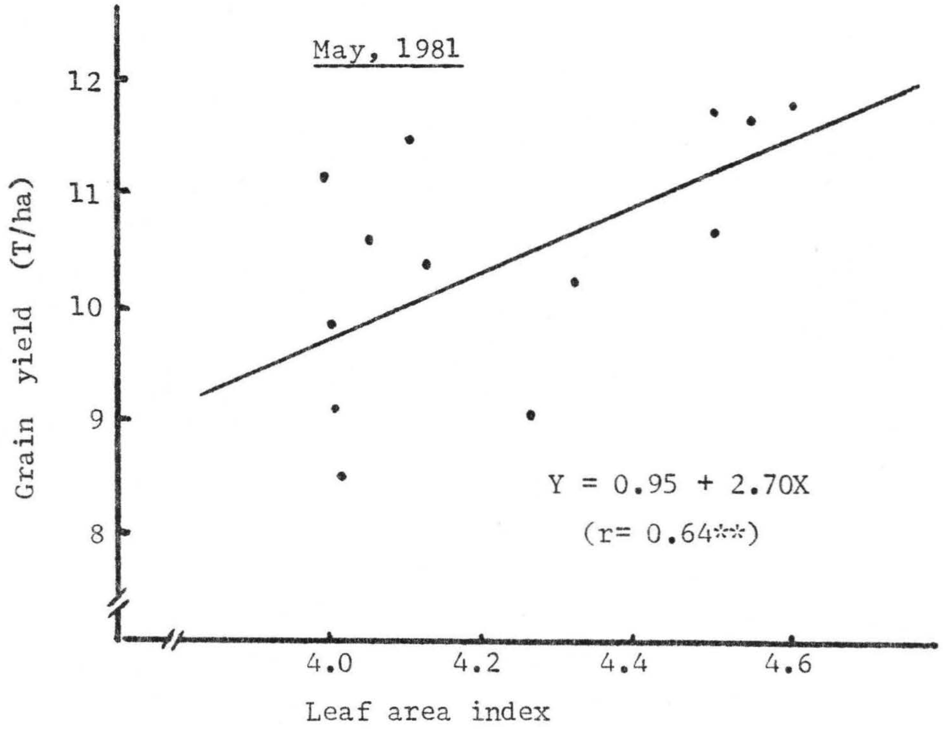
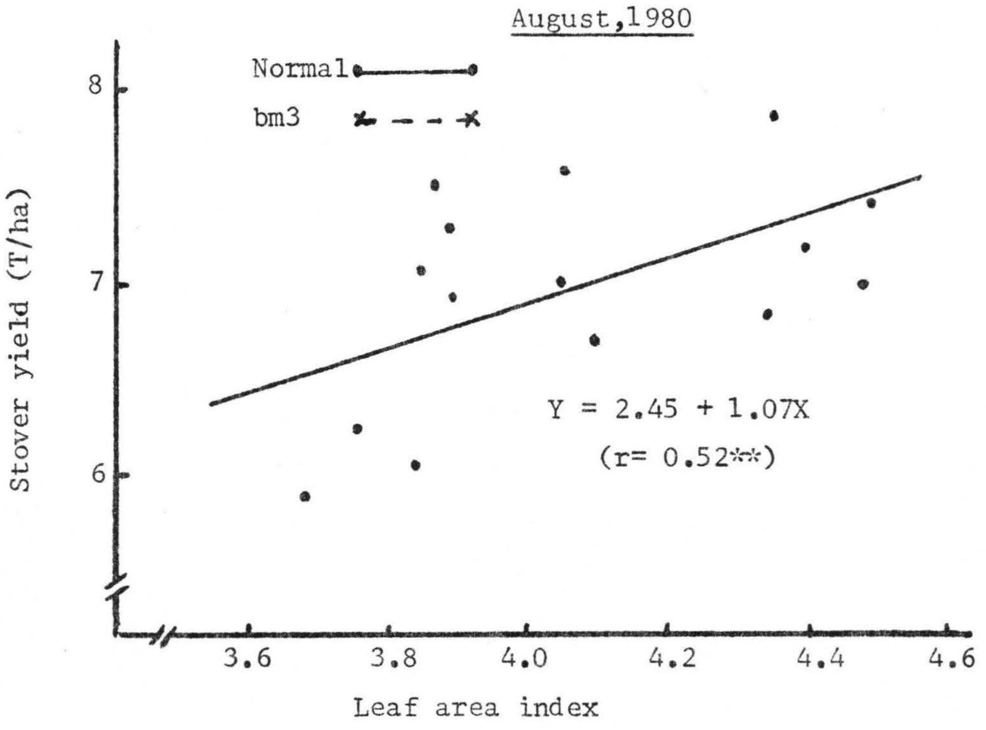


Figure 29. Relationship between leaf area index and grain yield.



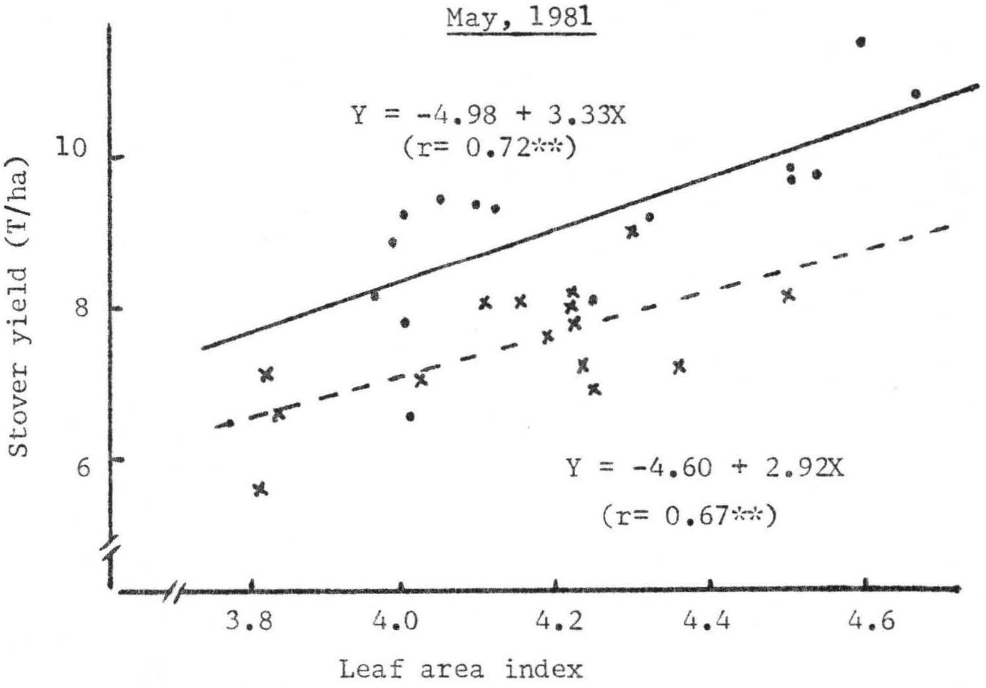


Figure 30. Relationship between leaf area index and stover yield

Table 17. Combined analysis of combining ability of normal and bm3 mutant corn over 2 seasons for yields, plant and ear height.

Source	df	Grain yield		Stover yield		Plant height		Ear height	
		Normal	bm3	Normal	bm3	Normal	bm3	Normal	bm3
GCA	5	2.23**	2.02**	2.79**	1.69**	171.20**	348.80**	1532.17**	1475.85**
SCA	9	1.47**	0.79**	0.59**	0.18*	47.22*	48.00*	32.53**	44.85**
Season (S)	1	37.28**	24.54**	35.64**	21.10**	239.00**	686.00**	236.63**	12.06**
GCA x S	5	1.29**	0.98**	0.98**	0.43**	39.60*	37.40	16.28	32.90*
SCA x S	9	0.11	0.14	0.18	0.09	34.00	32.44	18.53*	5.52
Error	84	0.14	0.13	0.19	0.08	20.53	24.08	9.64	10.31

* Significant at 5 % probability level.

** Significant at 1 % probability level.

significant for only plant height. Mean squares of seasons were highly significant for all yields and yield components. GCA x season interactions were highly significant for grain and stover yields, and were not significant for plant height, filled ear length, and number of kernels per row. No significant SCA x season interactions were observed for any of the characters tested.

GCA effects were more important than SCA effects for both grain and stover yields, although GCA and SCA effects were highly significant. The GCA/SCA mean squares ratios were 1.52 in normal corn and 2.56 in bm3. The ratios of stover yields for both normal and bm3 were 3 - 4 times higher than those of grain yields. The GCA/SCA ratio for plant height in normal corn was 3.63 and was twice as high (7.27) in bm3. The GCA/SCA ratios for filled ear length and number of kernels per row were 5 - 15 times higher than those of grain yields. These high ratios in filled ear length and number of kernels indicates that the GCA effects (additive) were more important than SCA effects (non-additive) in determining yield components.

Ant2, which is a tropical inbreds, had positive GCA effects while Oh545 and Hi27 had negative GCA effects for grain yield in both bm3 and normal corn (Table 18). This confirmed the high combining ability of Ant2 and the poor combining ability of Hi27 and Oh545 for grain yields. For stover yield (Table 19) Ant2 and Hi28 showed positive GCA effects indicating good combiners, while Mo17 and Oh545 showed negative GCA effects. Ant2 had high positive GCA effects for several characters observed with the exception of filled ear length of normal corn. These results showed that Ant2, which is a late

Table 18. Estimates of SCA and GCA effects for grain yield of normal and bm3 mutant corn over 2 seasons.

Inbreds	SCA effects					GCA effects
	B37	Hi27	Hi28	Mo17	Oh545	
Ant2	0.71 0.08	0.31 -0.50	-0.68 0.14	-0.94 0.20	0.60 0.08	0.80 0.93
B37		-0.39 -0.06	0.11 -0.11	0.42 0.38	-0.86 -0.28	-0.63 0.09
Hi27			-0.88 -0.69	0.81 0.31	0.15 0.94	-0.48 -0.55
Hi28				0.53 0.25	0.92 0.41	0.35 -0.28
Mo17					-0.82 -1.14	0.01 -0.08
Oh545						-0.05 -0.11

Upper and lower values are normal and bm3, repectively.

Table 19. Estimates of SCA and GCA effects for stover yield of normal and bm3 mutant corn over 2 seasons.

Inbreds	SCA effects					GCA effects
	B37	Hi27	Hi28	Mo17	Oh545	
Ant2	0.09	0.19	-0.56	-0.12	0.40	0.89
	-0.08	-0.26	-0.29	0.36	0.28	0.66
B37		-0.74	0.35	0.46	-0.15	-0.44
		-0.19	0.14	0.17	-0.04	0.06
Hi27			-0.19	0.48	0.26	0.17
			0.19	0.08	0.19	-0.05
Hi28				0.05	0.36	0.43
				-0.10	0.07	0.32
Mo17					-0.86	-0.55
					-0.50	-0.63
Oh545						-0.50
						-0.35

Upper and lower values are normal and bm3, respectively.

maturing-inbred, was the best combiner among the 6 inbreds used in this study for silage production. Mo17 and Oh545 had positive GCA effects for filled ear length and number of kernel per row.

Heritability estimates were calculated for several characters (Table 20). In general, high narrow sense heritability estimates were obtained for ear height, days to tasseling, LAI, filled ear length, number of kernels per row, and number of stem nodes in both bm3 and normal corn. The narrow sense heritability estimates of these characters ranged from 78 to 94 %. Grain yield, stover yield, plant height, and stem diameter showed relatively low narrow sense heritability estimates ranging from 6 to 66 %. Ear height, days to tasseling, and number of stem nodes had high broad sense heritability estimates (over 92 %) in both bm3 and normal corn.

4.2.3 Discussion

The quality of silage for ruminant animals is an important factor for improved utilization of feeding. The need for a good source of high quality feed for the beef and dairy industries has stimulated research on the brown midrib mutants of corn which has lowered lignin content in the vegetative parts of the plant and given high digestibility. The advantage of bm3 corn silage was obvious from the many *in vitro* chemical studies, however, some reports showed decreased total production of corn silage from the bm3 of corn. According to Frenchick et al. (1976), bm3 reduced total dry matter production in one hybrid by 17 % compared to the normal counterpart corn. Tu and Bauman (1977) reported 16 to 33% grain yield reduction

Table 20. Heritability estimates of normal and bm3 mutant corn for yields, plant characters ans yield components. (unit: %)

Characters	Type	Narrow sense	Broad sense
Grain yield	Normal	34	89
	bm3	52	87
Stover yield	Normal	41	77
	bm3	58	76
Plant height	Normal	42	69
	bm3	58	81
Ear height	Normal	93	98
	bm3	93	98
Days to tasseling	Normal	86	95
	bm3	93	93
Filled ear length	Normal	84	84
	bm3	83	88
Number of kernels per row	Normal	78	80
	bm3	81	81

in 3 bm3 hybrids.

In this study, grain and stover yields were decreased significantly compared to normal counterpart corn (17-20 %). This reduction of yields might be explained by the reduced yield components, including filled ear length and number of kernels per row, and by plant and ear height. Days to tasseling was highly correlated to grain and stover yields in both bm3 and normal corn. This indicated that late muturity genotypes produced higher yield than early mature genotypes. Ant2, which is late in maturity, was the best combiner among 6 inbreds used for grain and stover yields. Average TDM yield was reduced greatly in bm3 compared to normal corn, however, several genotypes (Ant2 x Mo17, B37 x Oh545) showed only 5-6 % reduction in summer planting. These small reductions of TDM yield indicated one potential of bm3 as a high quality corn silage. Frenchick et al. (1976) reported that milk production and body weight of Holstein cows were increased by 4-5 % with the bm3 corn silage feeding. Rising feeding costs is a major concern in livestock farming. It is estimated that a large portion of silage costs may be attributed to handling, transportation, and storage. If the reduced volume of bm3 corn silage is compensated for by its increased feeding value, bm3 corn silage can reduce the feeding costs.

High population density is usually used for silage production to increase the total production although the quality of the silage declines slightly. With higher population density, lodging is common in Hawaii, especially when coupled with unfavorable weather conditions such as concentrated heavy rainfall and strong winds. Lodging was not observed in this experiment because of favorable weather conditions. However, bm3 was likely to be more susceptible to lodging as indicated by a tendency of bm3 plants to lean after tasseling. Stem diameter of bm3 corn plants was a little smaller than for normal corn in both summer and spring plantings. This decreased stem diameter may be a reason for increased lodging in bm3 at high population density and during unfavorable weather conditions.

GCA indicates the presence of genes having largely additive effects while SCA is an indication of genes having non-additive effects. Lee (1978) tested a diallel set in different seasons in Hawaii and concluded that the GCA was more important than SCA for grain yield and yield components. Among inbreds tested in this study, Ant2 had good GCA effects for almost all characters studied. In general, higher narrow sense heritability estimates were observed for days to tasseling, ear height, LAI, filled ear length, number of kernels per row, and number of stem nodes, indicating that additive genes were larger for yield components than for grain and stover yields.

4.3 Extended Daylength Effects on Corn Yields and their Components.

4.3.1 Response of yields to extended light.

Under extended 16-hr daylength conditions, grain yield of corn decreased significantly compared to the normal 12-hr conditions in both September and May plantings. The average grain yields under normal and extended light conditions for both plantings are presented in Figure 31. In September planting, average grain yield under normal and extended light were 4.0 and 3.0 T/ha, respectively, showing significant 25 % reduction under the extended light. The grain yield reduction under extended light were not consistent among genotypes. Some genotypes such as Ant2 x Hi29, Hi28 x Hi29, and X304C revealed more than 40 % reductions, but Ant2 x Mo17, Hi29 x Hi31 were reduced less than 5 % under extended light conditions. However, Hi28 x Hi31, Hi31 x Mo17 showed 3 - 6 % increases in grain yield under light.

The grain yield responses of genotypes in May planting were similar to those in September, with a 22 % mean reduction in yield. Individual crosses performed differently in a few cases; e.g.Ant2 x Hi29 which showed 40 % reduction in September and a slight increase in grain yield in May. On the other hand, grain yield of Hi31 x Mo17 increased about 6 % under light in September, but decreased 22 % in May planting.

Stover yields increased significantly under the extended light environment in both seasons. The average stover yields in September planting were 5.0 and 6.2 T/ha under normal and extended light,

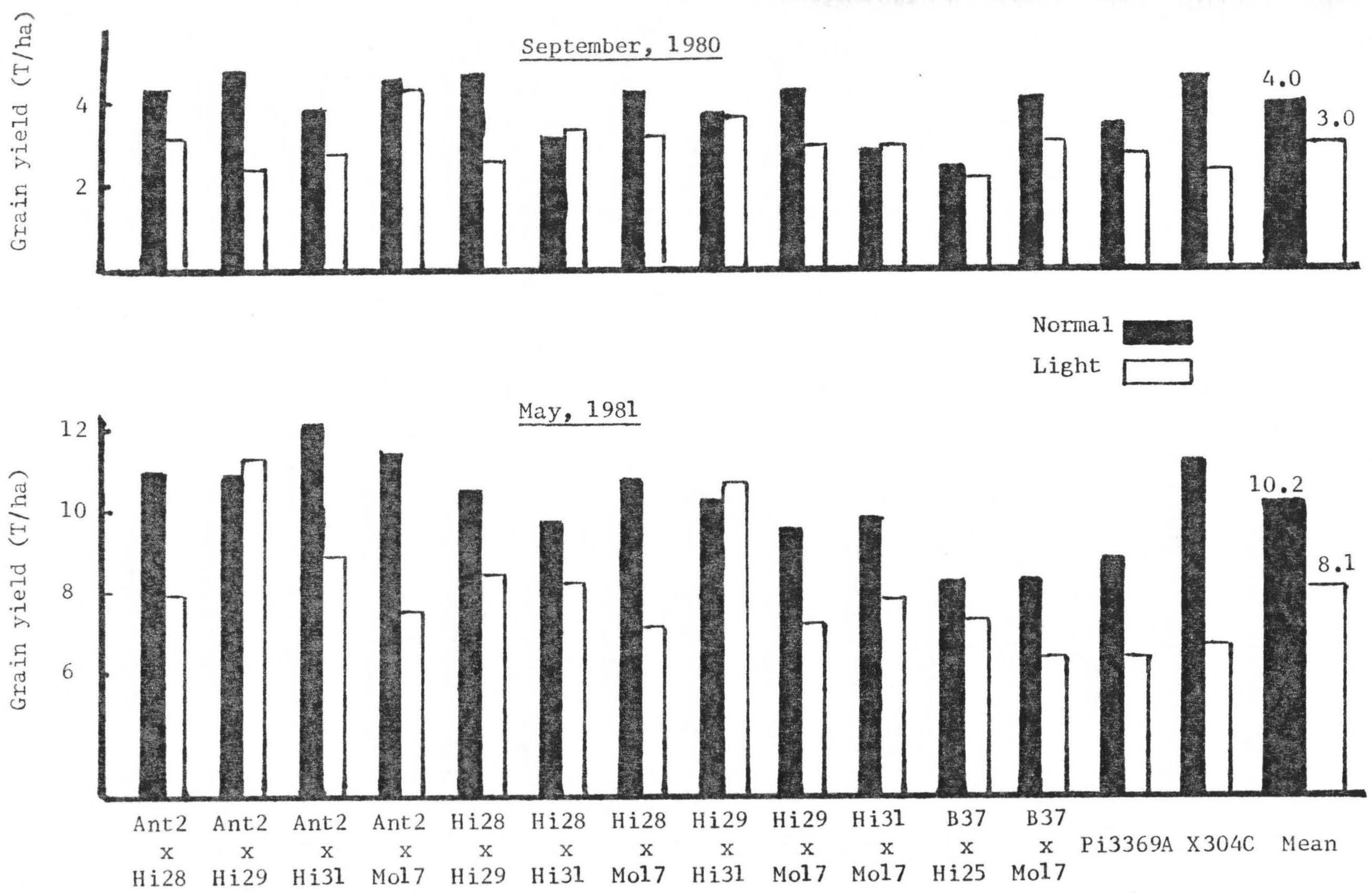


Figure 31. Comparison of grain yield under normal and extended light condition in different seasons.

respectively, indicating 24 % increase under extended light (Figure 32). The rates of yield increase among genotypes were different; i.e. some genotypes (Hi28 x Mo17, X304C) showed a 30 - 40 % increase, while others (Ant2 x Hi31, Hi29 x Hi31) indicated only a 2 - 5 % increase under extended light conditions. An average increase of 17 % in stover yield was observed under extended light in the May planting, In both seasons, X304C showed the largest increase in stover yield under extended light conditions, indicating that it was the most sensitive genotype, while Ant2 x Hi31, Hi28 x Hi31, and Hi28 x Mo17 showed small differences between normal and light conditions, showing that these genotypes were relatively less sensitive to photoperiod.

Total dry matter (TDM) yield was calculated by adding grain and stover yield. The overall average of TDM yield showed no significant difference between normal and extended light conditions in both plantings (Figure 33). TDM yields were 9.0 and 9.2 T/ha under normal and light, respectively. Among the 14 genotypes used, X304C showed the highest TDM yield, and Ant2 x Hi28, Ant2 x Hi29 also had relatively higher yields than other genotypes in both seasons. The temperate hybrid B37 x Hi25 had the lowest TDM yield in both plantings.

Combined analysis of variance revealed that genotype x daylength and genotype x season interactions were highly significant for both grain and stover yield (Table 21). These interactions indicated that genotypes were different in response to daylength, and seasons. For grain yield, season x daylength, and genotype x daylength x season

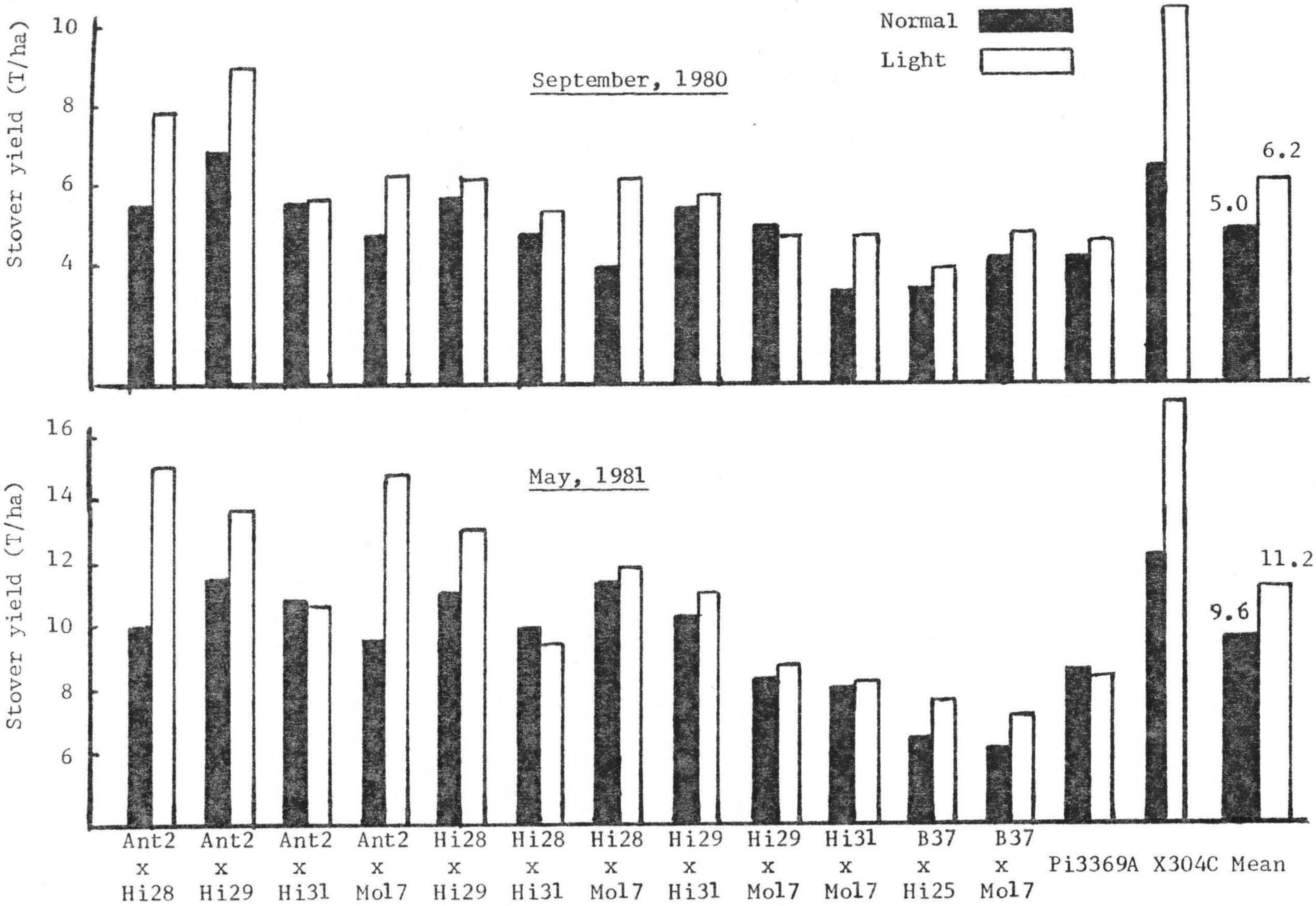


Figure 32. Comparison of stover yield under normal and extended light condition in different seasons.

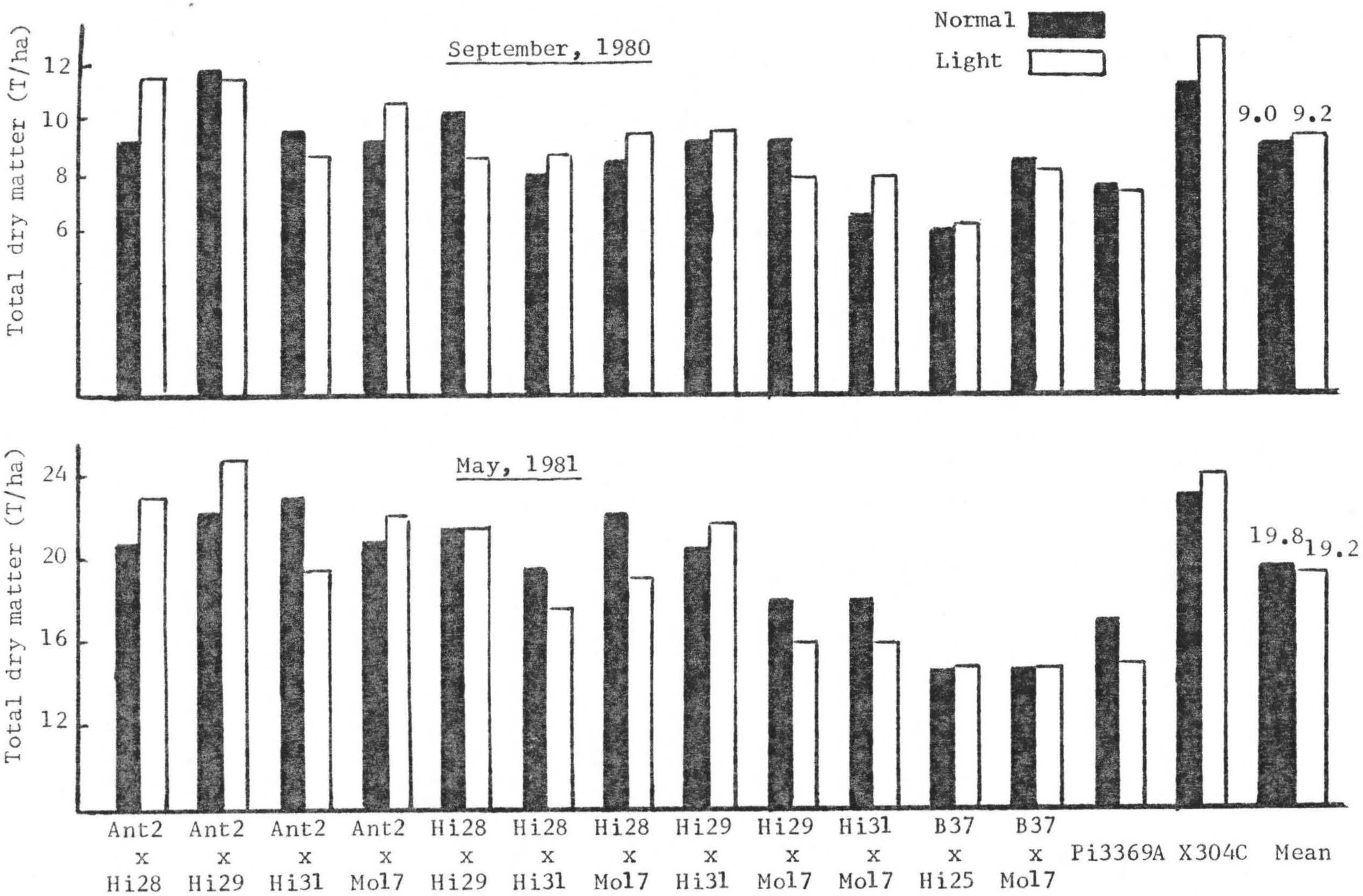


Figure 33. Comparison of total dry matter yield under normal and extended light condition in different seasons.

Table 21. Combined analysis of variance for grain and stover yields, days to tasseling and silking evaluated under normal and extended light conditions in different seasons.

Source	df	Mean squares			
		Grain yield	Stover yield	Days to tasseling	Days to silking
Daylength (D)	1	138.76	109.33	3696.88	7672.86
Reps in D	6	1.80	4.27	42.78	66.65
Season (S)	1	1765.81	1292.40	147.88	51.11
S x D	1	18.34*	2.77	129.02	96.47
Error (b)	6	1.82	4.15	25.47	31.48
Genotype (G)	13	7.25**	52.97**	174.30**	235.35**
G x D	13	3.38**	8.77**	36.09**	47.59**
G x S	13	3.66**	6.85**	16.11**	19.46**
G x D x S	13	2.60**	2.25	7.21*	8.03
Error (c)	156	0.59	1.28	3.22	5.06

* Significant at 5 % probability level.

** Significant at 1 % probability level.

interactions were significant, indicating daylength response was different in different seasons.

4.3.2 Plant characters and yield components.

Tasseling was delayed by the extended photoperiod in all genotypes. The overall average over 2 seasons indicated 8 days delay under light compared to normal (Table 22). Ant2 x Hi28, Ant2 x Hi29, Ant2 x Mo17, and X304C showed more than 10 days delay, indicating that these genotypes were more sensitive to photoperiod. Other genotypes, including B37 x Hi25, B37 x Mo17, and Pi3369A were delayed 5 - 6 days, showing relatively less sensitivity to photoperiod.

Silking was delayed 11.7 days as an average of all genotypes, almost 50 % greater delay than that of days to tasseling. Days to silking was delayed 9 days in B37 x Hi25, B37 x Mo17, and Pi3369A, whereas X304C showed 20 days delay under extended light conditions. The difference between days to tasseling and days to silking ranged from 2.2 to 4.2 days under normal condition, and from 4.5 to 9.2 days under extended light condition. These longer periods from tasseling to silking under extended light might be a cause of grain yield reductions due to poor pollination condition.

Plant and ear height increased significantly under extended light in both seasons. The overall average plant and ear heights under light showed 12 and 25 % increases, respectively, compared to those under normal conditions (Table 22). This result suggests that stem elongation below the ear was larger under extended light than

Table 22. Average days to tasseling and silking, and plant and ear height over 2 seasons under normal and extended light conditions.

Hybrids	Days to tasseling (day)		Days to silking (day)		Plant height (cm)		Ear height (cm)	
	Normal	Light	Normal	Light	Normal	Light	Normal	Light
Ant2 x Hi28	50.9	61.1	54.8	69.1	280	317	148	188
Ant2 x Hi29	51.3	64.1	55.5	71.9	286	341	156	208
Ant2 x Hi31	49.6	56.0	53.3	63.4	279	310	133	162
Ant2 x Mo17	49.1	60.0	53.0	67.0	262	292	121	142
Hi28 x Hi29	50.1	59.4	53.9	66.8	292	328	152	189
Hi28 x Hi31	49.3	56.3	53.0	64.3	274	305	126	152
Hi28 x Mo17	47.0	53.1	51.0	62.3	285	308	129	157
Hi29 x Hi31	49.1	54.9	52.9	61.1	279	309	128	154
Hi29 x Mo17	47.3	55.1	50.4	60.8	274	302	123	153
Hi31 x Mo17	47.3	52.9	50.3	58.4	265	287	105	129
B37 x Hi25	46.9	51.8	49.5	59.3	261	289	95	123
B37 x Mo17	46.3	52.0	49.5	57.9	252	283	95	121
Pi3369A	47.1	53.6	49.3	58.1	268	293	101	126
X304C	52.6	67.3	55.9	75.8	293	347	147	197
Mean	48.9	57.0	52.3	64.0	275	308	126	157

normal. The largest increase of plant and ear height were observed in Ant2 x Hi29 and X304C which showed 10 days delay for days to tasseling. This indicated that increased plant and ear height might be attributed to delayed tasseling.

Number of stem nodes was increased significantly in both plantings (Figure 34). The increase in the number of stem node was consistent in all genotypes. The rates of increase were 13 % in September and 20 % in May planting. Generally, genotypes which had high stover yields, late maturity and tall plant height had more stem nodes.

LAI was measured only in May planting, using the Pearce et al. (1975) rapid method. The overall average LAI under normal was 4.35, while under extended light it was 6.00, showing a 38 % increase under extended light. Ant2 x Hi28 and X304 which were sensitive to daylength had higher LAI values than relatively less sensitive genotypes (B37 x Hi25, Pi3369A). Highly significant correlations were observed between number of stem nodes and LAI under both normal and extended light conditions (Figure 35). LAI was significantly correlated with stover yield under both normal and extended light (Figure 36). Correlation coefficients were 0.73 and 0.91 under normal and extended light, respectively. Stem diameter was measured in both seasons. The average stem diameters were 24.3 and 26.4 mm under normal and light, respectively. X304C which was sensitive to daylength had the largest stem diameter among the genotypes.

Combined analysis of variance showed that genotype x daylength and genotype x season interactions were significant for days to tasseling and silking, and plant characters (Table 21). These

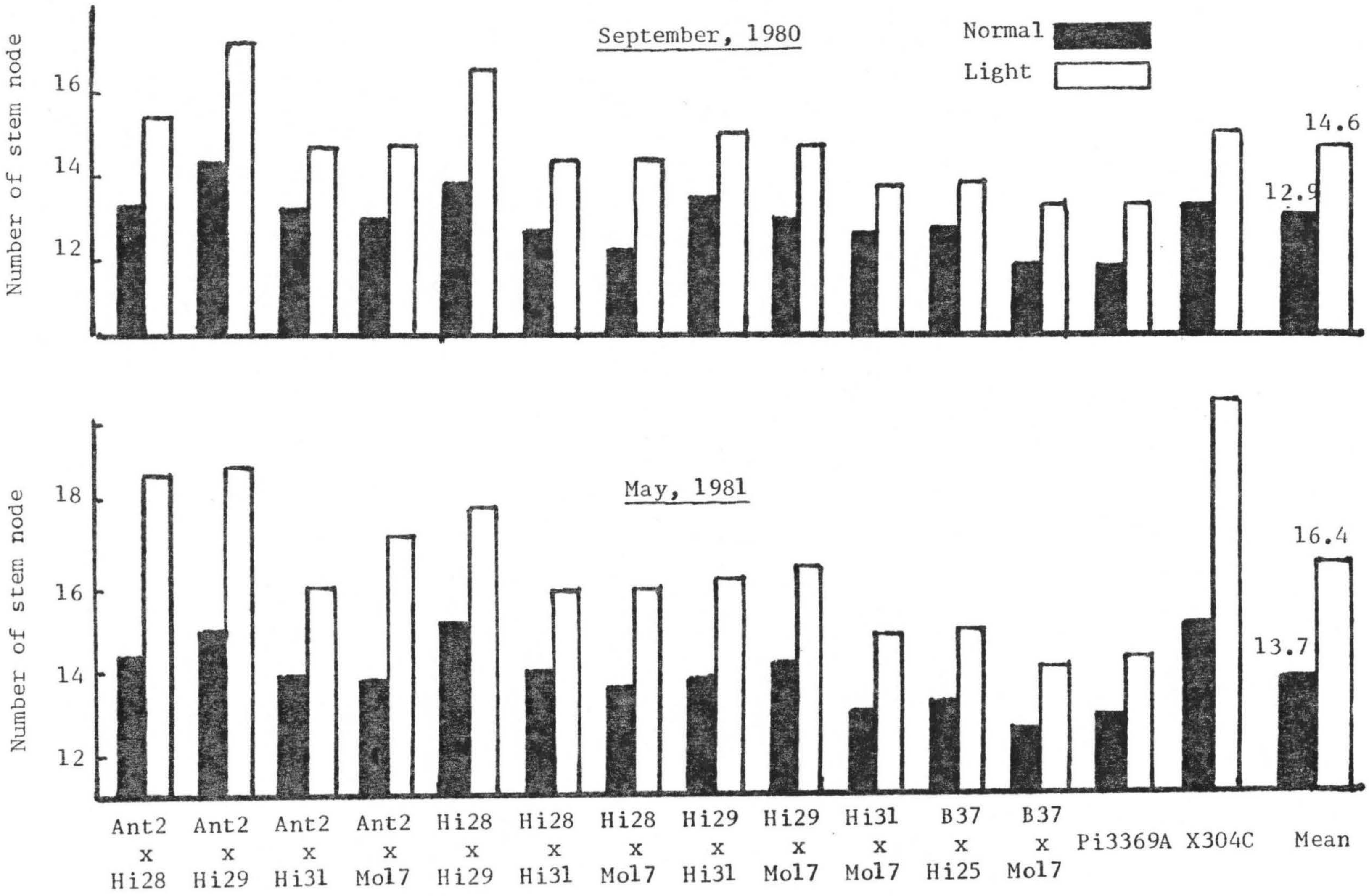


Figure 34. Comparison of number of stem node under normal and extended light condition in different seasons

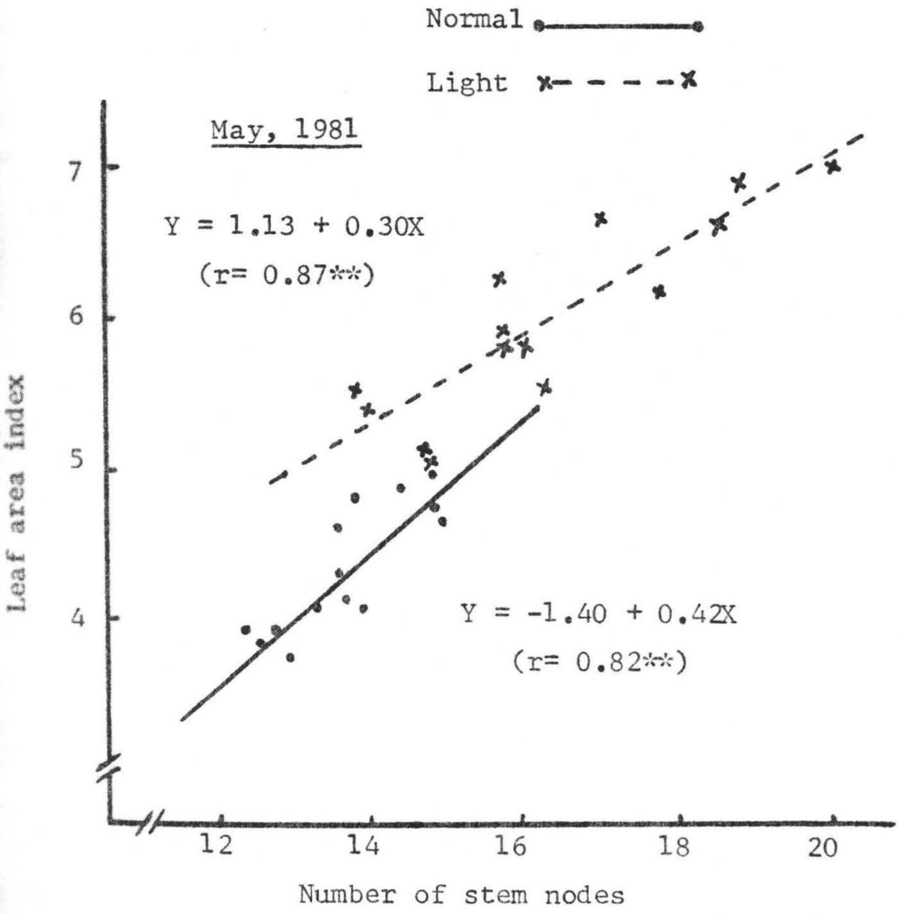


Figure 35. Relationship between number of stem node and leaf area index.

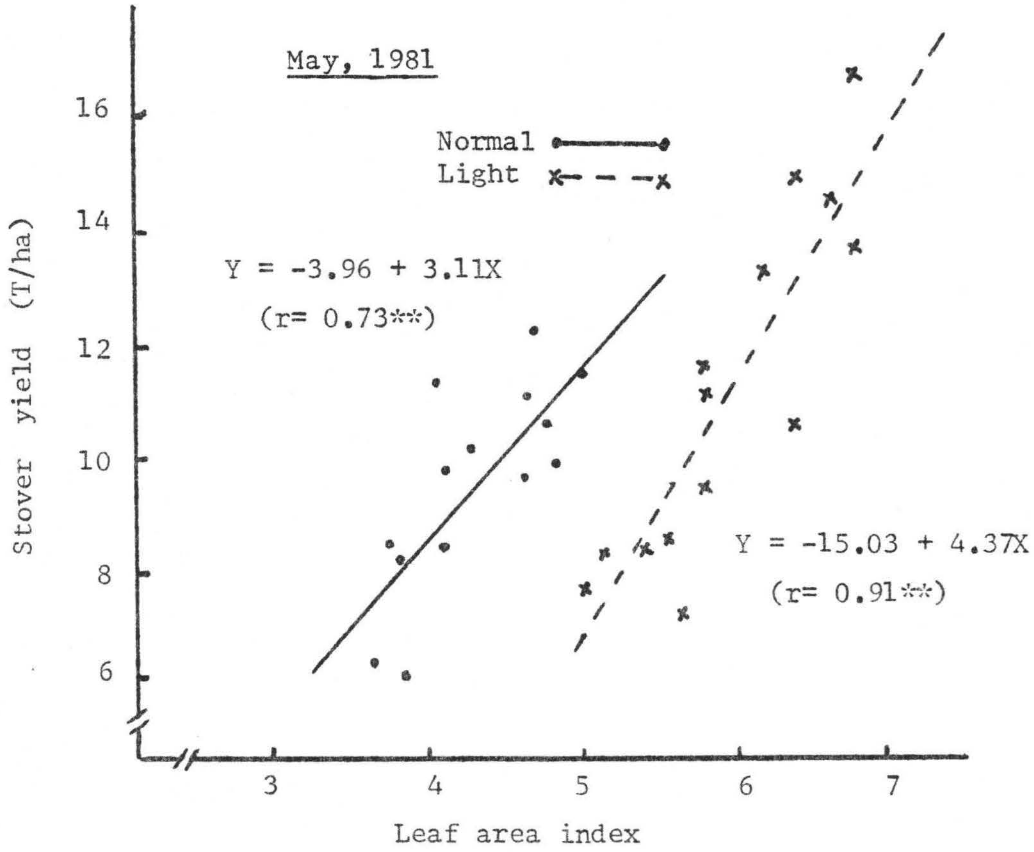


Figure 36. Relationship between leaf area index and stover yield.

results indicated that genotypes were different in their response to daylength and seasons. Season x daylength interaction was observed only for stem diameter, indicating that daylength response was different in different seasons.

Yield components such as filled ear length and number of kernel rows, were not different between normal and light conditions. Number of kernels/row was reduced about 9 % under light compared to those under normal condition (Table 23). 100 kernel weights were observed in May planting. There was no difference between normal and light for 100 kernel weight. Genotypes showed significantly differences for all yield components.

Combined analysis of variance showed that genotype x daylength interaction was observed for number of kernels/row, and genotype x season interaction was observed for filled ear length and number of kernels/row (Table 24). However, there was no interaction for number of kernel rows. These results suggested that number of kernel rows were more stable to environmental changes than other yield components.

Correlation coefficients over 2 seasons among yields, plant characters, and yield components are presented in Table 25. Grain yield was correlated to all characters, under normal condition, except stem diameter and number of kernel rows. However, grain yield under light was not correlated to plant characters and yield components. These results might be attributed to the low grain yield under the light, compared to the larger plant size. Stover yields under normal and light were correlated to all the plant

Table 23. Average yield components over 2 seasons under normal and extended light conditions.

Hybrids	Filled ear length (cm)		Number of kernel rows		Number of kernels per row		100 kernel weight (g)	
	Normal	Light	Normal	Light	Normal	Light	Normal	Light
Ant2 x Hi28	15.8	15.6	12.6	13.0	37.6	32.9	28.3	27.7
Ant2 x Hi29	17.9	16.3	13.8	13.5	38.8	33.7	29.2	28.5
Ant2 x Hi31	15.6	16.0	13.8	13.8	34.4	33.6	30.0	32.5
Ant2 x Mo17	15.6	15.6	12.8	12.5	39.3	31.4	29.7	29.4
Hi28 x Hi29	16.7	15.3	13.6	13.7	35.8	27.7	31.5	29.6
Hi28 x Hi31	16.1	16.0	14.6	13.5	32.8	29.8	29.3	28.2
Hi28 x Mo17	16.5	17.0	12.6	12.6	35.5	34.4	29.7	33.4
Hi29 x Hi31	16.0	16.8	14.1	14.3	31.9	33.4	31.7	30.9
Hi29 x Mo17	14.9	15.7	13.6	13.5	33.6	35.6	28.0	28.1
Hi31 x Mo17	15.7	16.3	13.3	14.1	33.2	33.3	32.4	27.8
B37 x Hi25	14.3	12.9	13.2	13.5	30.1	27.0	29.6	30.4
B37 x Mo17	15.5	15.2	13.3	13.2	35.5	34.0	30.9	31.5
Pi3369A	15.8	14.7	13.2	13.5	38.2	33.3	33.7	32.7
X304C	16.3	15.8	13.4	13.0	35.4	28.1	30.2	34.5
Mean	16.0	15.7	13.4	13.4	35.1	32.0	30.3	30.4

Table 24. Combined analysis of variance for yield components evaluated under normal and extended light conditions in different seasons

Source	df	Mean squares		
		Filled ear length	Number of kernel rows	Number of kernels per row
Daylength (D)	1	4.20	0.03	272.19
Reps in D	2	1.69	0.07	14.12
Season (S)	1	842.06	32.36	2874.49
S x D	1	7.67	0.06	9.03
Error (b)	2	3.94	1.12	17.16
Genotype (G)	13	5.94**	1.85**	37.00**
G x D	13	1.73	0.42	22.50**
G x S	13	4.80**	0.89	17.61*
G x D x S	13	1.31	0.69	10.64
Error (c)	52	1.43	0.68	9.20

* Significant at 5 % probability level.
** Significant at 1 % probability level.

Table 25. Correlation coefficients among yields, plant characters and yield components under normal and extended light conditions. Above diagonal: Normal Below diagonal: Light

	Grain yield	Stover yield	Tassel date	Silk date	Plant height	Ear height	No. of Nodes	Stem dia.	Filled ear length	No. of kernel rows	No. of kernels per row
Grain yield		0.85^{**}	0.69^{**}	0.77^{**}	0.66^{**}	0.82^{**}	0.67^{**}	0.41	0.67^{**}	-0.12	0.58^{*}
Stover yield	0.19		0.87^{**}	0.90^{**}	0.89^{**}	0.93^{**}	0.82^{**}	0.66^{*}	0.64^{*}	0.22	0.39
Days to tasseling	0.18	0.94^{**}		0.98^{**}	0.74^{**}	0.86^{**}	0.85^{**}	0.73^{**}	0.52	0.20	0.35
Days to silking	0.17	0.96^{**}	0.98^{**}		0.74^{**}	0.91^{**}	0.88^{**}	0.66^{*}	0.61^{*}	0.20	0.37
Plant height	0.22	0.83^{**}	0.86^{**}	0.88^{**}		0.89^{**}	0.79^{**}	0.64^{*}	0.40	0.15	0.17
Ear height	0.32	0.85^{**}	0.86^{**}	0.89^{**}	0.96^{**}		0.92^{**}	0.54^{*}	0.59^{*}	0.14	0.38
Number of stem node	0.33	0.90^{**}	0.92^{**}	0.93^{**}	0.91^{**}	0.96^{**}		0.51	0.50	0.27	0.22
Stem diameter	0.15	0.89^{**}	0.89^{**}	0.92^{**}	0.90^{**}	0.86^{**}	0.88^{**}		0.23	0.19	0.06
Filled ear length	0.57^{*}	0.36	0.24	0.25	0.34	0.40	0.31	0.33		-0.01	0.71^{**}
Number of kernel rows	0.32	-0.45	-0.33	-0.40	-0.10	-0.16	-0.22	-0.34	0.01		-0.42
Number of kernels per row	0.30	-0.22	-0.29	-0.34	-0.25	-0.14	-0.25	-0.34	0.53	0.01	

* Significant at 5 % probability level.

** Significant at 1 % probability level.

characters measured, but not correlated to yield components. Figure 37 shows highly significant correlations between days to tasseling and stover yields under both daylength conditions in different plantings. This relationship could indicate that relatively late maturing genotypes were high in stover yield under both normal and extended light.

4.3.4. Diallel Analysis

GCA effects of 5 inbred for yields, plant characters, and yield components are presented in Table 26. Ant2 had positive GCA effects for grain yield, while Hi28 and Mo17 had negative effects under normal and light. Hi29 and Hi31 had negative GCA effects under normal, while those inbreds had positive values under light, indicating that genotypes were different under different daylength. Ant2 was good and Mo17 was a poor combiner under both normal and extended light conditions. For stover yields, Ant2, Hi28, and Hi29 had positive GCA effects, and Hi31 and Mo17 had negative effects under both normal and light. Ant2, which is a late tropical inbred, was the best combiner for grain and stover yield under both normal and light, while Hi31 and Mo17, which are early maturing inbreds, were poor combiner for yields. These results showed that late maturing genotypes had high yields and early maturing genotypes were low in yield.

GCA effects for plant characters, including days to tasseling, plant and ear height, number of stem node, and stem diameter, showed similar effects to that of stover yield. Ant2, Hi28, and Hi29 had

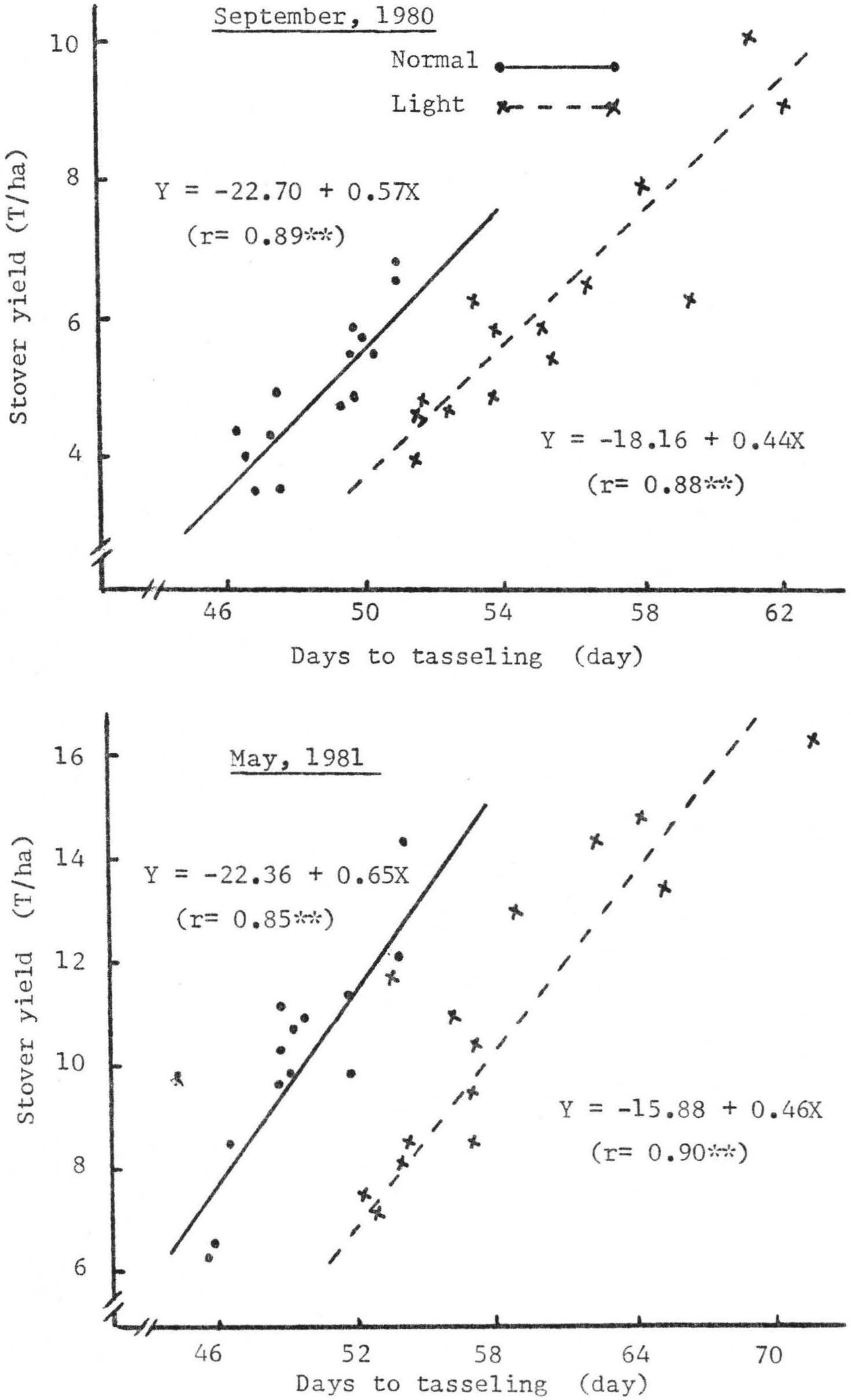


Figure 37. Relationship between days to tasseling and stover yield.

Table 26. Estimates of GCA effects of 5 inbreds for yields, plant characters and yield components under normal and light.

Characters	Daylength	Inbreds				
		Ant2	Hi28	Hi29	Hi31	Mo17
Grain yield	Normal	0.71	-0.01	-0.02	-0.52	-0.16
	Light	0.27	-0.43	0.43	0.31	-0.58
Stover yield	Normal	0.65	0.23	0.54	-0.37	-1.04
	Light	1.95	0.60	0.13	-1.71	-0.97
Plant height	Normal	-1.13	7.16	6.87	-4.63	-8.26
	Light	6.76	6.13	13.43	-9.16	-17.16
Ear height	Normal	9.61	8.94	10.11	-12.14	-16.52
	Light	15.63	10.92	16.54	-18.96	-24.13
Days to tasseling	Normal	1.51	0.30	0.47	-0.37	-1.91
	Light	4.03	0.24	1.45	-3.05	-2.68
Number of stem node	Normal	0.37	0.05	0.63	-0.40	-0.65
	Light	0.96	0.29	0.87	-1.15	-0.96
Stem diameter	Normal	-0.01	0.24	0.45	0.12	-0.80
	Light	0.30	0.80	0.76	-0.99	-0.87
Filled ear length	Normal	0.56	-0.02	0.15	-0.56	-0.13
	Light	-0.25	-0.11	-0.04	0.29	0.11
Number of kernel rows	Normal	-0.30	-0.17	0.39	0.62	-0.54
	Light	-0.35	-0.30	0.37	0.64	-0.35
Number of kernels /row	Normal	3.00	0.20	-0.38	-2.96	0.14
	Light	0.42	-1.86	0.03	-0.06	1.46

positive GCA effects, while Hi31 and Mo17 had negative effects for those characters under both normal and extended light conditions, except a few cases. GCA effects of yield components were quite different from those of yields and plant characters. Ant2 which was a good combiner for grain yield showed negative effects for number of kernel rows and positive effects for number of kernels/row. In general, genotypes which had negative GCA effects for kernel rows showed positive effects for number of kernels/row. Ratios of GCA/SCA mean squares for those characters were high than those of grain yield. There were differences between normal and extended light for days to tasseling, plant and ear height, but the trends were not constant.

Combined analysis of combining ability of yield components showed that GCA effects were less than SCA effects for filled ear length, indicating less importance of GCA effects. GCA and SCA mean squares did not show any trends (Table 27). GCA x season interaction was significant only for filled ear length under both daylengths, and number of kernels/row under light. However, SCA x season interactions were not observed for all yield components studied.

Combined analysis of combining ability for grain and stover yields are presented in Table 28. GCA and SCA effects were highly significant for both yields under normal and light. GCA x season and SCA x season interactions were either highly significant or significant except grain yield under normal. GCA/SCA mean squares ratios were calculated. The ratio indicated that GCA mean squares were larger than those of SCA. The GCA/SCA ratios for grain yield

Table 27. Combined analysis of combining ability for yield components evaluated under normal and extended light conditions over 2 seasons.

Source	df	Mean squares					
		Filled ear length		Number of kernel rows		Number of kernels/row	
		Normal	Light	Normal	Light	Normal	Light
GCA	4	1.00	0.26	1.42**	1.32*	26.97**	8.65
SCA	5	2.23**	0.84	0.40	0.17	2.54	12.66*
Season (S)	1	108.59**	176.72**	5.41**	3.53**	409.56**	475.81**
GCA x S	4	1.76**	3.21**	0.37	0.59	5.88	14.98*
SCA x S	5	0.93	0.78	0.37	0.15	1.41	5.35
Error	18	0.40	0.89	0.26	0.43	4.94	4.64

* Significant at 5% level.

** Significant at 1% level.

Table 28. Combined analysis of combining ability for grain and stover yields evaluated under normal and extended light conditions over 2 seasons.

Source	df	Mean squares			
		Grain yield		Stover yield	
		Normal	Light	Normal	Light
GCA	4	1.20**	1.32**	2.97**	12.09**
SCA	5	0.43**	0.63**	0.82**	1.86**
Season (S)	1	212.91**	141.87**	121.59**	146.50**
GCA x S	4	0.59**	2.34**	0.44*	1.40*
SCA x S	5	0.07	0.64**	0.57*	1.18*
Error	54	0.11	0.16	0.17	0.48

* Significant at 5 % level.
** Significant at 1 % level.

were 2.8 and 2.1 under normal and light, respectively. The ratios for stover yields under normal and light were 3.6 and 6.5, respectively.

GCA and SCA mean squares under normal and light were highly significant for days to tasseling, plant and ear height, except for a few cases (Table 29). However, GCA x season and SCA x season interactions were not significant for those characters except GCA x season under normal for days to tasseling. These results indicated that GCA and SCA effects for those characters were relatively less variable to environmental changes.

Heritability estimates for yields, plant characters, and yield components are presented in Table 30. Ear height, days to tasseling, and number of stem nodes showed higher narrow and broad sense heritability estimates than other characters under normal and extended light environments. Heritability estimates of those characters ranged from 77 to 92 % for narrow, and from 90 to 95 % for broad sense. Heritability estimates of grain yield and stover yield were lower than those of ear height, number of stem nodes, and days to tasseling. Heritability estimates of yields ranged from 34 to 69 % for narrow sense and from 68 to 88% for broad sense. There was no difference between normal and light for those characters. Stem diameter, and yield components showed low heritability estimates and heritability estimates of broad sense were lower than those of narrow sense, in some case indicating negative dominance variance for those characters.

Table 29. Combined analysis of combining ability for days to tasseling, plant and ear height evaluated under normal and extended light conditions over 2 seasons.

Source	df	Mean squares					
		Days to tasseling		Plant height		Ear height	
		Normal	Light	Normal	Light	Normal	Light
GCA	4	9.53**	52.31**	283.50**	962.00**	1041.98**	2367.75**
SCA	5	0.53**	7.44**	87.60**	145.20	41.43	214.20**
Season (S)	1	0.03	39.88**	2538.00**	5728.00**	1369.50**	3309.06**
GCA x S	4	0.53*	2.77	14.00	72.00	16.38	102.00
SCA x S	5	0.08	2.14	19.60	15.20	17.45	38.21
Error	54	0.13	1.28	15.17	70.29	19.64	57.38

* Significant at 5% level.

** Significant at 1% level.

Table 30. Heritability estimates of yields, plant characters and yield components under normal and light.

(unit : %)

Characters	Daylength	Narrow	Broad
Grain yield	Normal	66	85
	Light	34	68
Stover yield	Normal	48	88
	Light	69	88
Plant height	Normal	57	87
	Light	77	81
Ear height	Normal	92	95
	Light	85	93
Days to tasseling	Normal	91	96
	Light	77	93
Number of stem node	Normal	91	94
	Light	90	90
Stem diameter	Normal	48	48
	Light	62	62
Filled ear length	Normal	30	73
	Light	45	45
Number of kernel rows	Normal	37	37
	Light	81	81
Number of kernels per row	Normal	82	82
	Light	23	52

4.3.4 Discussion

Days to tasseling and silking were delayed in all the genotypes used under extended light. This delay in flowering was similar to those of other researchers. The magnitudes of delay in flowering were different among genotypes; i.e. photoperiod sensitive genotypes were delayed more and insensitive genotypes were delayed less. Lee (1978) also reported delay of flowering in Hawaii under conditions identical to the present study, with 4 hours of extended daylength. He observed that the difference in delay for flowering among genotypes depended on sensitivity to photoperiod. Francis et al. (1970) and Hunter et al. (1974) observed delayed tassel initiation with longer photoperiod. The interval between tassel initiation and silking was not affected by photoperiod.

Plant characters, including plant height, ear height, number of stem nodes, and stem diameter, were significantly increased under extended light. The degree of increase was prominent in photoperiod sensitive genotypes. Coligado and Brown (1975) observed increased number of leaves (i.e., nodes)under extended daylength. They stated that this increase of leaf number was due to prolongation of the time to tassel initiation. According to Hunter et al. (1974), leaf number and stem length increase with longer photoperiod. They also found that the magnitude of increase depended on sensitivity to photoperiod.

Lee (1978) observed significant increase of plant and ear height under extended light, but the degree of increase was higher in sensitive than in insensitive genotypes. LAI increased significantly under the light in this study. The increased LAI was primarily due to increased leaf number, because the size of individual leaf (leaf length and width) increased less than number of leaves. Bonaparts (1975) observed similar increase of LAI with longer photoperiod.

Reductions of grain yields were observed in all genotypes studied except in one case. Lee (1978) also found reduction of grain yield under extended light. The reduction rate was higher in sensitive genotypes. In this experiment, the yield components, including filled ear length, number of kernel rows, and 100 kernels weight, were not reduced, but slight reduction in number of kernels/row was noticed. Average reduction of grain yield was 20-25 %. This reduction could not be explained by the small reduction of kernel number. The interval between tasseling and silking was much longer under light (7 days) than normal condition (3 days). This prolongation might have caused poor pollination under extended daylength. Lee (1978) observed reduced kernel weight, while Bonaparte (1975) reported increased kernel weight and number of kernel rows with longer photoperiod. Ragland et al. (1966) observed increase of kernel rows, but decreased kernels/row and grain weight under supplementary light treatment.

Stover yield increased significantly under extended light in this experiment. This increase appears to be directly related to increased node and leaf number, plant height, and stem diameter. Hunter et al. (1974) reported that total dry weight increased with longer photoperiod. They also observed that genotypes varied in response to photoperiod for dry weight; i.e. photoperiod sensitive genotype increased more than insensitive genotypes.

There was no difference of TDM yield between normal and extended daylength conditions. The increase of stover yield was offset by the reduction of grain yield. Several genotypes showed increased TDM yield in both seasons. These genotypes show potential use for silage production under longer daylength conditions. It was reported that photoperiod response was more prominent under lower temperature conditions (Coligado and Brown, 1975). In this study, September planting might be under lower temperature condition than May planting, but there was no photoperiod response for yields and their characters in different seasons.

Combined analysis of variance over 2 seasons showed genotype x daylength interaction for both grain and stover yields. This suggested that genotypes were different in their photoperiod responses for silage production. Combining ability analysis indicated significance of both GCA and SCA in contributing to the genetic variation of grain and stover yields. The GCA/SCA ratio suggested that additive gene effects predominate in the genetic variation. GCA/SCA ratio for stover yield was higher than that for grain yield, indicating that the additive gene action was more important for stover yield than for grain yield. Dhillon and Singh (1977) reported that GCA was more important than SCA for yield.

Harville et al. (1978) observed that the GCA effect was larger than the SCA effect for ear height. They concluded that the inheritance of ear height was controlled primarily by additive gene effects. Rood and Major (1980) reported that flowering was largely determined by GCA effects. Narrow sense heritability estimates were higher for ear height, days to tasseling, and number of stem nodes than for other characters observed. This indicates that it will be relatively easy to select for these characters. Heritability estimates of those characters were not different between normal and extended daylength conditions.

4.4. Selection of Superior Hybrids for Silage Production

To select superior hybrids for silage production, 217 single cross hybrids from a factorial combination of 31 inbreds as females with 7 male tester inbreds were evaluation with 8 check hybrids in 3 different seasons at the Waimanalo Research Station. The data presented below in 3 sections: 4.4.1 Yields, 4.4.2 Plant characters, and 4.4.3 Yield components.

4.4.1. Yields

The average total dry matter (TDM) yields of 225 hybrids over 3 seasons are presented in Table 31. The best inbred among 31 female inbreds was CIMMYT-T11ES; its average performance over 7 tester male inbreds was 13.56 T/ha. H632A and ICA L221 were also high yielding combiners, with TDM yields of over 13 T/ha. These superior inbreds were 12 % higher than the overall average (11.85 T/ha). The average grain yields of 225 hybrids over 3 seasons are presented in Table 32. 77-4544 x Hi34 showed the highest grain yield (7.58 T/ha), showing 17 % higher than X304C which is widely used in the topics.

Data from the top 20 hybrids for grain and stover yields over 3 plantings among the 217 combinations are presented in Table 33. Eleven hybrids showed higher TDM yield than H823 which was the best check hybrid. The highest TDM yield was 15.13 T/ha (H632A x Hi29). CIMMYT-T11ES x Hi34 and ICA L221 x Hi28 were also superior hybrids for TDM yield. H763 and X304C which were used in the population density experiment showed much lower (10-15 %) TDM yields than the

Table 31. Total dry matter yield of 225 hybrids evaluated during 3 different seasons.

(unit : T/ha)

Female / Male	Hi26	Hi28	Hi29	Hi31	Hi33	Hi34	Tx601	Mean
CIMMYT-A21	12.98	13.25	14.68	12.40	11.22	11.94	12.12	12.66
CIMMYT-T11ES	14.57	14.83	12.98	13.05	11.60	15.06	12.82	13.56
Fla.2AT-112	11.62	11.09	12.12	9.61	11.48	12.53	12.57	11.58
Fla.2AT-114	12.92	13.31	12.68	10.80	10.90	13.89	12.78	12.47
Fla.2BT-54	11.20	11.33	12.09	9.09	10.34	13.11	13.05	11.46
H632A	13.48	13.62	15.13	11.21	11.65	14.58	13.23	13.27
H632F	13.86	12.39	13.61	9.80	12.77	14.14	12.80	12.76
H632G	11.20	11.51	11.32	11.38	11.03	11.61	11.41	11.35
ICA L25	13.53	11.98	13.11	11.28	11.81	12.93	11.40	12.29
ICA L27	12.54	12.30	12.07	10.46	11.57	13.82	12.21	12.14
ICA L210	14.42	12.15	10.50	12.15	12.16	14.18	11.86	12.48
ICA L221	14.46	15.00	12.08	11.53	12.82	13.04	13.88	13.26
ICA L223	12.53	13.91	11.24	11.07	11.93	14.04	13.82	12.65
INV138	11.47	12.12	12.70	9.94	10.74	12.82	12.10	11.70
INV302	12.96	12.79	13.40	9.64	10.41	14.32	10.34	11.98
INV443	12.32	12.26	10.49	11.24	11.39	14.45	12.11	12.04
INV534	12.60	12.45	12.55	11.33	12.42	14.30	12.54	12.60
MIT11 DMR	11.80	12.53	11.19	11.41	11.28	13.18	12.64	12.00
Pi4243	12.34	11.11	10.67	7.54	10.61	13.26	11.77	11.04
Pi4257	11.30	11.20	12.28	9.49	10.22	11.51	10.80	11.27
Pi4283	10.09	11.26	10.68	9.77	10.52	11.92	11.99	10.89
Pi4287	10.70	10.92	10.34	7.13	7.98	10.09	12.09	9.92
SR52-F	12.99	11.89	11.68	12.02	10.52	12.53	11.03	11.83
SR52-M	12.36	11.49	11.66	11.61	10.53	12.99	11.27	11.64
Tuxpeno	13.22	10.58	11.26	8.88	9.38	12.95	11.59	11.12
Tx602	12.47	12.47	10.95	11.39	10.00	13.87	9.69	11.55
77-4407	11.62	12.56	11.02	7.23	10.55	11.04	12.44	10.93
77-4412	9.93	11.32	11.53	6.92	11.18	11.36	11.99	10.61
77-4441	10.62	12.04	11.06	6.33	11.84	12.81	11.33	10.65
77-4449	12.96	12.58	11.99	7.72	10.78	14.14	11.40	11.65
77-4544	11.33	12.25	12.99	10.04	10.49	14.81	11.16	11.94
Mean	12.32	12.27	12.01	10.04	11.08	13.22	12.03	11.85

H636 : 10.61 H650 : 11.21 H763 : 12.70 H767 : 10.47
H823 : 14.38 H824 : 13.12 X105A: 13.23 X304C: 13.13

Table 32. Grain yield of 225 hybrids evaluated during 3 different seasons.

(unit : T/ha)

Male Female	Hi26	Hi28	Hi29	Hi31	Hi33	Hi34	Tx601	Mean
CIMMYT-A21	6.50	6.63	6.77	5.89	5.90	6.28	5.85	6.26
CIMMYT-T11ES	6.66	6.59	6.21	6.05	5.72	6.85	6.02	6.30
Fla.2AT-112	5.66	5.60	6.00	4.47	5.50	5.50	5.40	5.45
Fla.2AT-114	7.01	6.51	6.20	4.89	5.23	7.22	6.35	6.20
Fla.2BT-54	5.46	5.54	5.60	4.47	5.28	6.15	5.83	5.48
H632A	6.41	6.21	6.09	4.87	5.43	6.77	5.37	5.88
H632F	6.64	5.57	5.81	4.02	5.97	6.59	5.46	5.72
H632G	5.02	4.99	4.00	5.37	4.93	5.27	4.60	4.88
ICA L25	6.16	5.67	5.53	5.39	5.86	6.20	5.33	5.73
ICA L27	6.03	5.76	5.61	4.60	5.42	6.54	5.81	5.68
ICA L210	6.76	5.72	5.02	5.49	5.92	6.92	5.92	5.96
ICA L221	6.83	6.98	5.96	5.73	6.61	5.93	7.17	6.46
ICA L223	6.37	7.30	5.53	5.31	5.98	6.99	5.95	6.21
INV138	5.53	6.22	5.99	4.60	5.13	6.36	5.79	5.66
INV302	6.21	6.39	6.17	4.57	5.37	7.14	5.06	5.84
INV443	6.40	5.97	4.97	5.55	5.79	7.13	5.98	5.97
INV534	6.83	6.51	6.11	5.36	6.51	6.75	6.21	6.33
MIT11 DMR	6.18	5.70	5.44	5.30	5.69	6.08	5.67	5.72
Pi4243	5.87	5.50	5.12	3.18	5.18	6.47	5.31	5.23
Pi4257	5.32	5.01	5.32	4.05	5.15	6.20	5.65	5.24
Pi4283	4.92	5.84	4.96	4.55	5.24	5.80	5.55	5.27
Pi4287	5.24	5.59	4.22	2.97	3.52	4.44	5.23	4.46
SR52-F	5.99	5.47	5.28	5.82	4.80	5.40	4.58	5.34
SR52-M	5.82	5.70	4.89	4.74	5.66	5.83	4.25	5.27
Tuxpeno	5.95	5.21	4.68	3.87	4.33	5.90	5.15	5.01
Tx602	5.94	5.53	4.99	5.22	4.84	6.41	4.11	5.29
77-4407	5.85	6.19	5.20	3.21	5.37	5.30	6.29	5.35
77-4412	5.11	5.80	5.48	2.37	5.12	5.34	5.95	5.03
77-4441	5.35	6.04	5.26	2.90	5.55	5.59	4.92	5.08
77-4449	5.94	6.30	5.81	3.48	5.34	6.94	5.34	5.59
77-4544	5.97	6.02	6.33	3.58	5.34	7.58	5.24	5.72
Mean	5.98	5.93	5.52	4.54	5.43	6.27	5.53	5.60

H636 : 5.08 H650 : 5.48 H763 : 6.47 H767 : 4.32
H823 : 6.83 H824 : 6.17 X105A: 6.09 X304C: 6.49

Table 33. Superior hybrids selected from 225 hybrids evaluated over 3 different seasons for total dry matter yield. (unit : T/ha)

Ranking	Hybrids		Total dry matter	Grain yield	Stover yield	G/S Ratio
1	H632A	x Hi29	15.13	6.09	9.04	0.67
2	CIMMYT-T11ES	x Hi34	15.06	6.85	8.21	0.83
3	ICA L221	x Hi28	15.00	6.98	8.02	0.87
4	CIMMYT-T11ES	x Hi28	14.83	6.59	8.24	0.80
5	77-4544	x Hi34	14.81	7.58	7.23	1.05
6	CIMMYT-A21	x Hi29	14.68	6.77	7.91	0.86
7	H632A	x Hi34	14.58	6.77	7.81	0.87
8	CIMMYT-T11ES	x Hi26	14.57	6.66	7.91	0.84
9	ICA L221	x Hi26	14.46	6.83	7.63	0.90
10	INV443	x Hi34	14.45	7.13	7.32	0.97
11	ICA L210	x Hi26	14.42	6.76	7.66	0.88
12	INV302	x Hi34	14.32	7.14	7.18	0.99
13	INV534	x Hi34	14.30	6.75	7.55	0.89
14	ICA L210	x Hi34	14.18	6.92	7.26	0.95
15	77-4449	x Hi34	14.14	6.94	7.20	0.96
16	H632F	x Hi34	14.14	6.59	7.55	0.87
17	ICA L223	x Hi34	14.04	6.99	7.05	0.99
18	ICA L223	x Hi28	13.91	7.30	6.61	1.10
19	Fla.2AT-114	x Hi34	13.89	7.22	6.67	1.08
20	ICA L221	x Tx601	13.88	7.17	6.71	1.07
Check hybrids						
*	H763		12.70	6.47	6.23	1.04
*	H823		14.38	6.83	7.55	0.91
*	X304C		13.13	6.49	6.64	0.98

20 superior hybrids. Among the 20 superior hybrids, CIMMYT-T11ES had 3 combinations and H632A, ICA L220, ICA L221, and ICA L223 had 2 combinations with 7 male inbreds, indicating that these inbred were good combiners for TDM yields. Among the 7 male testers Hi34 had 11 combinations, indicating that this is the best combiner for TDM yields, while Hi26 and Hi28 showed 3 combinations each. Grain/stover ratios of the 20 superior hybrids ranged from 0.67 to 1.10. H632A x Hi29 which had the highest yield showed the lowest grain/stover ratio (0.67).

The superior hybrids in summer season (March and May plantings) are presented in Table 34. H632A x Hi29 had the highest TDM yield (20.60 T/ha) in favorable seasons and 77-4544 x Hi34 and CIMMYT-T11ES x Hi26 were also high in TDM yields. These hybrids were 6 to 11 % higher than the best check hybrid (H823). The highest grain yield under favorable seasons was obtained on 77-4544 x Hi34, showing 12 % higher than H823.

The rankings of the superior hybrids in winter season (November planting) were different from those in summer season (Table 35). Among the 10 superior hybrids in summer season, only 4 hybrids were listed among the 10 superior hybrids in the winter season. The best hybrids for TDM yield in winter was CIMMYT-T11ES x Hi34 (7.93 T/ha), indicating 14 % higher yield than X304C which was the best among the check hybrids. INV443 x Hi34 and INV534 x Hi34 had the highest grain yield in the winter planting with 57-62 % higher than X304C which was the best check in winter.

Table 36 shows 20 superior hybrids for grain and stover yield

Table 34. Top 10 hybrids selected from 217 hybrids evaluated in March and May.

Ranking	Hybrids		Total dry matter	Grain yield
			T/ha	
1	H632A	x Hi29	20.60	8.97
2	77-4544	x Hi34	19.65	10.51
3	CIMMYT-T11ES	x Hi26	19.56	9.51
4	CIMMYT-A21	x Hi29	19.23	9.32
5	ICA L221	x Hi26	18.98	9.53
6	H632A	x Hi34	18.86	9.47
7	ICA L221	x Hi28	18.70	9.26
8	Tx602	x Hi34	18.63	9.06
9	CIMMYT-T11ES	x Hi34	18.63	9.22
10	CIMMYT-T11ES	x Hi28	18.52	8.64
Check	H763		17.12	9.27
	H823		18.50	9.38
	X304C		16.25	8.77

Table 35. Top 10 hybrids selected from 217 hybrids evaluated in November.

Ranking	Hybrids	Total dry matter	Grain yield
		T/ha	
1	CIMMYT-T11ES x Hi34	7.93	2.11
2	ICA L221 x Hi28	7.63	2.45
3	CIMMYT-T11ES x Hi28	7.49	2.51
4	ICA L223 x Hi34	7.44	2.01
5	INV443 x Hi34	7.34	3.20
6	INV534 x Hi34	7.22	3.10
7	ICA L210 x Hi26	6.87	2.46
8	ICA L27 x Hi34	6.75	1.36
9	77-4544 x Hi34	6.63	1.73
10	ICA L210 x Hi28	6.58	2.52
Checks	H763	3.86	0.88
	H823	6.16	1.75
	X304C	6.93	1.98

Table 36. Superior hybrids selected from 225 hybrids evaluated over 3 different seasons for grain and stover yields.

(unit : T/ha)

Ranking	For grain yield		For stover yield	
	Hybrids	Yield	Hybrids	Yield
1	77-4544 x Hi34	7.58	H632A x Hi29	9.04
2	ICA L223 x Hi28	7.30	CIMMYT-T11ES x Hi28	8.24
3	Fla.2AT-114 x Hi34	7.22	CIMMYT-T11ES x Hi34	8.21
4	ICA L221 x Tx601	7.17	ICA L221 x Hi28	8.02
5	INV302 x Hi34	7.14	CIMMYT-T11ES x Hi26	7.91
6	INV443 x Hi34	7.13	CIMMYT-A21 x Hi29	7.91
7	Fla.2AT-114 x Hi26	7.01	ICA L223 x Tx601	7.87
8	ICA L223 x Hi34	6.99	H632A x Tx601	7.86
9	ICA L221 x Hi28	6.98	H632A x Hi34	7.81
10	77-4449 x Hi34	6.94	H632F x Hi29	7.80
11	ICA L210 x Hi34	6.92	ICA L210 x Hi26	7.66
12	CIMMYT-T11ES x Hi34	6.85	ICA L221 x Hi26	7.63
13	ICA L221 x Hi26	6.83	SR52-F x Hi34	7.59
14	INV534 x Hi26	6.83	ICA L25 x Hi29	7.58
15	CIMMYT-A21 x Hi29	6.77	H632F x Hi34	7.55
16	H632A x Hi34	6.77	INV534 x Hi34	7.55
17	ICA L210 x Hi26	6.76	H632A x Hi28	7.41
18	CIMMYT-T11ES x Hi26	6.66	ICA L25 x Hi26	7.37
19	H632F x Hi26	6.64	H632F x Hi34	7.34
20	CIMMYT-A21 x Hi28	6.63	INV443 x Hi34	7.32
Check hybrids				
*	H763	6.47		6.23
*	H823	6.83		7.55
*	X304C	6.49		6.64

over 3 plantings. The highest grain yield was observed in 77-4544 x Hi34 (7.58 T/ha). Also, ICA L223 x Hi28 and Fla.2AT-114 x Hi34 had 7.30 and 7.22 T/ha, respectively. When compared to the best check hybrid (H823), these superior hybrids showed 6 to 11 % higher grain yield. 12 hybrids had higher grain yield than H823. The highest stover yield was observed in H623A x Hi29 (9.04 T/ha), showing 20 % higher than H823 which was the best check hybrid. Among the 217 hybrids from 31 x 7 factorial combinations, 14 hybrids were better than H823 for stover yields.

GCA effects of 31 female inbreds for grain and stover yields over 3 plantings are shown in Table 37. In general, positive GCA effects for grain yield were observed in CIMMYT, H632, and ICA inbreds, indicating good combiner for grain yield. CIMMYT-A21, CIMMYT-T11ES, ICA L221, and INV534 showed high GCA effects, while all of Pi inbreds, SR52-F, SR52-M, Tuxpeno, Tx602, and all UH 77-lines except 77-4544 had negative GCA effects, indicating that they are poor combiners for grain yield. The highest GCA effect was observed in ICA L221, indicating the best combiner for grain yield. The performance of 31 inbreds as female for stover yields were similar to those of grain yield except a few cases. The high positive GCA effects for stover yields were observed in CIMMYT-T11ES, H632A,H632F, and ICA L221. All of the Pi inbreds and UH new lines had negative GCA effects. INV138, INV302, and INV443 showed positive effects for grain yield, while those inbreds had negative effects for stover yield. These inbreds might be used for grain yields rather than stover yields. However, H632A and H632F had higher GCA effects for stover yields than for

Table 37. Estimates of GCA effects for yields and plant characters of 31 female inbreds evaluated over 3 seasons.

Female parent	Grain yield	Stover yield	Days to tasseling	Plant height	Ear height
CIMMYT-A21	0.66	0.14	1.05	7.32	8.83
CIMMYT-T11ES	0.70	1.01	2.46	2.95	7.43
Fla.2AT-112	-0.15	-0.13	-0.93	-13.86	-12.07
Fla.2AT-114	0.60	0.02	-1.40	-13.22	-11.24
Fla.2BT-54	-0.12	-0.27	-0.24	6.83	5.50
H632A	0.29	1.14	2.19	11.95	9.78
H632F	0.12	0.79	1.50	14.19	11.07
H632G	-0.72	0.21	0.24	13.09	9.28
ICA L25	0.13	0.30	0.79	13.61	10.52
ICA L27	0.08	0.20	1.17	3.54	-0.07
ICA L210	0.36	0.27	0.24	4.59	2.55
ICA L221	0.86	0.55	1.24	9.04	2.52
ICA L223	0.60	0.19	1.48	8.61	4.88
INV138	0.06	-0.22	-0.81	12.30	7.66
INV302	0.24	-0.12	-0.31	1.38	4.83
INV443	0.37	-0.19	-1.59	-12.15	-9.65
INV534	0.73	0.02	-2.43	-15.55	-8.62
MIT11 DMR	0.12	0.03	-0.04	4.66	6.35
Pi4243	-0.37	-0.45	-1.28	-0.89	-4.41
Pi4257	-0.36	-0.23	-1.04	-2.58	-7.17
Pi4283	-0.34	-0.63	-0.74	-3.67	-4.98
Pi4287	-1.15	-0.79	-1.02	-17.96	-10.07
SR52-F	-0.27	0.24	-0.24	5.16	-0.50
SR52-M	-0.33	0.11	-0.31	6.19	-0.41
Tuxpeno	-0.59	-0.14	-0.47	-0.93	4.52
Tx602	-0.31	0.01	0.93	2.59	1.38
77-4407	-0.26	-0.67	0.55	-15.20	-5.98
77-4412	-0.57	-0.67	0.74	-17.86	-8.60
77-4441	-0.52	-0.48	-0.71	-15.03	-7.31
77-4449	-0.01	-0.19	-0.40	-10.03	-5.65
77-4544	0.12	-0.04	-0.64	10.92	-0.36

grain yields. Also, SR52-F and SR52-M had negative GCA effects for grain yield, while positive effects for stover yields. These results suggested that those inbreds would be better for stover yield production than for grain yield.

GCA effects of 7 male testers over 31 inbreds as female showed that Hi34 had the highest positive GCA effects for grain and stover yields (Table 38). Hi26 and Hi28 also had positive effects for those yields. Hi31 and Hi33 had negative GCA effects for both yields, while Hi29 and Tx601 were negative for grain yield and positive for stover yield. Therefore, it might be suggested that Hi34 was the best inbred for silage production and Hi26 and Hi28 also might be used for silage corn. However, Hi31 and Hi33 were poor combiners for silage production.

4.4.2. Plant Characters

Days to tasseling of 225 hybrids over 3 plantings ranged from 53 to 62 days with CIMMYT-T11ES x Hi34 and CIMMYT-T11ES x Tx601 tasseling at 62 days, while INV443 x Hi33 tasseled at 53 days for days to tasseling. The average days to tasseling of 31 female over 7 male testers ranged from 54 to 59 days. CIMMYT-T11ES and H632A which had higher GCA effects for grain and stover yields also took longer to tasseling (59 days). In general, GCA effects of 31 inbreds as female for days to tasseling revealed that inbreds which had positive GCA effects for grain and stover yields showed positive GCA effects for days to tasseling except a few cases (Table 37). This result suggested that late-maturing hybrids generally had higher silage

Table 38. Estimates of GCA effects of 7 male inbreds for yields, plant characters, and yield components.

Characters	Male parent						
	Hi26	Hi28	Hi29	Hi31	Hi33	Hi34	Tx601
Grain yield	0.38	0.33	-0.08	-1.06	-0.17	0.67	-0.07
Stover yield	0.08	0.09	0.23	-0.75	-0.60	0.69	0.25
Plant height	-0.06	-1.43	5.65	-4.91	-9.60	2.43	7.92
Ear height	-0.17	4.35	4.32	-7.96	-8.93	6.11	2.28
Days to tasseling	-0.19	-0.71	-0.36	-0.58	-2.20	2.02	2.02
Filled ear length	0.36	-0.31	-0.02	-1.10	0.74	0.54	-0.22
Number of kernel rows	0.24	0.67	0.26	0.27	-0.56	-1.31	0.44
Number kernels/ row	1.09	-0.35	-0.66	-4.98	2.51	1.91	1.50
100 kernel weight	0.38	-0.01	0.59	-0.80	-0.32	1.68	-1.51
LAI	0.20	-0.08	-0.17	-0.20	-0.16	0.65	-0.25
Number of stem node	-0.21	-0.28	0.33	-0.14	-0.88	-0.21	1.39
Stem diameter	0.75	-0.12	0.12	-0.08	-0.95	0.10	0.18

yields. GCA effects of 7 male testers for days to tasseling showed positive effects in Hi34 and Tx601 inbreds, indicating lateness in maturity, while other 5 inbreds had negative effects.

Plant heights of 225 hybrids ranged from 210 to 282 cm with H632F x Hi29 having the tallest and 77-4441 x Hi31 having the shortest plants. The highest positive GCA effect among 31 inbreds as female for plant height was observed on H632F, while Pi4287 had the highest negative effects. Generally, high GCA effects for plant height were observed on the inbreds which had high GCA effects for stover yield. CIMMYT inbreds, H632 inbreds, and ICA inbreds had positive GCA effects, indicating that these inbreds had taller plant heights, while Florida inbreds, Pi inbreds, and UH77-inbreds had negative GCA effects, showing short plant height. Among the 7 male testers, Tx601 was the tallest, and Hi29 and Hi34 also was 3 to 6 cm taller than the overall overall average, while Hi33 was the shortest in plant height.

GCA effects of ear height indicated similar results to those of plant height, with a few exceptions. CIMMYT inbreds and H632 inbreds had positive GCA effects, and Pi inbreds and UH 77-inbreds had negative effects. Hi34 had higher ear height and Hi31 was low in ear height.

LAI, number of stem nodes, and stem diameter were measured only in the March planting. LAI was highest in H632F x Hi34 (5.53), while Tuxpeno x Hi33 had the lowest value (3.22). It was found that H632 inbreds had positive GCA effects, while Pi inbreds and UH77-inbreds had lower or negative GCA effects (Table 39). Among the 7 male testers, Hi34 had the highest LAI value (4.86) and Tx601 the lowest (3.96).

Table 39. Estimates of GCA effects for LAI, number of stem node and stem diameter of 31 female inbreds.

Female parent	LAI	Number of stem nodes	Stem diameter
CIMMYT-A21	-0.09	0.62	0.04
CIMMYT-T11ES	0.27	0.93	0.40
Fla.2AT-112	-0.06	-0.21	-0.68
Fla.2AT-114	0.04	-0.06	0.18
Fla.2BT-54	-0.29	-0.16	-0.53
H632A	0.44	0.41	1.47
H632F	0.29	0.39	1.33
H632G	0.23	-0.09	0.90
ICA L25	0.36	0.42	0.97
ICA L27	0.13	0.29	-0.60
ICA L210	0.13	0.04	-0.82
ICA L221	0.34	0.00	0.40
ICA L223	0.29	0.37	0.83
INV138	-0.12	-0.31	-0.25
INV302	0.02	0.09	-0.03
INV443	0.01	-0.90	-0.68
INV534	-0.28	-0.48	-1.46
MIT 11 DMR	-0.25	-0.26	-1.75
Pi4243	-0.35	-0.37	-0.39
Pi4257	-0.30	-0.33	-0.18
Pi4283	0.07	-0.28	0.90
Pi4287	-0.17	0.00	0.33
SR52-F	0.31	-0.42	0.54
SR52-M	0.47	-0.54	0.18
Tuxpeno	-0.64	0.39	0.75
Tx602	-0.20	0.80	-0.46
77-4407	0.00	-0.21	-0.75
77-4412	-0.02	-0.27	-0.89
77-4441	-0.18	0.09	-0.03
77-4449	-0.21	-0.11	0.18
77-4544	-0.22	0.15	0.11

Hi26 also had a relatively high LAI value.

The range of number of stem nodes was from 12.4 (Pi4283 x Hi33 and SR52-F x Hi33) to 16.6 (CIMMYT-T11ES x Tx601). CIMMYT-A21 and CIMMYT-T11ES which were high in TDM yield had 14.5-14.9, and Pi inbreds which showed low yield had 13.6-13.9 of stem nodes. Tx601 had the highest and Hi33 had the lowest number of stem nodes among the 7 male inbreds. The number of stem nodes of the 8 check hybrids ranged from 13.1 to 13.8, showing relatively small variation among the hybrids.

Stem diameter was measured at the first stem from the ground. Stem diameter of 225 hybrids ranged from 20.0 (INV534 x Hi33) to 27.0 mm (H632A x Tx601, H632F x Hi26, H632F x Hi29, and H632G x Hi28). The average stem diameter of 31 female inbreds over 7 male testers indicated that H632A and H632F which were superior inbreds for stover yields had the largest stem diameter (24.6-24.8 mm). MIT 11 DMR had the smallest stem diameter (21.6 mm). GCA effects for stem diameter of 7 male testers showed that Hi26, Hi29, Hi34, and Tx601 had positive effects, indicating that these inbreds had big stem diameters, while Hi28, Hi31, and Hi33 had negative GCA effects.

Relative maturity of 225 hybrids was evaluated in the March planting on the basis of grading from 1 to 5. Grade 1 was very early and 5 was very late in maturity. Maturity grading of 225 hybrids varied from 1.0 to 5.0. The difference between 1.0 (very early) to 5.0 (very late) was about 10-15 days. INV138 x Hi31 and Pi4243 x Hi31 were classified as very early maturing hybrids, while CIMMYT-T11ES x Hi26, Fla.2BT-54 x Tx601, and H632A x Hi26, Hi28, Hi29, Hi31, Hi34, Tx601, were very late in maturity. Among the 31 inbreds over 7 male testers, H632 was the latest (4.7) and MIT 11 was the earliest (2.1) in maturity. CIMMYT-T11ES, ICA L27, ICA L221, SR52-F and SR52-M, were late, while Fla.2AT-112, INV302, Pi inbreds belonged to early-maturity inbreds. Hi34 was the latest (4.0) in maturity among 7 male testers over 31 inbreds as female, while Hi34 was the earliest. Hi26 and Tx601 were a little late, and Hi28 and Hi29 were medium in maturity. Among the check hybrids, the superior H823 was a little later than H763 and X304C in maturity.

Rust ratings were evaluated over 3 seasons. The rating scale was from 1 to 7 with a rating of 1 being highly resistant and 7 being highly susceptible. The overall average rust rating was recorded as 3.5. The ratings ranged from 1.8 (CIMMYT-A21 x Tx601, and CIMMYT-T11ES x Tx601) to 6.0 (Fla.2AT-112 x Hi31 and Pi4243 x Hi31). Among the 31 inbreds, CIMMYT-A21 and CIMMYT- T11ES which had high yield showed the lowest rust rating (2.3-2.6). Other superior inbreds, including H632A, H632F, ICA L221, and ICA L223, were slightly resistant to rust. However, Fla.2AT-112, all of the Pi inbreds, and some of UH 77-inbreds were relatively susceptible to rust. It was found that Hi34 and Tx601 were resistant to rust (2.8-2.9), and Hi31 and Hi33 were susceptible (4.0-4.7). Hi26, Hi28, and Hi29 showed medium resistance to rust. Within the check hybrids, X105A was highly resistant and H767 was highly susceptible to rust. H823, the superior hybrid, was resistant to rust.

4.4.3. Yield Components

Yield components, including filled ear length, number of kernel rows, number of kernels/row, and 100 kernel weight, were observed over 2 seasons (March and May plantings). In November plantings, no grain yields were observed in several hybrids, therefore, yield components data was not taken. Filled ear length varied widely among hybrids. ICA L221 x Hi34 had the longest filled ear length (19.4 cm), while 77-4441 x Hi31 had the shortest length (11.6 cm). GCA effects of yield components (Table 40) showed that CIMMYT, H632, ICA, and SR52 inbreds had long ear lengths, while INV, Pi, and UH 77-inbreds had short ear lengths. These results suggested that inbreds which were high in grain yields generally had longer filled ear length. H823 which had the highest grain yield among the check hybrids showed the longer filled ear length, while H763 had medium ear lengths.

Number of kernel rows followed different patterns from those of filled ear lengths. In general, inbreds which had longer filled ear lengths had fewer kernel rows, with a few exceptions. The range was from 17.7 (CIMMYT-A21 x Hi28) to 10.7 (Fla.2BT-54 x Hi34). GCA effects showed that CIMMYT, INV, and Pi inbred had positive effects while Florida, H632, and SR52 inbred had negative values.

Number of kernels/row varied widely among the 225 hybrids. The range of number of kernels/row was from 18.9 (77-4412 x Hi31) to 40.6 (ICA L210 x Hi33). The superior check hybrid, H823, had 39.2 kernels/row. Estimates of GCA effect (Table 40) showed that the number of kernels/row were not consistent within the same source of inbreds; i.e. CIMMYT-T11ES had more kernels than CIMMYT-A21, and H632F and H632G had more than H632A. These results were also found in ICA,

Table 40. Estimates of GCA effects for yield components of 31 female inbreds evaluated over 2 seasons.

Female parent	Filled ear length	Number of kernel rows	Number of kernels/row	100 kernel weight
CIMMYT-A21	0.24	1.27	-0.92	-0.13
CIMMYT-T11ES	0.65	0.53	2.47	-0.82
Fla.2AT-112	-0.23	-0.09	0.00	-1.42
Fla.2AT-114	0.81	-0.99	1.80	0.79
Fla.2BT-114	0.69	-0.75	2.27	-0.21
H632A	1.06	-1.20	-0.41	4.96
H632F	1.64	-0.54	0.62	2.19
H632G	1.06	-0.68	0.98	1.21
ICA L25	0.37	0.13	-0.05	1.38
ICA L27	0.02	0.51	-2.15	2.47
ICA L210	0.36	-0.28	0.97	0.28
ICA L221	1.52	-0.27	1.15	2.29
ICA L223	0.88	0.41	-1.33	4.07
INV138	-0.08	0.71	-1.20	-0.21
INV302	-0.62	0.77	0.62	-3.00
INV443	-2.05	0.47	-3.28	1.48
INV534	0.46	-0.32	2.18	-0.91
MIT11 DMR	0.27	0.04	0.27	-1.40
Pi4243	-0.20	0.38	2.08	-5.01
Pi4257	-1.75	1.35	-1.39	-2.80
Pi4283	-0.62	0.86	-1.99	-0.32
Pi4287	-1.91	-0.20	-5.16	-1.12
SR52-F	0.75	-0.93	1.15	2.97
SR52-M	0.82	-1.56	1.46	3.49
Tuxpeno	-0.58	-1.00	0.55	-0.80
Tx602	0.35	0.22	0.96	-1.71
77-4407	-0.54	-0.24	1.17	-2.02
77-4412	-1.25	0.12	-2.11	-1.83
77-4441	-1.42	0.62	-0.87	-2.32
77-4449	-1.20	-0.94	-0.96	-2.51
77-4544	0.49	-0.30	1.16	0.97

INV, Pi, and UH 77-inbreds.

The range of 100 kernel weight was from 18.7 g (Pi4243 x Hi31) to 37.5 g (77-4544 x Hi34). GCA effects indicated that H632, ICA, and SR52 inbreds had larger kernel weight, however, CIMMYT inbreds which were good combiners for grain yield showed smaller kernel weight. H632A and ICA L223 which were higher in grain yield had larger kernel weight. All of the Pi inbred and UH 77-inbreds except 77-4544 had negative GCA effects, indicating that these inbreds had smaller kernel weight.

In the November planting, severe barrenness was observed in all hybrids. The barrenness was due to concentrated heavy rainfall and strong wind resulting in almost 100 % lodging in all hybrids. This lodging occured twice during the vegetative stage (4-5 weeks after planting). Stalk breakage was observed in many hybrids due to the second lodging. Barrenness ranged from 15 to 100 %. Among the 225 hybrids, INV534 x Hi34 were the most tolerant to barrenness (15 %), while several hybrids, such as Fla.2AT-112 x Hi31 and Pi4243 x Hi31 showed 100 % barrenness, indicating highly susceptibility to barrenness. Average performance of 31 inbreds over 7 male tester inbreds showed that CIMMYT-A21, ICA L210, and INV534 were tolerant (less than 40 %), while H632G and Pi4287 were highly susceptible to barrenness (more than 80 %). H823, the superior check hybrid had 28 %, while H763 had 61 % barrenness. Among the 7 male testers, Hi34 was tolerant (41 %), and Hi31 was susceptible (78 %) to barrenness under stressed conditions. Hi26, Hi28, and Hi29 were average or slightly resistant while Hi33 and Tx601 were susceptible to barrenness. The resistance to barrenness might be an important factor to be considered for corn production under stressed unfavorable environments.

Estimates of GCA effects of 7 male testers for yield components showed that Hi26, Hi33, and Hi34 had positive GCA effects for filled ear length, number of kernels/row, and 100 kernel weight, while Hi28 and Hi31 had negative values for those components (Table 38). In general, inbreds which had positive GCA effects for filled ear length and number of kernels/row show negative GCA effects for number of kernel rows.

Analysis of variance revealed that blocks within replication were highly significant for grain and stover yields except in one case (Tables 41, 42). Plant and ear height also were significant for blocks within replications in all plantings (Tables 43, 44). Those results indicate that the lattice design was more efficient than a randomized complete block design for those characters. The block effects with replications were not significant for yield components except in a few cases, suggesting that blocking within replications was not as effecient as a randomized complete block design. Average efficiencies of the lattice design for yield over 3 plantings were 9 % (grain) and 16 % (stover) higher than with a randomized complete block design. Efficiency for plant and ear height was increased 28-29 % by blocking within replications compared to the randomized complete block design. For yield components, efficiency was not increased (1-3 %) except 100 kernel weight (10 %).

Heritability estimates of female and male inbreds for yield and

Table 41. Analysis of variance for grain yield of 225 hybrids in different seasons.

Source	df	Mean squares		
		March	May	November
Replication	1	8.00	1.57	0.28
Hybrid (Unadj.)	224	2.88	2.95	0.95
Block within rep. (Adj.)	28	0.88**	1.66**	0.09
Intra-block error	196	0.26	0.80	0.07
Randomized complete block error	224	0.34	0.91	0.08

** Significant at 1 % probability level.

Table 42. Analysis of variance for stover yield of 225 hybrids in different seasons.

Source	df	Mean squares		
		March	May	November
Replication	1	1.00	11.40	4.68
Hybrid (Unadj.)	224	2.66	3.99	1.34
Block within rep (Adj.)	28	1.86**	2.71**	0.63**
Intra-block error	196	0.43	1.38	0.24
Randomized complete block error	224	0.61	1.54	0.29

** Significant at 1 % probability level.

Table 43. Analysis of variance for plant height of 225 hybrids in different seasons.

Source	df	Mean squares		
		March	May	November
Replication	1	20085.12	162.61	1493.00
Hybrid (Unadj.)	224	668.06	852.25	141.25
Block within rep (Adj.)	28	456.32**	606.16**	61.62*
Intra-block error	196	61.31	181.22	37.18
Randomized complete block error	224	110.68	234.33	40.24

* Significant at 5 % level.
** Significant at 1 % level.

Table 44. Analysis of variance for ear height of 225 hybrids in different seasons.

Source	df	Mean squares		
		March	May	November
Replication	1	2726.46	2132.08	22.30
Hybrid (Unadj.)	224	346.13	600.50	54.22
Block within rep (Adj.)	28	179.18**	459.75**	70.81**
Intra-block error	196	33.71	133.43	17.46
Randomized complete block error	224	51.90	174.22	24.13

* Significant at 5 % level.
** Significant at 1 % level.

other characters are presented in Table 45. Heritability estimates of days to tasseling and plant height were higher than other characters. Among the yield components, number of kernel rows was higher than other components for heritability. Male testers were a little higher than parents as female for heritability of grain and stover yields. For other plant characters and yield components parents as female showed higher heritability estimates than male testers.

In summary, about 5 % of 217 factorial combinations were superior to the best check hybrid for silage production of corn. Among the 31 tropical inbreds used in this experiment, CIMMYT, H632, and ICA inbreds had good combining ability for silage yield. These inbreds also were good combiners for grain yields. Brewbaker (1974) reported that most tropical races were tall and late in maturity, silking at 65 to 75 days, while Corn Belt genotypes were too early in maturity in tropical conditions for maximum yield. In this study, most of the high yielding inbreds were late in flowering and maturity. The late maturing hybrids were 10-15 days longer in maturity than early maturing hybrids. In Hawaii, year-round planting of corn is possible. If duration of the growing period is considered, early maturing hybrids will have an advantage due to short growing periods. However, much yield reduction of early maturing hybrids was observed and most of the superior hybrids for silage were late in maturity. Therefore, late maturing hybrids had higher silage yields per year even if they had longer growing periods.

Most of the high yielding hybrids showed superior plant

Table 45. Heritability estimates of female and male inbreds for yields, plant characters and yield components.

(unit: %)

Characters	Female parent	Male parent	Mean
Grain yield	45	52	49
Stover yield	31	35	33
Days to tasseling	47	82	65
Plant height	69	28	65
Ear height	57	40	49
Filled ear length	54	23	39
Number of kernel rows	55	53	54
Number of kernels/row	29	61	45
100 kernel weight	79	15	47

characters, such as tall plant height, large number of stem nodes, and larger stem diameter. They also were highly resistant to rust in all seasons studied. No lodging was observed in March and May plantings, but those high yielding tall hybrids showed a tendency for lodging. Therefore, lodging would be expected if high population density would be used for maximum silage yield. Severe barrenness was observed in winter planting resulted from nearly 100 % lodging in all hybrids. This winter lodging was due to unfavorable weather conditions such as strong wind and heavy rainfall. The severe lodging and barrenness problems were observed in a previous bimonthly population density experiment. From a practical standpoint, winter planting is very unstable for corn production, although inbreds which were tolerant to barrenness had higher grain yields in winter planting. CIMMYT-A21, ICA L210, and INV534 which showed high yield in spring and summer were generally tolerant to barrenness.

Among the 7 tester inbreds, Hi34, which is late in maturity, was the best combiner, while Hi31 and Hi33 which are early maturing inbred were poor combiners for silage production. A lattice design was used in this experiment to increase statistical efficiency by blocking the replication. The average efficiency was increased more for plant characters than for grain and stover yields.

4.5 Silage Yield Trial of 7-Entry Diallel

4.5.1. Yields and Yield Components

A 7-entry diallel, utilizing parent inbreds from the 31 x 7 factorial, was evaluated for silage yields and their components over 3 different seasons. Average TDM, grain and stover yields over 3 plantings are presented in Table 46. The highest TDM yield was observed in Hi34 x Tx601 (12.78 T/ha). Hi26 x Hi34 and Hi29 x Hi34 also had high TDM yields, but Hi31 x Hi33 showed the lowest TDM yield (7.70 T/ha). The highest grain yield was observed in Hi26 x Hi34, while the highest stover yield was observed in Hi34 x Tx601 which had the highest TDM yield. The grain/stover ratio ranged from 0.78 (Hi29 x Tx601), indicating poor quality, to 1.23 (Hi26 x Hi28), indicating high quality for silage. Hi34 x Tx601 had the highest TDM yield but had a little lower than average ratio.

Yield components, including filled ear length, number of kernel rows, number of kernels/row, and 100 kernel weight were measured with 6-7 ears after harvesting. In general, hybrids which were high in grain yield had longer filled ear length, more number of kernel rows, and number of kernels/row (Table 47). There were significant correlations between grain yield and yield components (Table 48). Grain yield was also correlated with days to tasseling. Stover yield was highly significantly correlated with all plant characters, such as days to tasseling, plant and ear height.

The theoretical grain yield was calculated using average yield components, such as number of kernel rows, number of kernels/row,

Table 46. Average total dry matter, grain and stover yields, and grain/stover ratio of a 7-entry diallel.

Hybrids	U.H. Number	Total dry matter	Grain yield	Stover yield	G/S ratio
		T/ha			
Hi26 x Hi28	H648	10.98	6.05	4.93	1.23
Hi26 x Hi29	H634	9.41	4.90	4.51	1.09
Hi26 x Hi31	H764	8.48	4.26	4.22	1.01
Hi26 x Hi33	--	9.22	4.75	4.47	1.06
Hi26 x Hi34	H620	12.49	6.70	5.79	1.16
Hi26 x Tx601	H863	10.42	5.40	5.02	1.08
Hi28 x Hi29	H825	10.61	5.30	5.31	1.00
Hi28 x Hi31	H766	10.52	5.61	4.91	1.14
Hi28 x Hi33	H650	8.43	4.44	3.99	1.11
Hi28 x Hi34	H823	11.02	5.67	5.35	1.06
Hi28 x Tx601	H861	10.48	4.94	5.54	0.86
Hi29 x Hi31	H767	9.22	4.78	4.44	1.08
Hi29 x Hi33	H636	8.96	4.76	4.20	1.13
Hi29 x Hi34	H824	12.26	6.10	6.16	0.99
Hi29 x Tx601	H862	10.40	4.57	5.83	0.78
Hi31 x Hi33	H905	7.70	3.99	3.71	1.08
Hi31 x Hi34	H763	9.26	4.71	4.55	1.04
Hi31 x Tx601	H865	9.26	4.82	4.44	1.09
Hi33 x Hi34	H622	9.60	5.15	4.45	1.16
Hi33 x Tx601	H896	9.66	4.65	5.01	0.93
Hi34 x Tx601	H860	12.78	5.97	6.81	0.88
Mean		10.06	5.12	4.94	1.04

Table 47. Average yield components over 3 seasons and barrenness in November planting of 7-entry diallel.

Hybrids	Filled ear length	Number of kernel rows	Number of kernels per row	100 kernel weight	Barren -ness
	(cm)			(g)	(%)
Hi26 x Hi28	12.8	14.1	26.9	27.1	18
Hi26 x Hi29	12.7	12.0	26.4	24.0	24
Hi26 x Hi31	11.7	11.2	21.8	27.9	56
Hi26 x Hi33	13.3	10.7	29.1	25.1	57
Hi26 x Hi34	13.4	12.7	30.4	25.9	15
Hi26 x Tx601	12.9	13.0	27.4	24.5	38
Hi28 x Hi29	13.0	13.9	27.0	25.3	31
Hi28 x Hi31	12.9	13.0	26.2	28.6	45
Hi28 x Hi33	13.3	11.9	27.0	25.3	46
Hi28 x Hi34	13.2	12.7	29.7	25.4	15
Hi28 x Tx601	13.2	13.8	28.8	24.5	39
Hi29 x Hi31	11.4	11.4	21.5	27.1	58
Hi29 x Hi33	12.6	12.5	26.6	23.4	55
Hi29 x Hi34	13.3	12.7	28.3	26.5	15
Hi29 x Tx601	13.0	12.5	26.7	23.7	31
Hi31 x Hi33	11.7	11.1	24.6	23.5	91
Hi31 x Hi34	10.4	11.5	23.0	26.7	31
Hi31 x Tx601	12.1	11.2	23.0	25.2	67
Hi33 x Hi34	12.5	11.7	27.0	25.6	38
Hi33 x Tx601	13.4	12.0	29.0	22.5	42
Hi34 x Tx601	14.1	12.0	30.9	28.6	30
Mean	12.7	12.3	26.7	25.5	40

Table 48. Correlation coefficients among yields, yield components and plant characters of a 7-entry diallel over 3 different seasons.

Characters	Stover yield	Days to tassel	Plant height	Ear height	Filled ear length	No. of kernel rows	No. of kernels per row	100 kernel weight	Rust
Grain yield	0.69**	0.45*	0.22	0.56**	0.53*	0.57**	0.59**	0.44*	-0.86**
Stover yield		0.78**	0.59**	0.82**	0.62**	0.49*	0.64**	0.26	-0.77**
Days to tasseling			0.73**	0.68**	0.26	0.18	0.31	0.15	-0.55*
Plant height				0.70**	0.29	0.34	0.20	-0.05	-0.36
Ear height					0.44*	0.67**	0.41	0.19	-0.70**
Filled ear length						0.43	0.89**	-0.09	-0.69**
Number of kernel rows							0.41	0.05	-0.67**
Number of kernels per row								-0.16	-0.74**
100 kernel weight									-0.19

* Significant at 5 % probability level.

** Significant at 1 % probability level.

and 100 kernel weight. In this experiment, the population density used was 60,000 plants/ha, therefore, theoretical grain yield could be calculated as follows; 60 x 12.3 x 26.7 x 25.5 / 100,000 = 5.03 T/ha. This theoretical grain yield was 98 % of actual average grain yield of 21 hybrids. This result suggested that yield components could be used as a criteria for grain yields prediction.

Barrenness in winter plantings ranged from 15 to 91 %. Hi26 x Hi34, Hi28 x Hi34, and Hi29 x Hi34 showed relatively high grain yields and were tolerant to barrenness (15 %), while high barrenness (60-90 %) was generally observed in poor yielding hybrids.

Days to tasseling ranged from 54 days (Hi28 x Hi33) to 60 days (Hi34 x Tx601), with average 57 days. Hi31 x Hi33, the poorest hybrid for TDM yield, was 55 days for days to tasseling. This indicated that the late maturing hybrids had high yields. Plant heights ranged from 209 cm (Hi33 x Hi34) to 251 cm (Hi29 x Tx601).

LAI was measured only in May planting. The range of LAI was from 3.54 (Hi29 x Hi33) to 4.48 (Hi34 x Tx601). Highly significant correlations were observed between LAI and grain and stover yields (Figure 38). Correlation coefficients for stover yield (r=0.72**) was higher than grain yield (r=0.56**).

Rust ratings were recorded for 3 seasons on a 1-7 scale. The average rust rating in November, February, and May plantings were 5.2, 2.7, and 2.9, respectively. This indicated that rust was more severe in winter season than spring and summer. The overall average rating showed that Hi26 x Hi28, Hi26 x Hi34, and Hi34 x Tx601 were resistant, while Hi29 x Hi31 and Hi31 x Hi33 were susceptible to rust.

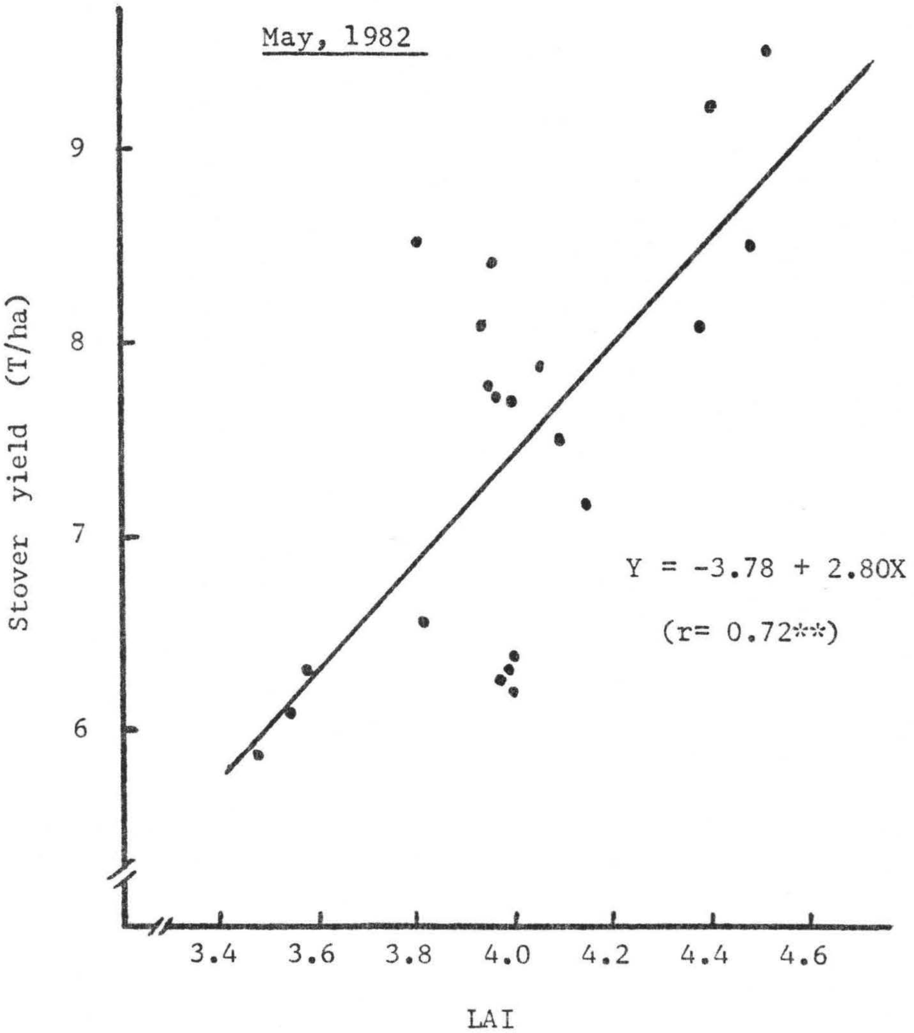


Figure 38. Relationship between LAI and stover yield

Significant negative correlations between rust and grain and stover yields were observed (Table 48). Also, rust rating was negatively correlated to all yield components except 100 kernel weight. These results suggested that rust might be one of the factors reducing corn yields in this trial and in the 225-entry silage trials.

Maturity was recorded on a scale from 1 to 5 in May planting, with 1 being very early and 5 being very late in maturity. Highly significant correlations were observed between maturity and grain and stover yield (Figure 39, 40). These relationships suggested that late maturing hybrids had high grain and stover yields.

Combined analysis of variance of yields, plant characters, and yield components were presented in Tables 49 and 50. Hybrids were significantly different for all characters studied. Also, hybrid x season interactions of all characters were highly significant. This indicated that hybrids were different in response of yields, plant characters, and yield components under different seasons.

4.5.2. Diallel Analysis

Estimates of SCA and GCA effects for grain and stover yields are presented in Table 51. GCA effects of 7 inbreds indicated that Hi34 was the best combiner for both grain and stover yields, while Hi31 and Hi33 were poor combiners for those yields. GCA effects for yield components indicated that Hi26 and Hi28 had positive effects for all of the yield components, and Hi34 which was the best combiner for yields had the largest effects for number of kernels/row and 100

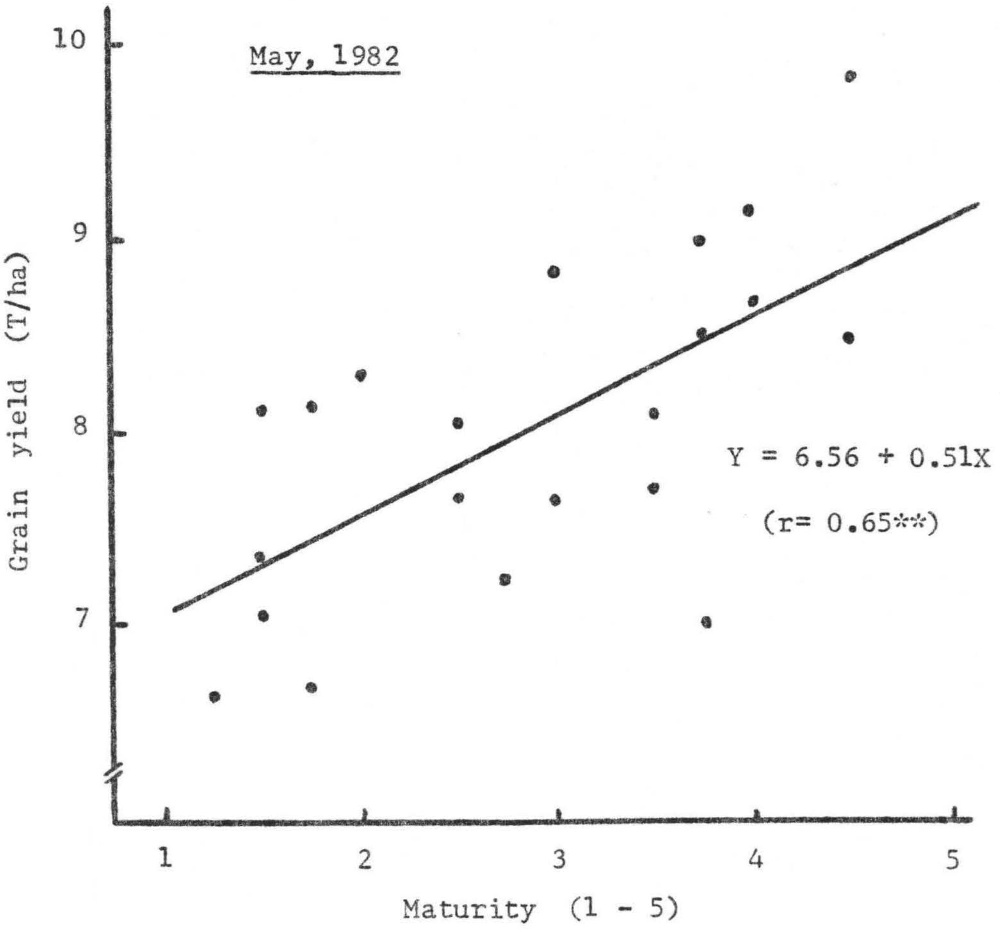


Figure 39. Relationship between maturity and grain yield

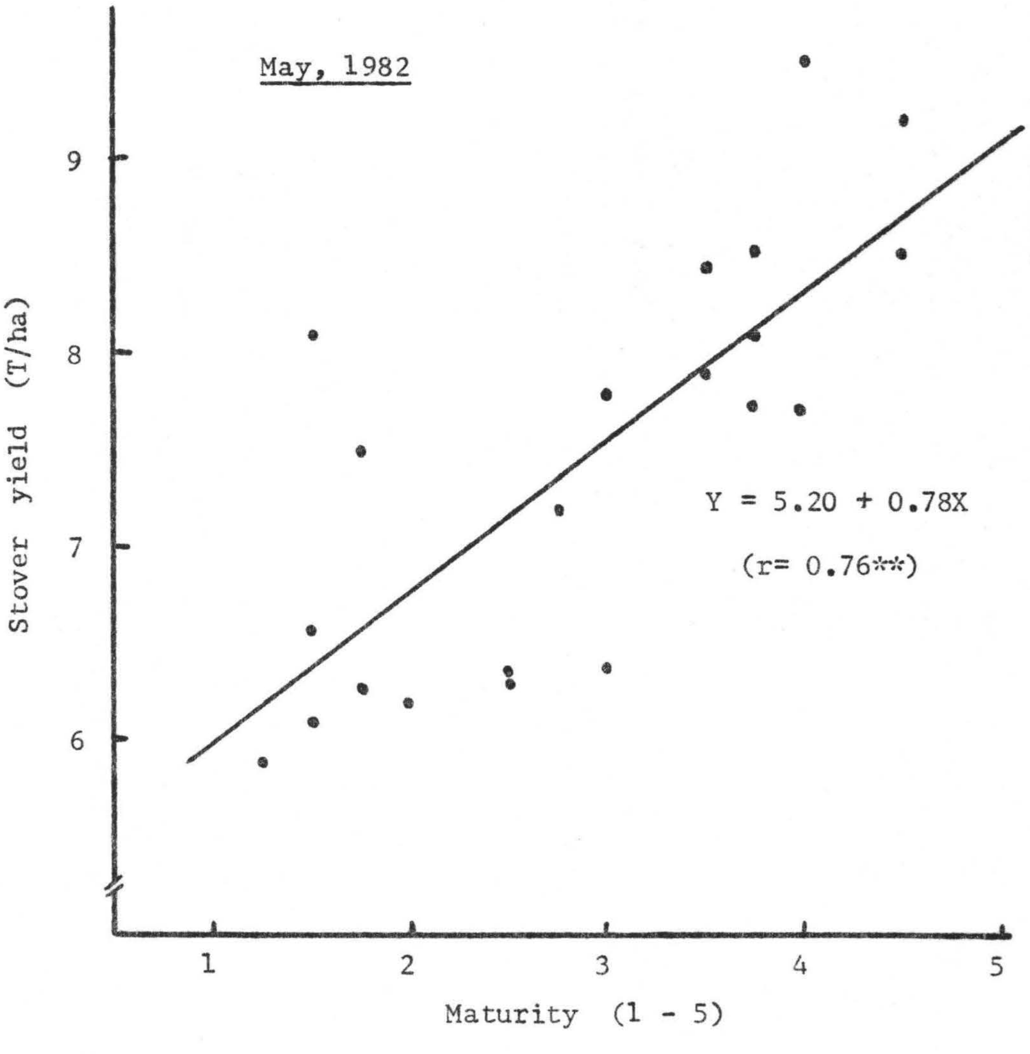


Figure 40. Relationship between maturity and stover yield

Table 49. Combined analysis of variance of yields and plant characters for a 7-entry diallel evaluated in 3 different seasons.

Source	df	Mean squares				
		Grain yield	Stover yield	Plant height	Ear height	Days to tasseling
Season (S)	2	1067.17	454.40	526356.50	173929.50	4086.06
Reps in S	9	1.26	0.59	518.44	243.56	2.52
Hybrid (H)	20	5.52**	7.20**	1272.50**	741.80**	28.07**
H x S	40	0.68**	1.10**	271.93**	148.03**	1.42**
Error	180	0.28	0.32	90.88	31.99	0.61

Table 50. Combined analysis of variance for yield components of a 7-entry diallel evaluated in 3 different seasons.

Source df	df	Mean squares			
		Filled ear length	Number of kernel rows	Number of kernels per row	100 kernel weight
Season (S)	2	702.34	246.30	5282.94	1939.47
Reps in S	3	1.93	0.15	5.23	1.25
Hybrid (H)	20	4.28**	5.46**	42.83**	17.39**
H x S	40	1.59**	4.46**	9.34**	4.22**
Error	60	0.66	0.48	4.18	1.87

* Significant at 5 % probability level.
** Significant at 1 % probability level.

Table 51. Estimates of SCA and GCA effects for grain and stover yield of a 7-entry diallel evaluated during 3 different seasons.

Inbreds	SCA effects						GCA effects
	Hi28	Hi29	Hi31	Hi33	Hi34	Tx601	
Hi26	0.38 0.04	-0.41 -0.47	-0.60 0.09	-0.07 0.42	0.61 0.29	0.10 -0.37	0.26 -0.13
Hi28		-0.04 0.13	0.72 0.56	-0.21 -0.27	-0.45 -0.37	-0.39 -0.09	0.29 0.08
Hi29			0.24 0.01	0.27 -0.14	0.34 0.36	-0.40 0.11	-0.08 0.17
Hi31				-0.05 0.20	-0.60 -0.42	0.30 -0.44	-0.52 -0.67
Hi33					-0.12 -0.43	0.18 0.22	-0.57 -0.76
Hi34						0.22 0.57	0.71 0.70
Tx601							-0.09 0.61

Upper and lower values are grain yield and stover yield, respectively.

kernel weight. GCA effects for plant and ear height showed that Tx601 had positive effects, indicating taller plant, and Hi33 had negative effects.

Combined analysis of combining ability showed that GCA and SCA effects were highly significant for grain and stover yields (Table 52). Also, GCA x season, and SCA x season interactions were significant. Ratio of GCA/SCA mean squares for grain and stover yield were 5 and 10, respectively. This indicated GCA effects were more important for stover yield than grain yield.

Plant height, ear height, and days to tasseling were highly significant for GCA and SCA effects, and GCA x season, SCA x season interactions were significant (Table 53). GCA/SCA ratios for plant height, ear height, days to tasseling were 13, 21, and 37, respectively, suggesting that GCA effects for plant characters were larger than for grain and stover yields. -

Heritability estimates of yields and other characters over 3 seasons were presented in Table 54. Heritability estimates of grain and stover yields were as large as those of other characters. Narrow and broad sense heritability estimates for days to tasseling were a little higher than other characters. High narrow sense heritability estimates for all characters studied indicated that additive gene effects were high and important for those characters.

In summary, the highest silage yield of corn was observed in late maturing hybrid, while the early maturing hybrids were very low for silage yield. These results could be explained by the significant correlation between yields and days to tasseling and

Table 52. Combined analysis of combining ability for grain and stover yields evaluated in 3 different seasons for a 7-entry diallel.

Source	df	Mean squares	
		Grain yield	Stover yield
GCA	6	3.14**	4.86**
SCA	14	0.63**	0.49**
Season (S)	2	266.79	113.60
GCA x S	12	0.26**	0.21**
SCA x S	28	0.13*	0.30**
Error	180	0.07	0.08

* Significant at 5 % probability level.
** Significant at 1 % probability level.

Table 53. Combined analysis of combining ability for plant height, ear height and days to tasseling evaluated in 3 different seasons for a 7-entry diallel.

Source	df	Mean squares		
		Plant height	Ear height	Days to tasseling
GCA	6	900.17**	556.83**	22.02**
SCA	14	68.64**	26.34**	0.59**
Season (S)	2	131589.50	43482.28	1021.53
GCA x S	12	123.08**	85.42**	0.47**
SCA x S	28	44.46*	16.27**	0.31*
Error	180	22.72	8.00	0.15

* Significant at 5 % probability level.

** Significant at 1 % probability level.

Table 54. Heritability estimates of yields, plant characters and yield components of 7-entry diallel over 3 different seasons. (unit: %)

Characters	Narrow	Broad
Grain yield	57	90
Stover yield	66	86
Plant height	66	86
Ear height	80	92
Days to tasseling	88	95
Filled ear length	55	76
Number of kernel rows	61	81
Number of kernels per row	66	83
100 kernels weight	42	81
Rust	77	93

relative maturity. Most of the plant characters studied were significantly correlated to stover yield.

Rust rating was negatively correlated to grain and stover yields. This indicates that rust disease is one of the factors reducing silage yields. Diallel analysis revealed that Hi34 which is late in maturity and of high rust resistance was the best combiner for grain and silage yields. Hi31 and Hi33, early maturing genotypes of high rust susceptibility, were poorer combiners for both grain and silage yields. These results were the same as the previous 31x7 factorial hybrid selection experiment.

Combining ability analysis indicated that GCA and SCA were both significant in contributing to the genetic variations of grain and stover yields of corn. The GCA/SCA ratio showed that additive genes were more important in the genetic variations. GCA x season and SCA x season interactions were significant for grain and stover yields.

CONCLUSION

Year-round planting of population density experiments may be used to recommend the best population density for maximum silage yield of corn in different seasons. Extremely higher population densities in unfavorable seasons reduced both the silage and grain yield.

As population density increased, days to tasseling was delayed and ear height increased, while plant height and stem diameter decreased significantly. The yield components, including filled ear length, number of kernel rows, number of kernels/row, and 100 kernel weight, were reduced significantly with increasing population. Leaf area per plant was reduced significantly, but LAI increased significantly as population increased. Kernel fusarium and barrenness in winter season increased significantly at higher populations.

Temperature was significantly correlated to days to tasseling, indicating that temperature was the more important determinant factor than solar radiation for flowering in corn. Among the climatic factors, solar radiation was the most important before tasseling, while minimum temperature was more important than solar radiation during the growing period. In either cases, maximum temperature was not an important factor for corn production in Hawaii.

Quality of corn silage may be improved with genetic modification. The _brown_ _midrib-3_ mutant corn has been proved to be inferior for grain and silage yields. However, a few genotypes showed small reduction of yields indicating possible use of _bm3_ as a high quality corn silage. The advantage of _bm3_ will be more prominent as the cost for transportation and storage of corn silage increase.

Plant height (-15 %), ear height (-7 %), filled ear length (-10 %), and number of kernels/row (-12 %) decreased in bm3. Other characters, including LAI, number of stem nodes, and stem diameter, were reduced less than 5 % in bm3. No difference was observed for days to tasseling between bm3 and normal corn.

Studies of photoperiod sensitivity for corn silage production could provide useful information for corn breeding programs in different latitudes. Reduction of grain yield under longer photoperiods might not be true photoperiod effects since yield components were not reduced under extended daylength. Photoperiod sensitive genotypes may be used in longer daylength temperate regions.

GCA and SCA mean squares for grain and stover yields were significant under normal and extended light, indicating that both additive and non-additive genes contributed to the genetic variation of grain and stover yields.

Selection of superior hybrid for silage production showed that late-maturing tropical inbreds had high performance for silage and grain yields under both favorable and unfavorable conditions.

Most of the high yielding hybrids for silage had superior plant characters, including taller plant height, larger number of stem nodes, LAI, stem diameter, high resistance to rust, and low barrenness in unfavorable seasons. In winter planting, nearly 100 % lodging was observed in all genotypes. The severe lodging was due to extremely unfavorable weather conditions, such as heavy rainfall and strong wind. Among the 7 Hawaiian tester inbreds, Hi34 -- a late-maturing inbred -- was the best combiner, while early maturing Hi31 (B68) and Hi33 (Mo17) were poor combiners for grain and silage yields.

The genotype x season interaction was primarily due to response of additive genes to the environment. Planting corn in unfavorable seasons should be carefully timed so as to avoid negative environmental effects on critical stages such as flowering and fertilization.

APPENDIX

Appendix 1. Grain yield of 2 hybrids under different population densities over 12 bimonthly plantings.

(unit : T/ha)

Hybrid	Month	Population density (1,000 plants/ha)						
		50	75	100	125	150	200	Mean
H763	Jan '80	9.12	9.17	9.24	9.72	10.52	10.38	9.69
	Mar '80	9.31	10.95	11.60	12.14	13.10	13.02	11.69
	May '80	8.65	9.92	10.09	11.78	10.26	9.32	10.00
	Jul '80	9.59	9.82	9.85	10.06	9.44	8.07	9.47
	Sep '80	3.54	3.01	2.66	2.55	2.07	1.90	2.62
	Nov '80	1.37	1.26	1.20	1.22	0.83	0.78	1.11
	Jan '81	5.39	5.48	5.76	5.77	6.16	5.50	5.68
	Mar '81	7.07	8.11	8.52	7.58	7.11	7.23	7.60
	May '81	8.91	10.35	10.36	10.06	9.58	8.92	9.70
	Jul '81	7.69	8.08	8.23	8.36	8.15	7.35	7.98
	Sep '81	1.39	1.38	2.02	1.68	1.16	0.98	1.43
	Nov '81	0.81	0.94	0.80	0.97	0.79	0.76	0.84
	Mean	6.07	6.54	6.69	6.82	6.60	6.18	
X304C	Jan '80	7.94	8.68	8.84	9.33	9.75	8.84	8.90
	Mar '80	10.01	11.15	12.96	14.11	15.09	14.20	12.92
	May '80	8.47	9.51	9.89	12.37	10.37	8.62	9.87
	Jul '80	9.26	10.07	10.10	11.22	11.06	9.39	10.18
	Sep '80	4.33	4.08	4.52	3.42	2.87	2.82	3.67
	Nov '80	2.31	2.62	2.37	2.43	2.34	2.09	2.36
	Jan '81	6.11	6.15	6.41	6.30	6.59	5.59	6.19
	Mar '81	7.50	8.44	8.27	10.91	12.49	11.82	9.91
	May '81	10.22	10.34	11.41	12.57	12.35	10.32	11.20
	Jul '81	8.61	9.85	11.34	11.68	11.26	10.20	10.48
	Sep '81	2.96	3.68	3.26	3.02	3.30	2.85	3.18
	Nov '81	1.94	2.41	2.78	2.82	3.00	2.78	2.62
	Mean	6.64	7.25	7.68	8.35	8.37	7.46	

Appendix 2. Stover yield of 2 hybrid under different population densities over 12 bimonthly plantings.

(unit : T/ha)

Hybrid	Month	Population density (1,000 plants/ha)						
		50	75	100	125	150	200	Mean
H763	Jan '80	6.30	6.93	7.02	7.76	8.44	9.01	7.58
	Mar '80	6.18	8.19	8.61	9.10	11.23	11.74	9.17
	May '80	6.93	8.33	8.63	10.53	9.54	9.38	8.89
	Jul '80	7.67	9.78	9.96	10.49	11.54	11.60	10.17
	Sep '80	4.28	5.43	6.06	5.78	7.85	8.19	6.26
	Nov '80	2.37	2.76	3.08	3.56	3.79	3.87	3.24
	Jan '81	5.70	5.47	6.57	7.07	8.03	8.71	6.93
	Mar '81	6.97	7.99	9.57	9.82	9.94	10.76	9.17
	May '81	6.86	7.75	8.95	9.44	9.88	10.73	8.93
	Jul '81	7.28	7.29	8.82	8.94	8.66	9.46	8.41
	Sep '81	3.99	5.78	5.99	5.31	5.41	5.38	5.31
	Nov '81	2.56	3.08	3.43	3.54	3.73	4.04	3.40
	Mean	5.59	6.57	7.22	7.61	8.17	8.57	
X304C	Jan '80	6.42	6.87	7.28	7.91	8.32	9.37	7.70
	Mar '80	7.08	7.89	9.14	10.28	11.91	10.92	9.54
	May '80	8.14	9.12	11.32	11.98	10.83	10.54	10.32
	Jul '80	9.29	9.96	11.45	12.36	12.92	13.71	11.62
	Sep '80	4.95	5.04	5.34	5.49	7.84	7.45	6.02
	Nov '80	2.60	2.98	3.51	4.00	3.88	4.40	3.56
	Jan '81	5.40	5.42	5.94	6.79	7.53	8.56	6.60
	Mar '81	7.84	9.29	10.22	8.59	8.76	8.15	8.81
	May '81	10.62	10.67	10.76	11.71	12.58	13.91	11.71
	Jul '81	7.05	7.66	10.60	10.71	9.92	11.24	9.53
	Sep '81	3.82	5.44	6.47	5.60	7.03	7.82	6.03
	Nov '81	3.83	4.18	4.97	5.64	6.26	6.43	5.22
	Mean	6.42	7.04	8.08	8.42	8.98	9.38	

Appendix 3. Regression equation of grain and stover yields with population densities.

Characters	Hybrid	Month	Equation	r^2
Grain yield	H763	Jan	$Y= 6.96 + 0.0062X$	0.66^{**}
		Mar	$Y= 8.43 + 0.0104X$	0.57
		May	$Y= 9.82 + 0.00026X$	0.01
		Jul	$Y= 9.42 - 0.0060X$	0.37
		Sep	$Y= 2.85 - 0.0071X$	0.87^{**}
		Nov	$Y= 1.26 -0.0024X$	0.74^{*}
	X304C	Jan	$Y= 7.27 + 0.0024X$	
		Mar	$Y= 7.57 + 0.033X$	0.80^{*}
		May	$Y= 10.07 + 0.0040X$	0.03
		Jul	$Y=9.58 + 0.0065X$	0.14
		Sep	$Y= 4.26 - 0.0071X$	0.75^{*}
		Nov	$Y= 2.29 + 0.0017X$	0.21
Stover yield	H763	Jan	$Y= 4.83 + 0.021X$	0.98^{**}
		Mar	$Y= 5.64 + 0.030X$	0.94^{**}
		May	$Y= 6.48 + 0.021X$	0.80^{*}
		Jul	$Y= 7.01 + 0.020X$	0.89^{**}
		Sep	$Y= 4.00 + 0.015X$	0.74^{*}
		Nov	$Y= 2.16 + 0.0099X$	0.92^{**}
	X304C	Jan	$Y= 4.65 + 0.021X$	0.99^{**}
		Mar	$Y= 7.56 + 0.014X$	0.55
		May	$Y= 8.73 + 0.020X$	0.86^{*}
		Jul	$Y= 7.21 + 0.029X$	0.85^{*}
		Sep	$Y= 3.45 + 0.022X$	0.87^{*}
		Nov	$Y= 2.58 + 0.016X$	0.94^{**}

* Significant at 5% level.

** Significant at 1% level.

Appendix 4. Days to tasseling of two hybrids under different population densities over 12 bimonthly plantings.

(unit : day)

Hybrid	Month	Population density (1,000 plants/ha)						
		50	75	100	125	150	200	Mean
H763	Jan '80	63.3	63.5	64.3	64.0	64.5	64.8	64.0
	Mar '80	58.8	59.5	59.3	60.0	59.5	60.3	59.5
	May '80	54.0	54.3	54.5	54.3	55.0	54.8	54.5
	Jul '80	43.8	44.3	44.8	45.0	46.0	45.8	44.9
	Sep '80	48.3	48.5	49.0	49.3	49.0	49.0	48.8
	Nov '80	60.0	60.3	61.0	60.8	61.3	62.0	60.9
	Jan '81	62.0	62.0	62.0	62.8	63.8	63.3	62.6
	Mar '81	56.8	57.0	58.5	58.5	58.8	59.8	58.2
	May '81	51.0	51.8	51.3	51.5	52.3	52.8	51.8
	Jul '81	45.8	46.3	46.8	46.5	47.3	47.3	46.6
	Sep '81	50.0	50.0	51.8	51.5	51.3	52.0	51.1
	Nov '81	62.0	62.3	62.5	62.3	63.0	63.0	62.5
	Mean	54.6	55.0	55.5	55.5	56.0	56.2	
X304C	Jan '80	63.0	63.3	63.8	63.8	64.3	64.8	63.8
	Mar '80	60.3	60.5	60.5	60.5	61.3	61.5	60.8
	May '80	54.3	54.5	54.8	54.8	54.8	55.3	54.7
	Jul '80	48.0	48.0	48.3	48.5	49.3	49.0	48.5
	Sep '80	50.8	50.8	50.8	51.0	51.0	51.0	50.9
	Nov '80	60.8	60.8	61.5	61.5	62.3	62.5	61.5
	Jan '81	61.0	61.3	61.0	61.5	61.5	62.0	61.4
	Mar '81	60.3	60.3	61.3	61.3	61.8	62.3	61.2
	May '81	55.5	55.3	56.0	55.5	56.3	56.5	55.8
	Jul '81	48.8	48.8	49.0	49.5	49.3	49.5	49.1
	Sep '81	52.5	52.8	52.8	53.5	53.5	53.5	53.1
	Nov '81	62.8	63.5	63.3	63.3	63.8	63.5	63.3
	Mean	56.5	56.6	56.9	57.0	57.4	57.6	

Appendix 5. Plant height of 2 hybrids under different population densities over 12 bimonthly plantings.

(unit : cm)

Hybrid	Month	Population density (1,000 plants/ha)						
		50	75	100	125	150	200	Mean
H763	Jan '80	213	212	213	210	210	206	210
	Mar '80	255	246	248	251	256	249	251
	May '80	275	275	272	274	268	275	273
	Jul '80	279	275	280	250	273	276	272
	Sep '80	271	265	259	252	255	247	258
	Nov '80	184	175	170	168	157	151	167
	Jan '81	236	236	235	233	230	229	233
	Mar '81	276	280	273	275	267	272	274
	May '81	280	280	287	294	297	265	284
	Jul '81	287	292	291	284	284	279	286
	Sep '81	263	267	259	256	258	255	260
	Nov '81	155	145	140	141	138	132	142
	Mean	248	246	244	241	241	236	
X304C	Jan '80	218	208	211	204	207	202	208
	Mar '80	271	257	255	259	258	245	258
	May '80	292	286	284	287	282	281	285
	Jul '80	302	301	301	299	293	287	297
	Sep '80	272	270	266	263	264	255	265
	Nov '80	177	172	168	169	157	150	165
	Jan '81	240	237	234	231	226	226	232
	Mar '81	288	281	286	290	282	279	286
	May '81	320	311	300	310	293	306	307
	Jul '81	308	309	305	309	303	313	308
	Sep '81	264	258	267	264	271	259	264
	Nov '81	144	137	137	138	127	123	134
	Mean	258	253	251	252	247	244	

Appendix 6. Ear height of two hybrids under different population densities over 12 bimonthly plantings.

(unit : cm)

Hybrid	Month	Population density (1,000 plants/ha)						
		50	75	100	125	150	200	Mean
H763	Jan '80	89	90	90	93	94	96	92
	Mar '80	111	109	109	112	126	122	115
	May '80	128	129	132	134	137	139	133
	Jul '80	129	132	133	130	133	140	133
	Sep '80	127	125	127	125	135	133	129
	Nov '80	69	68	70	73	68	67	69
	Jan '81	97	95	94	96	94	95	95
	Mar '81	138	148	146	148	146	148	146
	May '81	129	132	143	146	151	140	140
	Jul '81	136	142	140	140	143	145	141
	Sep '81	120	128	122	114	118	121	120
	Nov '81	60	54	57	58	54	52	56
	Mean	111	113	113	114	117	117	
X304C	Jan '80	87	89	89	88	90	91	89
	Mar '80	119	113	116	118	129	125	120
	May '80	136	140	138	144	143	146	141
	Jul '80	147	150	155	153	154	157	153
	Sep '80	131	130	128	125	139	133	131
	Nov '80	67	67	69	71	69	75	70
	Jan '81	92	89	91	88	91	91	90
	Mar '81	147	147	141	151	148	151	146
	May '81	164	164	157	165	155	173	163
	Jul '81	144	148	154	154	150	150	150
	Sep '81	120	122	132	126	132	129	127
	Nov '81	56	55	58	56	56	55	56
	Mean	117	118	119	120	121	123	

Appendix 7. Leaf area per plant of two hybrids under different population densities over 12 bimonthly plantings.

(unit : cm^2)

Hybrid	Month	Population density (1,000 plants/ha)						
		50	75	100	125	150	200	Mean
H763	Jan '80	6126	5015	5313	5246	5314	4868	5464
	Mar '80	7002	6423	6244	5776	5320	5351	6023
	May '80	6708	6601	5982	5918	5348	4713	5878
	Jul '80	7400	6762	6318	5852	5320	4807	6076
	Sep '80	--	--	--	--	--	--	--
	Nov '80	3942	3560	3161	3061	2652	2392	3128
	Jan '81	5863	5391	5119	4801	4434	4395	5000
	Mar '81	7172	6816	6265	6160	5021	5201	6106
	May '81	6528	5885	5726	6563	4805	4274	5630
	Jul '81	6701	6130	5521	5291	4679	4250	5429
	Sep '81	--	--	--	--	--	--	--
	Nov '81	--	--	--	--	--	--	--
	Mean	6383	5942	5519	5408	4766	4472	
X304C	Jan '80	5363	5200	5044	4858	4134	4466	4844
	Mar '80	6460	5623	5533	5240	4852	4577	5381
	May '80	7078	6034	5533	5567	5049	4560	5637
	Jul '80	7073	6279	5936	6219	5258	4587	5892
	Sep '80	--	--	--	--	--	--	--
	Nov '80	3790	3372	3281	3094	2783	2641	3160
	Jan '81	5288	4938	4206	4162	4066	3674	4389
	Mar '81	6990	6559	6334	6229	5371	5007	6082
	May '81	7030	6276	5331	5577	5039	4637	5648
	Jul '81	6504	5971	5612	5650	4602	4407	5458
	Sep '81	--	--	--	--	--	--	--
	Nov '81	--	--	--	--	--	--	--
	Mean	6175	5583	5201	5177	4573	4284	

Appendix 8. Leaf area index of two hybrids under different population densities over 12 bimonthly plantings.

Hybrid	Month	Population density (1,000 plants/ha)						
		50	75	100	125	150	200	Mean
H763	Jan '80	3.11	4.32	5.38	6.28	7.77	9.86	6.12
	Mar '80	3.55	4.70	6.34	6.91	7.78	10.83	6.68
	May '80	3.40	4.83	6.06	7.08	7.82	9.54	6.45
	Jul '80	3.70	5.07	6.32	7.32	7.98	9.61	6.67
	Sep '80	--	--	--	--	--	--	--
	Nov '80	2.00	2.60	3.20	3.66	3.88	4.84	3.36
	Jan '81	2.97	3.94	5.18	5.74	6.48	8.90	5.54
	Mar '81	3.63	4.98	6.34	7.37	7.34	10.53	6.70
	May '81	3.33	4.30	5.80	6.64	7.02	8.65	5.96
	Jul '81	3.36	4.60	5.52	6.62	7.02	8.50	5.93
	Sep '81	--	--	--	--	--	--	--
	Nov '81	--	--	--	--	--	--	--
	Mean	3.22	4.37	5.57	6.40	7.01	9.03	
X304C	Jan '80	2.72	3.80	5.10	5.81	6.05	9.04	5.42
	Mar '80	3.27	4.11	5.60	6.27	7.10	9.27	5.93
	May '80	3.58	4.41	5.60	6.66	7.38	9.23	6.14
	Jul '80	3.54	4.71	5.94	7.77	7.89	9.17	6.50
	Sep '80	--	--	--	--	--	--	--
	Nov '80	1.92	2.47	3.32	3.70	4.07	5.35	3.47
	Jan '81	2.68	3.61	4.26	4.98	5.95	7.44	4.82
	Mar '81	3.54	4.80	6.41	7.45	7.85	10.14	6.70
	May '81	3.56	4.59	5.39	6.67	7.37	9.39	6.16
	Jul '81	3.26	4.48	5.62	7.06	6.91	8.81	6.02
	Sep '81	--	--	--	--	--	--	--
	Nov '81	--	--	--	--	--	--	--
	Mean	3.12	4.11	5.25	6.26	6.73	8.65	

Appendix 9. Filled ear length of two hybrids under different popula population densities over 12 bimonthly plantings.

(unit : cm)

Hybrid	Month	Population density (1,000 plants/ha)						
		50	75	100	125	150	200	Mean
H763	Jan '80	12.3	12.9	11.0	10.7	10.9	9.5	11.2
	Mar '80	16.4	13.4	12.0	11.5	10.7	10.2	12.3
	May '80	17.3	12.7	10.4	9.5	9.3	9.3	11.4
	Jul '80	18.2	13.2	12.3	11.7	10.5	10.0	12.6
	Sep '80	12.3	10.4	9.8	9.2	9.0	8.0	9.8
	Nov '80	7.0	6.3	5.4	4.8	5.0	4.7	5.5
	Jan '81	13.5	11.7	9.8	9.1	9.3	7.9	10.2
	Mar '81	14.6	11.9	12.6	12.1	9.7	10.4	11.9
	May '81	17.4	14.6	12.3	11.1	10.8	10.7	12.8
	Jul '81	13.9	12.7	11.0	10.3	9.8	9.3	11.2
	Sep '81	9.5	9.3	10.7	8.4	8.0	8.1	9.0
	Nov '81	5.7	5.6	4.8	5.4	4.9	4.0	5.0
	Mean	13.2	11.2	10.1	9.4	9.0	8.5	
X304C	Jan '80	14.2	11.9	12.8	11.4	11.8	10.0	12.0
	Mar '80	16.7	15.6	13.9	13.1	12.4	11.3	13.8
	May '80	18.2	16.4	14.9	13.8	12.7	11.0	11.5
	Jul '80	17.4	13.9	13.7	13.6	13.5	11.2	13.9
	Sep '80	13.4	12.5	12.7	11.9	9.6	10.0	11.7
	Nov '80	9.5	8.7	8.2	7.1	7.7	5.9	7.8
	Jan '81	13.2	11.8	10.9	10.1	9.3	8.4	10.6
	Mar '81	16.6	14.9	13.3	12.6	12.4	11.8	13.6
	May '81	18.2	15.7	16.5	14.7	12.6	12.0	14.9
	Jul '81	16.9	14.9	14.5	12.9	10.6	11.8	13.6
	Sep '81	12.9	9.7	9.7	10.2	8.2	8.4	9.8
	Nov '81	8.7	9.0	8.2	8.4	7.0	6.9	8.0
	Mean	14.6	12.9	12.4	11.6	10.6	9.9	

Appendix 10. Number of kernel rows of two hybrids under different population densities over 12 bimonthly plantings.

Hybrid	Month	Population density (1,000 plants/ha)						
		50	75	100	125	150	200	Mean
H763	Jan '80	13.0	13.1	13.0	12.9	12.2	12.4	12.8
	Mar '80	13.2	13.5	13.5	13.0	13.0	12.5	13.1
	May '80	13.7	13.1	13.3	13.3	12.6	11.7	12.9
	Jul '80	14.3	12.8	13.1	13.4	12.8	11.0	12.9
	Sep '80	12.9	11.8	11.8	9.8	9.1	8.8	10.7
	Nov '80	11.8	10.4	8.7	9.3	9.2	8.0	9.5
	Jan '81	13.2	12.6	12.2	12.6	12.2	11.7	12.4
	Mar '81	14.2	13.9	12.4	12.7	13.3	11.8	13.0
	May '81	14.4	13.7	12.7	12.3	12.0	12.5	12.9
	Jul '81	14.4	13.3	12.6	13.1	12.0	12.4	13.0
	Sep '81	11.1	10.9	9.8	9.6	9.0	10.2	10.1
	Nov '81	7.2	6.2	5.9	5.9	6.5	5.1	6.1
	Mean	12.8	12.1	11.6	11.5	11.1	10.7	
X304C	Jan '80	13.3	12.5	13.0	12.8	12.9	12.3	12.8
	Mar '80	13.1	12.8	12.9	12.7	12.5	12.9	12.8
	May '80	13.7	13.2	13.5	12.9	13.0	12.2	13.1
	Jul '80	13.4	13.3	13.7	13.9	13.5	12.8	13.4
	Sep '80	12.4	12.7	13.2	12.4	11.8	10.6	12.2
	Nov '80	11.9	12.4	12.1	12.2	11.0	11.0	11.8
	Jan '81	12.0	11.1	11.4	11.2	11.6	10.7	11.3
	Mar '81	12.9	13.5	12.8	13.0	13.2	12.7	13.0
	May '81	13.0	13.9	11.8	12.7	12.5	12.0	12.6
	Jul '81	13.0	13.4	13.3	12.8	12.0	12.5	12.8
	Sep '81	13.0	13.4	13.4	12.2	11.7	12.2	12.6
	Nov '81	12.3	12.7	11.1	10.8	10.0	10.3	11.2
	Mean	12.8	12.9	12.7	12.5	12.1	11.8	

Appendix 11. Number of kernels/row of two hybrids under different population densities over 12 bimonthly plantings.

Hybrid	Month	Population density (1,000 plants/ha)						
		50	75	100	125	150	200	Mean
H763	Jan '80	26.3	28.4	22.8	21.8	22.4	19.0	23.4
	Mar '80	36.0	26.6	24.7	24.3	23.1	21.7	26.1
	May '80	36.8	28.6	23.2	20.4	19.8	18.5	24.5
	Jul '80	37.6	25.8	26.2	22.6	19.9	18.8	25.1
	Sep '80	27.0	22.9	15.2	13.7	12.2	9.8	16.8
	Nov '80	15.8	13.5	11.8	11.8	10.6	8.5	12.0
	Jan '81	29.7	27.3	21.9	20.2	20.5	18.4	23.0
	Mar '81	30.3	24.8	26.5	24.6	18.6	17.1	23.6
	May '81	35.8	30.5	23.8	21.2	19.2	18.2	24.8
	Jul '81	29.4	25.2	21.6	20.4	18.9	14.8	21.7
	Sep '81	17.5	17.1	16.5	15.7	15.9	14.7	16.2
	Nov '81	7.8	8.8	7.5	8.0	7.2	6.7	7.6
	Mean	27.5	23.3	20.1	18.7	17.3	15.5	
X304C	Jan '80	31.7	24.9	26.8	25.0	25.3	19.8	25.6
	Mar '80	38.1	35.9	29.7	28.9	26.5	23.7	30.4
	May '80	39.3	35.9	33.2	30.6	27.4	21.7	31.3
	Jul '80	37.8	30.4	28.2	29.0	28.6	24.3	29.7
	Sep '80	29.2	26.8	28.3	24.7	16.7	15.1	23.4
	Nov '80	22.2	20.0	16.8	14.0	15.0	12.1	16.7
	Jan '81	33.3	28.0	26.7	23.2	20.0	18.7	25.0
	Mar '81	36.6	29.5	27.7	26.4	25.8	23.8	28.3
	May '81	40.3	33.9	33.8	31.8	26.1	22.1	31.3
	Jul '81	37.5	31.8	30.3	27.7	22.4	21.6	28.5
	Sep '81	29.7	21.2	19.6	21.4	16.4	16.5	20.8
	Nov '81	15.9	15.7	13.8	13.9	11.9	12.3	13.9
	Mean	32.6	27.8	26.2	24.7	21.8	19.3	

Appendix 12· Kernel fusarium of two hybrids under different population densities over 12 bimonthly plantings.

(unit : %)

Hybrid	Month	Population density (1,000 plants/ha)						
		50	75	100	125	150	200	Mean
H763	Jan '80	3.6	4.2	5.1	9.3	7.2	10.5	6.6
	Mar '80	0.3	1.1	0.6	1.4	4.2	5.2	2.1
	May '80	0.3	1.0	0.7	0.6	1.5	2.1	1.0
	Jul '80	0.4	0.9	1.6	0.8	0.9	2.8	1.2
	Sep '80	2.4	3.1	2.7	4.2	3.4	4.1	3.3
	Nov '80	5.6	6.5	12.9	14.7	10.4	15.0	10.8
	Jan '81	0.4	0.6	1.1	1.1	1.0	1.8	1.0
	Mar '81	0.3	0.3	0.3	0.5	1.7	3.0	1.0
	May '81	1.0	0.8	1.6	2.2	1.3	1.7	1.4
	Jul '81	0.3	0.8	0.5	1.1	1.1	0.8	0.8
	Sep '81	0.9	0.8	0.8	1.2	0.7	0.7	0.8
	Nov '81	1.4	2.5	4.1	2.7	2.8	3.0	2.8
	Mean	1.4	1.9	2.7	3.3	3.0	4.2	
X304C	Jan '80	1.6	3.6	2.1	4.0	2.5	4.8	3.1
	Mar '80	0.2	0.0	0.0	0.8	1.0	1.4	0.6
	May '80	0.0	0.3	0.1	0.9	1.1	1.6	0.6
	Jul '80	0.0	0.2	0.2	0.1	0.3	0.5	0.2
	Sep '80	1.0	0.8	0.6	0.8	1.5	0.8	0.9
	Nov '80	1.4	1.9	2.5	2.3	2.1	2.8	2.1
	Jan '81	0.5	0.2	0.8	0.6	1.0	0.7	0.6
	Mar '81	0.2	0.2	0.4	0.5	0.7	0.5	0.4
	May '81	0.0	0.4	0.0	0.4	0.4	1.0	0.4
	Jul '81	0.0	0.4	0.3	0.2	0.7	0.5	0.3
	Sep '81	0.7	0.9	1.2	0.7	1.3	1.3	1.0
	Nov '81	1.7	1.3	1.6	1.7	1.5	1.9	1.6
	Mean	0,6	0,8	0,8	1,1	1,1	1,5	

Appendix 13. Regression equation of yields, plant characters, and yield components with population densities.

Characters	Hybrid	Equation	r^2
Grain yield	H763	Y= 6.46 + 0.00023X	0.01
	X304C	Y= 6.84 + 0.0067X	0.29
Stover yield	H763	Y= 5.02 + 0.019X	0.93**
	X304C	Y= 5.70 + 0.0202X	0.93**
Days to tasseling	H763	Y= 54.21 + 0.011X	0.95**
	X304C	Y= 56.08 + 0.0080X	0.78*
Plant height	H763	Y= 251.29 - 0.076X	0.97**
	X304C	Y= 260.85 - 0.087X	0.92**
Ear height	H763	Y= 109.46 + 0.039X	0.91**
	X304C	Y= 114.48 + 0.043X	0.99**
Leaf area index	H763	Y= 1.54 + 0.038X	0.99**
	X304C	Y= 1.44 + 0.036X	0.99**
Stem diameter	H763	Y= 2.24 - 0.0046X	0.93**
	X304C	Y= 2.53 - 0.0056X	0.96**
Cob length	H763	Y= 18.55 - 0.032X	0.91**
	X304C	Y= 18,85 - 0.037X	0.95**
Filled ear length	H763	Y= 13.65 - 0.029X	0.85*
	X304C	Y= 15.59 - 0.031X	0.94**
Number of kernel rows	H763	Y= 13.14 - 0.013X	0.94**
	X304C	Y= 13.34 - 0.0076X	0.94**
Number of kernels per row	H763	Y= 29.29 - 0.076X	0.90**
	X304C	Y= 35.24 - 0.084X	0.95**
100 kernels weight	H763	Y= 28.32 - 0.0011X	0.95**
	X304C	Y= 26.90 - 0.018X	0.90**
Kernel fusarium	H763	Y= 0.63 + 0.018X	0.93**
	X304C	Y= 0.32 + 0.0057X	0.96**
Barrenness	H763	Y= -1.34 + 0.19X	0.97**
	X304C	Y= -6.66 + 0.13X	0.97**

* Significant at 5 % level

** Significant at 1 % level

Appendix 14. Multiple regression of yields and their components with growing degree days.

Characters	Hybrids	Equation	r^2
Grain yield	H763	$Y = -39.64 + 0.019X_1 + 0.020X_2$	0.39
	X304C	$Y = -34.12 + 0.018X_1 + 0.017X_2$	0.37
Stover yield	H763	$Y = -1.68 - 0.011X_1 + 0.011X_2$	0.46
	X304C	$Y = -13.46 + 0.0003X_1 + 0.014X_2$	0.44
Total dry matter yield	H763	$Y = -41.33 + 0.0008X_1 + 0.031X_2$	0.40
	X304C	$Y = -47.71 + 0.019X_1 + 0.031X_2$	0.41
Plant height	H763	$Y = 242.87 - 0.45X_1 + 0.23X_2$	0.63^*
	X304C	$Y = 193.84 - 0.55X_1 + 0.32X_2$	0.57^*
Filled ear length	H763	$Y = -5.48 - 0.0078X_1 + 0.014X_2$	0.52^*
	X304C	$Y = -6.49 - 0.0025X_1 + 0.013X_2$	0.49^*
Number of kernels/ row	H763	$Y = -24.39 + 0.0024X_1 + 0.027X_2$	0.35
	X304C	$Y = -21.37 - 0.0038X_1 + 0.032X_2$	0.50^*

X_1 and X_2 are growing degree days from planting to tasseling and from planting to harvesting, respectively.

Appendix 15. Effects of growing degree days on yields and their components.

Characters	Hybrids	Growing degree days from planting to tasseling	Growing degree days from planting to harvesting
Grain yield	H763	0.18	0.64
	X304C	0.14	0.58
Stover yield	H763	-0.18	0.62
	X304C	0.01	0.67
Total dry matter yield	H763	0.05	0.65
	X304C	0.09	0.64
Plant height	H763	-0.38	0.62
	X304C	-0.28	0.73
Filled ear length	H763	-0.12	0.69
	X304C	-0.03	0.70
Number of kernels/row	H763	0.02	0.59
	X304C	0.02	0.72

Appendix 16. Average days to tasseling and plant characters of normal and bm3 mutant over 2 seasons.

Hybrids	Days to tasseling (day)		Leaf area index		Number of stem nodes		Stem diameter (mm)	
	Normal	bm3	Normal	bm3	Normal	bm3	Normal	bm3
Ant2 x B37	47.4	47.0	4.53	4.14	12.7	12.7	24.3	22.4
Ant2 x Hi27	49.1	47.9	4.51	4.48	13.0	12.5	24.3	23.3
Ant2 x Hi28	48.0	47.6	4.61	4.18	13.2	13.3	24.0	22.4
Ant2 x Mo17	46.9	46.9	4.30	4.03	12.7	12.3	23.3	22.3
Ant2 x Oh545	46.1	45.6	4.43	4.05	13.1	12.4	23.5	22.1
B37 x Hi27	46.6	46.8	4.06	4.31	12.1	12.1	23.1	24.1
B37 x Hi28	46.1	46.4	3.94	4.06	12.6	12.8	23.9	23.1
B37 x Mo17	45.6	45.9	3.93	3.89	12.0	11.1	24.8	22.0
B37 x Oh545	45.5	45.0	3.90	3.80	11.9	11.3	24.1	22.8
Hi27 x Hi28	48.5	47.9	4.09	4.24	13.0	12.9	24.1	23.3
Hi27 x Mo17	46.9	46.9	4.05	4.10	12.4	11.5	23.5	23.1
Hi27 x Oh545	46.3	45.6	4.34	4.20	12.5	11.9	24.6	23.4
Hi28 x Mo17	45.9	46.3	3.92	4.00	13.1	12.2	23.6	22.8
Hi28 x Oh545	45.5	45.0	4.00	3.99	12.6	12.1	24.6	22.6
Mo17 x Oh545	45.1	44.9	3.86	3.74	11.8	10.4	23.4	22.4
Mean	46.6	46.4	4.16	4.08	12.6	12.1	23.9	22.8

Appendix 17. Average yield components and ear height of normal and bm3 mutant corn over 2 seasons.

Hybrids	Number of kernels per row		Number of kernel rows		Ear height (cm)	
	Normal	bm3	Normal	bm3	Normal	bm3
Ant2 x B37	35.8	31.2	13.8	14.2	120	128
Ant2 x Hi27	35.7	28.3	13.9	14.3	140	129
Ant2 x Hi28	39.4	34.0	13.7	13.7	136	132
Ant2 x Mo17	43.0	35.4	13.3	12.8	116	111
Ant2 x Oh545	39.2	36.8	14.2	13.9	114	103
B37 x Hi27	32.2	28.6	15.6	15.5	116	106
B37 x Hi28	35.3	32.5	13.9	13.9	126	121
B37 x Mo17	37.4	33.9	13.5	12.5	98	98
B37 x Oh545	35.6	33.3	13.4	13.6	83	79
Hi27 x Hi28	31.9	26.4	15.9	15.5	142	125
Hi27 x Mo17	36.6	29.5	14.3	13.4	120	109
Hi27 x Oh545	34.4	32.4	14.8	14.9	105	100
Hi28 x Mo17	39.0	33.8	13.8	12.6	124	109
Hi28 x Oh545	38.4	32.7	14.5	13.4	113	96
Mo17 x Oh545	39.4	36.6	12.6	12.3	92	79
Mean	36.9	32.3	14.1	13.8	116	108

Appendix 18. Combined analysis of combining ability of normal and bm3 mutant corn for days to tasseling and yield components over 2 seasons.

Source	df	Days to tasseling		df	Filled ear length		Number of kernels/row	
		Normal	bm3		Normal	bm3	Normal	bm3
GCA	5	7.04**	5.61**	5	10.27**	18.29**	45.76**	46.03**
SCA	9	0.38**	0.10	9	0.79	1.37*	1.95	3.69
Season (S)	1	33.07**	19.20**	1	53.77**	119.85**	287.08**	465.74**
GCA x S	5	0.41*	0.29*	5	1.11	0.06	5.04	4.70
SCA x S	9	0.24	0.12	9	0.07	0.29	3.83	1.69
Error	84	0.10	0.13	28	0.62	0.58	2.78	2.76

* Significant at 5 % probability level.
** Significant at 1 % probability level.

Appendix 19.

Estimates of SCA and GCA effects for days to tasseling of normal and bm3 mutant corn over 2 seasons.

Inbreds	SCA effects					GCA effects
	B37	Hi27	Hi28	Mo17	Oh545	
Ant2	0.14	0.36	0.08	-0.14	-0.43	1.08
	0.05	-0.08	0.14	-0.01	-0.11	0.79
B37		-0.58	-0.24	0.17	0.51	-0.48
		-0.20	-0.11	-0.01	0.27	-0.21
Hi27			0.61	-0.11	-0.27	1.05
			0.39	-0.01	-0.11	0.79
Hi28				-0.27	-0.18	0.21
				-0.17	-0.26	0.32
Mo17					0.36	-0.70
					0.21	-0.27
Oh545						-1.17
						-1.43

Upper and lower values are normal and bm3, respectively.

Appendix 20. Estimates of SCA and GCA effects for plant height of normal and bm3 mutant corn over 2 seasons.

Inbreds	SCA effects					GCA effects
	B37	Hi27	Hi28	Mo17	Oh545	
Ant2	2.14	1.71	-7.04	-2.33	5.52	2.02
	6.86	-1.02	-8.55	1.64	1.08	3.74
B37		-2.70	5.42	2.64	-7.51	-1.95
		0.20	1.92	-2.27	-6.71	2.65
Hi27			-0.64	-1.54	3.18	1.99
			-0.58	-1.02	2.42	0.52
Hi28				2.33	-0.08	6.62
				2.83	4.39	8.55
Mo17					-1.11	-6.98
					-1.18	-9.26
Oh545						-1.70
						-6.20

Upper and lower values are normal and bm3, respectively.

Appendix 21.

Estimates of SCA and GCA effects for ear height of normal and bm3 mutant corn over 2 seasons.

Inbreds	SCA effects					GCA effects
	B37	Hi27	Hi28	Mo17	Oh545	
Ant2	2.39	1.71	-6.20	-3.17	5.27	11.06
	6.58	-1.42	-2.29	-3.67	0.80	12.26
B37		-0.70	4.02	-0.45	-5.26	-9.66
		-6.58	4.55	1.05	-5.61	-2.58
Hi27			0.83	1.24	-3.08	10.41
			-0.33	2.80	5.52	6.92
Hi28				0.33	1.02	14.81
				-0.70	-1.23	10.42
Mo17					2.05	-7.84
					0.52	-8.83
Oh545						-18.78
						-21.18

Upper and lower values are normal and bm3, respectively.

Appendix 22. Estimates of SCA and GCA effects for filled ear length of normal and bm3 mutant corn over 2 seasons.

Inbreds	SCA effects					GCA effects
	B37	Hi27	Hi28	Mo17	Oh545	
Ant2	0.32	0.17	-0.28	0.44	-0.65	-0.17
	0.02	-0.24	0.58	-0.28	-0.07	0.03
B37		-0.24	0.34	0.27	-0.69	-0.68
		0.28	0.40	0.27	-0.97	-1.15
Hi27			-0.32	0.12	0.26	-1.48
			0.12	-1.09	0.92	-1.49
Hi28				-0.83	1.09	-0.33
				-0.07	-0.04	-0.83
Mo17					-0.01	1.11
					1.16	0.92
Oh545						1.55
						2.52

Upper and lower values are normal and bm3, respectively.

Appendix 23. Estimates of SCA and GCA effects for number of kernels per row of normal and bm3 mutant corn over 2 seasons.

Inbreds	SCA effects					GCA effects
	B37	Hi27	Hi28	Mo17	Oh545	
Ant2	-1.20 -1.56	0.04 -0.93	0.47 1.30	1.21 0.25	-0.51 0.95	2.15 0.97
B37		0.74 0.99	0.56 1.29	-0.18 0.24	0.08 -0.96	-2.04 -0.55
Hi27			-1.50 -1.21	0.39 -0.53	0.32 1.69	-3.41 -4.18
Hi28				-0.53 0.17	1.00 -1.55	-0.11 -0.61
Mo17					-0.89 -0.13	2.78 1.87
Oh545						0.64 2.49

Upper and lower values are normal and bm3, respectively.

Appendix 24. Average grain and stover yields, and grain/stover ratio over 2 seasons under normal and extended light conditions.

Hybrids	Grain yield (T/ha)		Stover yield (T/ha)		Grain/Stover ratio	
	Normal	Light	Normal	Light	Normal	Light
Ant2 x Hi28	7.71	5.57	7.72	11.45	1.00	0.49
Ant2 x Hi29	7.89	6.84	9.14	11.34	0.86	0.60
Ant2 x Hi31	8.07	5.83	8.30	8.25	0.97	0.71
Ant2 x Mo17	7.97	5.92	7.16	10.53	1.11	0.56
Hi28 x Hi29	7.61	5.48	8.34	9.66	0.91	0.57
Hi28 x Hi31	6.46	5.83	7.34	7.41	0.88	0.79
Hi28 x Mo17	7.70	5.16	7.67	8.99	1.00	0.57
Hi29 x Hi31	7.02	7.20	7.87	8.38	0.89	0.86
Hi29 x Mo17	6.95	5.13	6.65	6.74	1.05	0.76
Hi31 x Mo17	6.41	5.41	5.78	6.54	1.11	0.83
B37 x Hi25	5.36	4.66	4.94	5.79	1.09	0.81
B37 x Mo17	6.25	5.25	5.19	6.01	1.20	0.87
Pi3369A	6.17	4.57	6.41	6.52	0.96	0.70
X304C	7.88	4.57	9.37	13.85	0.84	0.33
Mean	7.10	5.53	7.28	8.67	0.99	0.68

Appendix 25. LAI, number of stem node and stem diameter under normal and extended light conditions.

Hybrids	Leaf area index		Number of stem nodes		Stem diameter (mm)	
	Normal	Light	Normal	Light	Normal	Light
Ant2 x Hi28	4.90	6.68	13.7	17.0	24.1	27.5
Ant2 x Hi29	5.00	6.94	14.5	18.0	24.4	28.1
Ant2 x Hi31	4.83	6.40	13.5	15.2	24.4	25.0
Ant2 x Mo17	4.65	6.72	13.2	15.8	23.5	26.4
Hi28 x Hi29	4.65	6.21	14.4	17.1	25.3	27.8
Hi28 x Hi31	4.14	5.86	13.2	15.0	24.0	26.8
Hi28 x Mo17	4.08	5.83	12.7	15.0	23.8	26.5
Hi29 x Hi31	4.33	5.80	13.5	15.4	24.9	26.5
Hi29 x Mo17	4.09	5.51	13.4	15.4	23.3	25.8
Hi31 x Mo17	3.91	5.15	12.6	14.2	23.5	24.1
B37 x Hi25	3.77	5.04	12.8	14.2	23.5	24.8
B37 x Mo17	3.95	5.54	12.0	13.5	24.1	25.3
Pi3369A	3.86	5.39	12.2	13.6	23.8	25.1
X304C	4.74	6.92	14.0	17.7	27.5	29.8
Mean	4.35	6.00	13.3	15.5	24.3	26.4

Appendix 26. Combined analysis of variance for plant characters evaluated under normal and extended light conditions in different seasons.

Source	df	Mean squares			
		Plant height	Ear height	Number of stem nodes	Stem diameter
Daylength (D)	1	61645.79	56261.16	279.69	250.76
Reps in D	6	693.96	769.49	2.57	4.96
Seasons (S)	1	45943.14	26404.57	106.29	1326.01
S x D	1	1909.45	1216.45	11.93	63.22*
Error (b)	6	848.33	578.71	3.17	5.23
Genotype (G)	13	3912.23**	9520.51**	18.94**	302.33**
G x D	13	397.28*	366.99**	2.47**	3.42*
G x S	13	321.33*	557.57**	2.27**	4.75**
G x D x S	13	72.90	110.22	0.89*	1.94
Error (c)	156	179.94	139.41	0.42	1.74

* Significant at 5 % probability level.
** Significant at 1 % probability level.

Appendix 27. Estimates of SCA effects of grain and stover yields, plant height and ear height under normal and extended light.

Hybrids	Grain yield		Stover yield		Plant height		Ear height	
	Normal	Light	Normal	Light	Normal	Light	Normal	Light
Ant2 x Hi28	-0.37	-0.10	-0.75	-0.03	-3.06	-5.54	-2.88	-1.85
Ant2 x Hi29	-0.18	0.30	0.36	0.33	2.73	11.04	4.21	12.65
Ant2 x Hi31	0.50	-0.59	0.42	-0.92	6.73	2.50	3.08	2.02
Ant2 x Mo17	0.05	0.39	-0.04	0.62	-6.40	-8.00	-4.12	-12.81
Hi28 x Hi29	0.26	-0.35	-0.02	-0.01	0.69	-1.71	0.63	-2.27
Hi28 x Hi31	-0.39	0.12	-0.11	-0.41	-6.06	-1.50	-2.75	-3.15
Hi28 x Mo17	0.49	0.34	0.89	0.44	8.44	8.75	5.00	7.27
Hi29 x Hi31	0.17	0.62	0.10	1.03	-1.02	-4.79	-2.29	-7.40
Hi29 x Mo17	-0.26	-0.57	-0.44	-1.35	-2.40	-4.54	-2.54	-2.97
Hi31 x Mo17	-0.29	-0.16	-0.41	0.29	0.35	3.79	1.96	8.52

Appendix 28. Estimates of SCA effects of days to tasseling, number of stem node and stem diameter under normal and extended light conditions.

Hybrids	Days to tasseling		Number of stem node		Stem diameter	
	Normal	Light	Normal	Light	Normal	Light
Ant2 x Hi28	-0.02	-0.44	-0.15	-0.05	-0.21	-0.31
Ant2 x Hi29	0.19	1.35	0.08	0.38	-0.17	0.60
Ant2 x Hi31	-0.60	-2.27	0.02	-0.36	0.17	-0.77
Ant2 x Mo17	0.44	1.35	0.05	0.03	0.21	0.48
Hi28 x Hi29	0.27	0.40	0.24	0.13	0.46	-0.27
Hi28 x Hi31	0.23	1.77	0.06	0.05	-0.46	0.48
Hi28 x Mo17	-0.48	-1.73	-0.15	-0.13	0.21	0.10
Hi29 x Hi31	-0.06	-0.81	-0.25	-0.14	0.21	0.27
Hi29 x Mo17	-0.40	-0.94	-0.07	-0.36	-0.50	-0.61
Hi31 x Mo17	0.44	1.31	0.16	0.46	0.08	0.02

Appendix 29. Estimates of SCA effects of yield components under normal and extended light conditions.

Hybrids	Filled ear length		Number of kernel rows		Number of kernels per row	
	Normal	Light	Normal	Light	Normal	Light
Ant2 x Hi28	-1.07	-0.12	-0.38	0.23	-0.86	1.69
Ant2 x Hi29	0.94	0.55	-0.18	-0.13	0.85	0.70
Ant2 x Hi31	-0.73	-0.15	0.03	0.09	-0.90	0.66
Ant2 x Mo17	0.85	-0.29	0.17	-0.19	0.91	-3.05
Hi28 x Hi29	0.27	-0.58	-0.08	0.24	0.70	-3.07
Hi28 x Hi31	0.43	-0.20	0.65	-0.28	0.28	-0.84
Hi28 x Mo17	0.38	0.90	-0.19	-0.19	-0.12	2.22
Hi29 x Hi31	0.16	0.50	-0.41	-0.15	-0.07	0.85
Hi29 x Mo17	-1.37	-0.47	0.30	0.04	-1.48	1.51
Hi31 x Mo17	0.14	-0.15	-0.28	0.34	0.69	-0.68

Appendix 30. Stover yield of 225 hybrids evaluated during 3 different seasons.

(unit : T/ha)

Male Female	Hi26	Hi28	Hi29	Hi31	Hi33	Hi34	Tx601	Mean
CIMMYT-A21	6.48	6.62	7.91	6.51	5.32	5.66	6.27	6.40
CIMMYT-T11ES	7.91	8.24	6.77	7.00	5.88	8.21	6.80	7.26
Fla.2AT-112	5.96	5.49	6.12	5.14	5.98	7.03	7.17	6.13
Fla.2AT-114	5.91	6.80	6.48	5.91	5.67	6.67	6.43	6.27
Fla.2BT-54	5.74	5.79	6.49	4.62	5.06	6.96	7.22	5.98
H632A	7.07	7.41	9.04	6.34	6.22	7.81	7.86	7.39
H632F	7.22	6.82	7.80	5.78	6.80	7.55	7.34	7.04
H632G	6.18	6.52	7.32	6.01	6.10	6.34	6.81	6.47
ICA L25	7.37	6.31	7.58	5.89	5.95	6.73	6.07	6.56
ICA L27	6.51	6.54	6.46	5.86	6.15	7.28	6.40	6.46
ICA L210	7.66	6.43	5.48	6.66	6.24	7.26	5.94	6.52
ICA L221	7.63	8.02	6.12	5.80	6.21	7.11	6.71	6.80
ICA L223	6.16	6.61	5.71	5.76	5.95	7.05	7.87	6.44
INV138	5.94	5.90	6.71	5.34	5.61	6.46	6.31	6.04
INV302	6.75	6.40	7.23	5.07	5.04	7.18	5.28	6.14
INV443	5.92	6.29	5.52	5.69	5.60	7.32	6.13	6.07
INV534	5.77	5.94	6.44	5.97	5.91	7.55	6.33	6.27
MIT11 DMR	5.62	6.83	5.75	6.11	5.59	7.10	6.97	6.28
Pi4243	6.47	5.61	5.55	4.36	5.43	6.79	6.46	5.81
Pi4257	5.98	6.19	6.96	5.44	5.07	5.31	5.25	6.03
Pi4283	5.17	5.42	5.72	5.22	5.28	6.12	6.44	5.62
Pi4287	5.66	5.33	6.12	4.16	4.46	5.65	6.86	5.46
SR52-F	7.00	6.42	6.40	6.20	5.72	7.23	6.45	6.49
SR52-M	6.37	6.02	6.38	5.79	5.73	7.59	6.69	6.37
Tuxpeno	7.27	5.37	6.58	5.01	5.05	7.05	6.44	6.11
Tx602	6.53	6.94	5.96	6.17	5.16	7.46	5.58	6.26
77-4407	5.77	6.37	5.82	4.02	5.18	5.74	6.15	5.58
77-4412	4.82	5.52	6.05	4.55	6.06	6.02	6.04	5.58
77-4441	5.27	6.00	5.80	3.43	6.29	7.22	6.41	5.77
77-4449	7.02	6.28	6.18	4.24	5.44	7.20	6.06	6.06
77-4544	5.36	6.23	6.66	6.46	5.15	7.23	5.92	6.22
Mean	6.34	6.34	6.49	5.50	5.65	6.95	6.50	6.25

H636 :5.53 H650 : 5.73 H763 : 6.23 H767 : 6.15
H823 :7.55 H824 : 6.95 X105A: 7.14 X304C: 6.64

Appendix 31. Days to tasseling of 225 hybrids over 3 seasons.

(unit : day)

Male Female	Hi26	Hi28	Hi29	Hi31	Hi33	Hi34	Tx601	Mean
CIMMYT-A21	56.8	56.3	57.3	56.3	55.2	61.3	61.2	57.8
CIMMYT-T11ES	59.3	59.2	58.5	57.5	55.7	62.2	62.0	59.2
Fla.2AT-112	55.8	54.0	56.3	55.0	53.3	59.3	56.8	55.8
Fla.2AT-114	56.0	54.0	53.8	54.3	53.8	57.8	57.5	55.3
Fla.2BT-54	57.7	55.7	54.8	56.2	54.0	58.5	58.7	56.5
H632A	59.8	59.2	58.3	58.2	54.8	61.7	60.5	58.9
H632F	57.0	57.5	60.0	57.2	57.0	60.7	58.3	58.2
H632G	57.7	58.5	57.2	55.3	56.0	56.2	58.0	57.0
ICA L25	56.5	57.8	57.0	56.5	54.8	60.7	59.3	57.5
ICA L27	56.7	56.8	58.5	56.3	56.5	60.7	59.8	57.9
ICA L210	56.3	56.0	55.8	56.2	54.5	59.3	60.7	57.0
ICA L221	58.2	56.5	57.8	57.8	55.3	59.7	60.5	57.0
ICA L223	57.3	57.7	58.0	58.3	55.7	60.2	60.3	58.2
INV138	56.5	55.3	55.3	55.0	54.0	58.8	56.5	55.9
INV302	56.8	56.5	54.7	54.5	54.5	59.2	58.8	56.4
INV443	53.8	55.2	54.7	55.3	52.5	56.7	57.8	55.1
INV534	53.7	53.3	53.5	53.0	53.0	56.5	57.2	54.3
MIT11 DMR	56.2	57.0	55.2	55.7	54.8	58.8	59.2	56.7
Pi4243	55.5	53.7	55.0	55.5	52.7	57.5	58.3	55.4
Pi4257	57.2	53.7	55.5	55.3	53.7	57.7	56.8	55.7
Pi4283	56.3	56.7	54.7	56.8	53.5	57.5	56.5	56.0
Pi4287	55.3	54.5	55.7	55.8	53.8	57.0	57.8	55.7
SR52-F	56.3	56.0	57.0	55.7	54.5	58.0	58.0	56.5
SR52-M	56.5	56.0	56.3	55.3	54.8	56.3	59.7	56.4
Tuxpeno	56.0	55.7	57.0	55.3	53.5	57.2	59.2	56.3
Tx602	57.8	55.0	58.3	57.5	54.5	58.5	61.8	57.7
77-4407	57.0	56.3	58.0	58.0	54.7	58.8	58.2	57.3
77-4412	56.8	56.5	56.3	58.7	56.3	60.0	57.7	57.5
77-4441	54.7	55.3	55.2	56.8	53.8	58.5	57.8	56.0
77-4449	56.0	55.5	56.0	55.8	54.8	58.7	57.5	56.3
77-4544	55.3	55.5	55.6	55.3	54.5	57.5	58.8	56.1
Mean	56.6	56.0	56.4	56.2	54.5	58.8	58.8	56.7

H636 :54.3   H650 :52.5   H763 :56.0   H767 :55.7
H823 :57.0   H824 :59.3   X105A:57.8   X304C:59.2

Appendix 32. Maturity of 225 hybrids in March planting

Male Female	Hi26	Hi28	Hi29	Hi31	Hi33	Hi34	Tx601	Mean
CIMMYT-A21	2.5	2.5	4.0	2.5	1.5	4.0	3.0	2.9
CIMMYT-T11ES	5.0	4.5	3.0	4.0	3.5	5.0	3.5	4.1
Fla.2AT-112	2.5	2.5	3.0	2.5	2.0	3.0	3.0	2.6
Fla.2AT-114	3.0	4.0	3.0	2.0	1.5	4.0	4.5	3.1
Fla.2BT-54	3.5	4.0	3.0	3.5	3.0	4.0	5.0	3.7
H632A	5.0	5.0	5.0	5.0	3.0	5.0	5.0	4.7
H632F	5.0	3.5	4.5	2.5	2.5	5.0	3.0	3.7
H632G	3.5	3.5	3.5	3.5	3.0	3.5	3.0	3.4
ICA L25	3.5	3.5	2.0	2.0	1.5	4.5	3.5	2.9
ICA L27	5.0	4.5	4.0	3.5	4.0	4.5	3.5	4.1
ICA L210	5.0	3.0	3.5	2.5	2.0	4.5	3.0	3.4
ICA L221	5.0	5.0	5.0	3.5	4.0	4.5	5.0	4.6
ICA L223	4.5	5.0	3.5	3.5	2.5	5.0	2.5	3.8
INV138	3.0	3.0	3.5	1.0	2.5	3.0	3.5	2.8
INV302	4.0	1.5	4.0	2.0	1.5	3.5	1.0	2.5
INV443	2.5	3.5	2.5	4.0	2.5	3.5	3.0	3.1
INV534	3.0	3.5	2.5	2.5	2.5	3.5	3.5	3.0
MIT11 DMR	1.5	1.5	1.5	2.5	2.5	2.5	2.5	2.1
Pi4243	3.0	2.5	2.5	1.0	3.0	3.0	3.0	2.6
Pi4257	1.5	1.0	2.0	3.0	2.0	2.5	4.5	2.4
Pi4283	2.5	3.0	3.0	3.5	2.0	3.0	3.0	2.9
Pi4287	3.0	1.5	2.0	1.5	2.5	3.5	4.0	2.6
SR52-F	4.5	4.5	4.5	5.0	3.0	5.0	3.5	4.3
SR52-M	5.0	4.0	3.0	3.5	3.0	5.0	5.0	4.1
Tuxpeno	4.5	4.0	2.0	2.5	3.5	4.5	4.5	3.6
Tx602	4.5	3.5	4.0	3.5	1.5	4.5	3.5	3.6
77-4407	3.5	4.5	2.5	2.5	2.5	3.5	4.0	3.3
77-4412	3.0	4.5	3.5	3.0	1.5	4.5	2.5	3.2
77-4441	3.0	3.5	4.5	2.0	3.5	3.0	4.5	3.4
77-4449	5.0	4.0	3.0	2.5	2.5	5.0	3.5	3.6
77-4544	2.0	1.5	3.5	3.5	3.0	4.5	3.0	3.0
Mean	3.6	3.4	3.3	2.9	2.6	4.0	3.5	3.3

H636 : 2.0 H650 : 2.0 H763 : 3.5 H767 : 2.0
H823 : 4.5 H824 : 5.0 X105A: 4.5 X304C: 3.0

* 1 : Very early.
2 : Early.
3 : Medium.
4 : Late.
5 : Very late.

Appendix 33. Average plant height of 225 hybrid evaluated during 3 seasons.

(unit : cm)

Male Female	Hi26	Hi28	Hi29	Hi31	Hi33	Hi34	Tx601	Mean
CIMMYT-A21	254	249	267	260	254	247	260	256
CIMMYT-T11ES	256	250	267	255	231	245	256	251
Fla.2AT-112	241	225	241	231	221	245	239	235
Fla.2AT-114	229	241	232	234	223	239	250	235
Fla.2BT-54	260	244	268	246	246	258	267	255
H632A	259	261	269	257	252	256	268	260
H632F	256	260	282	259	255	264	265	263
H632G	257	259	262	263	256	265	270	262
ICA L25	269	265	270	260	247	269	256	262
ICA L27	246	248	265	253	238	258	258	252
ICA L210	258	244	254	253	247	257	259	253
ICA L221	251	261	261	260	241	261	269	258
ICA L223	261	264	234	262	250	251	278	257
INV138	255	267	266	254	251	267	267	261
INV302	253	255	257	240	233	258	253	250
INV443	235	238	240	236	220	245	241	236
INV534	238	231	239	227	223	235	239	233
MIT11 DMR	251	252	255	255	247	251	262	253
Pi4243	251	242	255	235	240	258	253	248
Pi4257	259	233	250	235	237	240	269	246
Pi4283	235	241	255	244	240	241	258	245
Pi4287	228	224	241	223	226	231	240	231
SR52-F	254	263	250	250	239	251	268	254
SR52-M	258	256	254	251	245	257	261	255
Tuxpeno	254	240	250	244	239	250	257	248
Tx602	262	250	260	256	235	254	241	251
77-4407	234	233	244	218	228	234	244	233
77-4412	228	232	243	210	230	225	249	231
77-4441	228	236	240	213	230	243	245	234
77-4449	228	246	242	224	230	250	250	239
77-4544	254	252	270	249	254	277	259	259
Mean	248	247	254	244	239	251	256	248

H636 : 238 H650 : 239 H763 : 239 H767 : 242
H823 : 251 H824 : 257 X105A: 249 X304C: 243

Appendix 34. Average ear height of 225 hybrids evaluated during 3 seasons.

(unit : cm)

Female \ Male	Hi26	Hi28	Hi29	Hi31	Hi33	Hi34	Tx601	Mean
CIMMYT-A21	120	127	138	116	120	122	124	124
CIMMYT-T11ES	129	124	134	114	106	129	121	122
Fla.2AT-112	106	103	106	98	87	114	106	103
Fla.2AT-114	101	111	103	99	93	108	112	104
Fla.2BT-54	119	119	127	111	109	129	128	120
H632A	128	129	132	117	115	127	126	125
H632F	114	131	144	120	115	126	132	126
H632G	126	126	120	121	117	132	128	124
ICA L25	126	133	138	117	112	137	116	125
ICA L27	108	121	122	110	102	126	115	115
ICA L210	126	120	113	114	113	119	119	117
ICA L221	113	126	121	110	108	123	121	117
ICA L223	120	134	115	112	111	116	131	120
INV138	125	127	123	115	115	131	123	123
INV302	120	128	120	110	106	127	126	120
INV443	103	115	110	102	91	114	102	105
INV534	113	102	118	100	99	111	102	106
MIT11 DMR	121	127	129	117	111	120	125	121
Pi4243	115	115	114	98	97	122	112	110
Pi4257	114	104	110	98	102	110	117	107
Pi4283	103	119	116	100	104	115	114	110
Pi4287	103	110	109	96	98	107	111	105
SR52-F	114	124	110	109	103	120	120	114
SR52-M	116	117	114	109	109	120	116	115
Tuxpeno	123	117	122	112	110	132	121	119
Tx602	123	114	121	116	105	126	109	116
77-4407	108	113	112	94	106	118	113	109
77-4412	105	111	112	89	104	106	118	106
77-4441	107	116	108	91	107	119	106	108
77-4449	105	117	111	99	106	117	110	109
77-4544	108	117	126	103	105	131	112	114
Mean	115	119	119	107	106	121	117	115

H636 : 99	H650 :110	H763 :107	H767 :103
H823 :118	H824 :124	X105A:108	X304C:106

Appendix 35. LAI of 225 hybrids in March planting.

Male Female	Hi26	Hi28	Hi29	Hi31	Hi33	Hi34	Tx601	Mean
CIMMYT-A21	4.32	3.76	3.86	4.34	4.19	4.50	3.87	4.12
CIMMYT-T11ES	4.81	4.38	4.30	4.37	4.38	5.10	4.00	4.48
Fla.2AT-112	4.38	3.76	4.01	4.15	4.16	4.96	3.62	4.15
Fla.2AT-114	4.17	4.16	3.94	3.96	4.07	5.48	3.97	4.25
Fla.2BT-54	4.24	3.73	3.48	3.85	3.49	4.65	3.99	3.92
H632A	4.90	4.37	4.64	4.47	4.33	5.28	4.53	4.65
H632F	4.71	3.99	4.54	4.36	4.25	5.53	4.10	4.49
H632G	4.48	4.64	4.41	4.54	4.15	4.60	4.24	4.43
ICA L25	4.53	4.65	4.28	4.34	4.53	5.40	4.20	4.56
ICA L27	4.30	4.14	4.07	4.09	4.41	5.43	3.91	4.33
ICA L210	4.47	4.24	4.09	4.01	4.31	4.89	4.34	4.33
ICA L221	4.82	4.30	4.24	4.31	4.29	5.37	4.49	4.54
ICA L223	4.91	4.54	4.03	4.50	4.19	5.01	4.26	4.50
INV138	4.56	4.16	5.96	3.99	3.78	4.36	3.81	4.09
INV302	4.38	4.40	3.74	4.14	3.66	5.34	3.92	4.22
INV443	4.33	4.30	4.11	4.15	3.99	4.74	3.88	4.21
INV534	4.40	3.56	3.43	3.55	3.89	4.81	3.85	3.93
MIT11 DMR	3.93	3.98	3.84	3.56	3.89	4.71	3.78	3.95
Pi4243	3.96	3.90	3.56	3.64	4.00	4.38	3.55	3.85
Pi4257	3.91	3.67	4.06	3.95	3.65	4.13	3.95	3.90
Pi4283	4.54	4.30	4.22	4.06	4.51	4.49	3.79	4.27
Pi4287	4.44	3.80	3.92	3.74	3.76	4.29	4.29	4.03
SR52-F	4.58	4.56	4.45	4.53	4.25	5.03	4.19	4.51
SR52-M	5.22	4.67	4.29	4.46	4.38	5.47	4.20	4.67
Tuxpeno	4.02	3.46	3.55	3.43	3.22	3.83	3.44	3.56
Tx602	4.32	4.21	4.00	3.83	3.78	4.56	3.35	4.00
77-4407	4.50	4.30	3.87	3.47	4.33	4.78	4.17	4.20
77-4412	3.98	4.30	4.37	3.49	4.13	5.03	4.00	4.18
77-4441	3.94	4.11	4.04	3.46	3.87	4.98	3.75	4.02
77-4449	3.82	3.99	4.07	3.78	3.88	4.82	3.64	4.00
77-4544	4.65	3.75	3.87	3.69	3.76	4.61	3.60	3.99
Mean	4.40	4.13	4.04	4.01	4.05	4.86	3.96	4.21

H636 : 3.57 H650 : 3.74 H763 : 4.18 H767 : 3.83
H823 : 4.26 H824 : 5.03 X105A: 4.52 X304C: 3.80

Appendix 36. Number of stem node of 225 hybrids in March planting.

Male / Female	Hi26	Hi28	Hi29	Hi31	Hi33	Hi34	Tx601	Mean
CIMMYT-A21	14.1	14.5	15.3	13.4	14.0	13.9	16.6	14.5
CIMMYT-T11ES	15.4	14.5	15.1	14.8	13.5	14.1	16.6	14.9
Fla2AT-112	13.5	13.4	14.3	13.5	12.2	13.8	15.5	13.7
Fla.2AT-114	13.9	13.3	13.7	13.9	13.3	13.9	15.3	13.9
Fla.2BT-54	14.0	12.9	13.7	13.5	13.1	13.7	15.6	13.8
H632A	13.9	14.8	14.2	14.3	13.0	14.4	16.0	14.3
H632F	14.2	14.2	15.8	14.3	13.3	13.8	14.9	14.3
H632G	13.5	13.7	13.7	13.5	13.6	13.4	15.6	13.8
ICA L25	13.9	15.1	14.0	14.9	13.4	13.7	15.5	14.3
ICA L27	13.7	14.0	14.6	14.4	13.3	13.5	16.1	14.2
ICA L210	13.9	13.9	14.1	13.9	12.9	13.5	15.6	14.0
ICA L221	13.9	13.8	14.4	13.9	12.9	13.6	15.2	13.9
ICA L223	13.9	14.1	14.3	14.5	13.1	14.2	16.1	14.3
INV138	13.9	13.1	14.1	13.6	12.6	13.2	15.0	13.6
INV302	13.9	13.5	14.3	13.5	13.1	14.6	15.3	14.0
INV443	13.0	12.4	13.6	13.5	11.4	13.0	14.4	13.0
INV534	13.1	13.5	13.8	13.4	12.6	13.1	14.7	13.4
MIT11 DMR	13.9	12.9	14.0	13.4	13.4	13.8	14.4	13.7
Pi4243	13.8	12.8	13.8	13.4	12.7	13.6	15.0	13.6
Pi4257	13.3	13.7	13.4	13.8	13.2	13.4	14.5	13.6
Pi4283	13.5	13.7	14.4	13.5	12.4	13.0	15.1	13.6
Pi4287	13.2	13.3	14.2	13.8	13.4	14.1	15.5	13.9
SR52-F	13.5	13.0	13.6	13.4	12.4	13.5	15.3	13.5
SR52-M	12.7	13.1	13.6	13.0	12.9	13.2	15.2	13.4
Tuxpeno	14.0	13.9	14.7	14.5	13.4	14.0	15.8	14.3
Tx602	14.5	13.9	15.8	14.8	13.7	15.0	15.5	14.7
77-4407	13.0	13.2	14.4	13.9	13.2	13.7	14.8	13.7
77-4412	13.1	13.5	13.8	13.2	13.5	13.6	15.0	13.7
77-4441	14.0	14.1	14.5	13.3	13.0	14.2	15.2	14.0
77-4449	14.0	13.7	14.5	13.3	13.3	13.4	14.6	13.8
77-4544	13.5	14.2	14.6	14.0	13.0	13.8	15.5	14.1
Mean	13.7	13.6	14.3	13.8	13.0	13.7	15.3	13.9

H636 : 13.4 H650 : 13.1 H763 : 13.4 H767 : 13.7
H823 : 13.3 H824 : 13.8 X105A: 13.7 X304C: 13.4

Appendix 37. Stem diameter of 225 hybrids in March planting

(unit : mm)

Male Female	Hi26	Hi28	Hi29	Hi31	Hi33	Hi34	Tx601	Mean
CIMMYT-A21	24.5	22.5	22.5	22.5	23.0	23.0	25.5	23.4
CIMMYT-T11ES	24.0	23.5	25.0	24.5	22.0	23.0	24.0	23.7
Fla.2AT-112	22.5	22.0	22.5	22.5	24.0	23.0	22.0	22.6
Fla.2AT-114	24.0	23.0	23.0	23.0	23.0	24.5	24.0	23.5
Fla.2BT-54	23.5	22.5	23.5	21.5	22.0	23.5	23.0	22.8
H632A	26.0	23.5	25.0	25.0	23.0	24.0	27.0	24.8
H632F	27.0	21.5	27.0	25.0	23.0	25.5	23.5	24.6
H632G	25.0	27.0	22.5	24.5	22.0	24.5	24.0	24.2
ICA L25	26.0	26.0	23.5	24.5	23.5	23.0	23.5	24.3
ICA L27	23.5	22.5	23.0	22.5	22.5	23.0	22.0	22.7
ICA L210	23.5	21.5	22.0	23.0	22.0	21.5	24.0	22.5
ICA L221	24.5	24.0	22.0	23.5	23.5	24.0	24.5	23.7
ICA L223	25.5	24.5	23.0	24.5	22.5	24.0	25.0	24.1
INV138	23.5	23.0	23.0	23.0	22.5	24.0	22.5	23.1
INV302	22.5	23.5	23.5	23.5	21.5	24.0	24.5	23.1
INV443	23.5	22.5	22.0	24.5	20.5	22.0	23.5	22.6
INV534	24.5	21.0	21.0	21.5	20.0	22.0	23.0	21.9
MIT11 DMR	22.5	22.0	22.0	20.5	21.5	21.0	21.5	21.6
Pi4243	24.5	22.5	23.0	21.5	22.0	24.0	23.0	22.9
Pi4257	22.0	22.0	26.5	23.5	22.0	22.5	23.5	23.1
Pi4283	25.0	24.5	23.5	24.0	25.0	23.0	24.5	24.2
Pi4287	25.0	23.0	23.5	23.0	23.0	24.5	23.5	23.6
SR52-F	23.5	23.5	24.5	25.5	22.0	24.5	23.5	23.9
SR52-M	24.0	24.0	23.0	24.0	23.0	23.5	23.0	23.5
Tuxpeno	26.0	24.0	23.5	23.0	22.5	24.0	25.5	24.1
Tx602	23.5	23.5	24.0	23.5	21.0	23.0	21.5	22.9
7704407	23.0	22.0	22.5	22.0	22.5	22.5	23.5	22.6
77-4412	21.0	23.5	23.5	21.5	22.0	23.5	22.0	22.4
77-4441	23.5	24.0	24.5	21.5	23.0	23.5	23.0	23.3
77-4449	23.0	23.0	24.5	23.5	22.5	25.0	23.0	23.5
77-4544	26.0	23.5	24.0	24.5	21.0	23.0	22.0	23.4
Mean	24.1	23.2	23.4	23.2	22.4	23.4	23.5	23.3

H636 : 22.0　H650 : 24.0　H763 : 23.0　H767 : 24.0
H823 : 21.5　H824 : 24.5　X105A: 24.0　X304C: 24.0

Appendix 38. Average rust ratings of 225 hybrids evaluated during 3 different seasons.

(Scale:1-7)

Male / Female	Hi26	Hi28	Hi29	Hi31	Hi33	Hi34	Tx601	Mean
CIMMYT-A21	2.3	2.3	2.7	3.7	3.0	2.5	1.8	2.6
CIMMYT-T11ES	2.5	2.0	2.5	3.0	2.5	2.0	1.8	2.3
Fla.2AT-112	4.3	4.0	3.7	6.0	4.3	2.8	3.2	4.1
Fla.2AT-114	2.8	3.8	3.3	5.0	4.3	2.2	2.2	3.4
Fla.2BT-54	3.3	2.8	3.2	4.8	3.8	3.0	3.3	3.5
H632A	3.2	2.7	3.0	4.0	3.5	2.2	2.8	3.1
H632F	2.7	2.3	3.8	5.2	2.5	2.2	3.3	3.1
H632G	3.2	4.3	4.5	4.8	4.2	2.8	3.7	3.9
ICA L25	3.7	3.7	3.7	4.5	3.8	3.5	2.6	3.6
ICA L27	3.2	3.5	2.5	4.7	4.3	2.3	2.7	3.3
ICA L210	2.8	2.5	3.5	4.3	4.0	2.3	2.2	3.1
ICA L221	3.2	2.7	2.8	4.0	3.0	2.8	2.3	3.0
ICA L223	3.3	2.3	3.0	4.8	4.2	2.2	2.5	3.2
INV138	3.7	3.2	3.7	5.2	4.0	2.5	2.7	3.6
INV302	2.8	2.2	3.2	4.3	5.0	2.5	2.5	3.2
INV443	3.3	2.2	3.5	3.2	3.7	2.2	2.2	2.9
INV534	4.2	2.8	3.3	4.8	2.7	2.3	2.2	3.2
MIT11 DMR	3.0	2.3	2.8	4.3	3.5	3.0	2.5	3.1
Pi4243	3.5	4.2	4.0	6.0	4.5	3.2	4.0	4.2
Pi4257	4.0	4.8	3.8	4.8	4.5	3.3	3.5	4.1
Pi4283	3.7	3.5	4.3	4.5	4.7	3.3	3.8	4.0
Pi4287	4.3	4.5	4.3	5.3	5.2	4.0	3.5	4.5
SR52-F	2.8	2.7	3.5	4.2	3.8	2.5	3.3	3.3
SR52-M	2.7	3.0	3.0	4.8	3.8	2.5	3.2	3.3
Tuxpeno	4.0	4.2	4.2	5.0	4.7	3.3	3.3	4.1
Tx602	3.2	3.2	3.0	4.3	4.3	3.2	3.0	3.5
77-4407	4.3	3.3	4.0	5.3	4.7	3.3	3.5	4.1
77-4412	4.3	3.5	4.0	5.5	4.2	3.7	3.5	4.1
77-4441	3.8	4.2	4.5	5.7	3.8	3.5	3.2	4.1
77-4449	3.3	3.3	4.0	5.2	4.7	3.7	3.0	3.9
77-4544	3.5	3.3	3.5	4.8	4.2	2.8	2.7	3.6
Mean	3.4	3.2	3.5	4.7	4.0	2.8	2.9	3.5

H636 : 4.2   H650 : 3.8   H763 : 3.7   H767 : 4.7

H823 : 2.7   H824 : 2.5   X105A: 2.3   X304C: 2.7

Appendix 39. Average filled ear length of 225 hybrids over 2 seasons.

(unit : cm)

Male Female	Hi26	Hi28	Hi29	Hi31	Hi33	Hi34	Tx601	Mean
CIMMYT-A21	15.6	15.0	17.4	15.4	16.3	16.6	15.9	16.0
CIMMYT-T11ES	17.8	16.8	16.4	14.9	17.0	16.4	15.7	16.4
Fla.2AT-112	16.1	15.5	17.5	13.5	16.1	15.8	14.5	15.5
Fla.2AT-114	16.4	16.6	16.5	16.2	17.1	16.6	16.7	16.6
Fla.2BT-54	17.5	14.4	15.9	15.5	17.3	18.0	16.7	16.5
H632A	18.3	16.2	17.6	16.2	15.8	18.0	15.7	16.8
H632F	18.0	16.0	17.7	16.6	17.8	18.6	17.2	17.4
H632G	15.8	16.6	17.1	17.4	17.6	16.2	17.1	16.8
ICA L25	16.5	15.1	15.6	15.8	17.7	16.4	16.1	16.1
ICA L27	15.9	15.7	16.2	14.3	15.6	17.7	15.3	15.8
ICA L210	16.7	16.2	14.9	15.6	17.5	17.4	14.7	16.1
ICA L221	16.4	16.7	15.4	17.0	18.4	19.4	17.7	17.3
ICA L223	16.7	16.5	16.9	15.3	17.3	17.4	16.6	16.7
INV138	16.6	16.3	16.2	14.5	15.5	15.1	15.7	15.7
INV302	15.2	14.6	15.1	14.5	16.4	15.9	14.5	15.2
INV443	14.6	13.8	13.3	13.0	14.0	13.3	14.1	13.7
INV534	17.2	16.2	15.3	15.0	18.1	16.7	15.2	16.2
MIT11 DMR	15.5	16.2	17.2	14.5	17.0	14.9	17.1	16.0
Pi4243	15.7	16.2	15.9	12.3	17.4	16.3	15.3	15.6
Pi4257	14.4	13.2	13.8	13.3	14.9	13.9	14.8	14.0
Pi4283	13.8	16.5	15.4	14.1	16.7	15.4	14.3	15.2
Pi4287	14.9	13.0	12.7	12.6	15.1	14.6	14.4	13.9
SR52-F	18.2	15.4	16.7	16.1	15.3	16.4	17.7	16.5
SR52-M	17.6	16.9	16.2	16.1	17.1	16.7	15.7	16.6
Tuxpeno	15.5	14.7	15.1	14.6	16.0	15.2	15.3	15.2
Tx602	16.6	15.3	15.8	15.5	16.6	19.3	13.8	16.1
77-4407	15.8	16.8	15.5	13.0	16.6	13.2	15.7	15.2
77-4412	15.0	13.8	15.6	12.4	15.4	15.0	14.6	14.5
77-4441	14.2	15.0	13.5	11.6	16.3	15.2	14.6	14.4
77-4449	14.6	14.1	14.0	13.1	15.4	16.3	14.9	14.6
77-4544	17.4	14.7	16.3	15.4	17.4	17.9	15.0	16.3
Mean	16.1	15.5	15.8	14.7	16.5	16.3	15.6	15.8

H636 : 15.9 H650 : 16.4 H763 : 15.7 H767 : 13.2
H823 : 17.2 H824 : 17.1 X105A: 13.5 X304C: 17.1

Appendix 40. Average number of kernel rows of 225 hybrid over 2 seasons.

Male Female	Hi26	Hi28	Hi29	Hi31	Hi33	Hi34	Tx601	Mean
CIMMYT-A21	15.3	17.7	14.9	16.3	14.5	13.4	15.5	15.4
CIMMYT-T11ES	15.8	14.9	14.8	15.7	14.1	13.1	14.1	14.6
Fla.2AT-112	14.7	15.0	14.2	14.6	13.2	12.4	13.9	14.0
Fla.2AT-114	13.7	13.6	12.9	14.2	13.2	11.8	12.4	13.1
Fla2BT-54	13.5	14.1	13.5	15.1	12.4	10.7	14.1	13.3
H632A	13.2	13.1	12.7	13.4	12.5	11.5	13.7	12.9
H632F	13.9	13.5	14.6	13.7	12.8	12.5	14.0	13.5
H632G	13.6	14.5	13.0	13.6	12.9	12.9	13.4	13.4
ICA L25	13.8	15.3	14.9	15.1	13.3	12.8	14.3	14.2
ICA L27	14.4	15.6	14.3	15.0	14.7	13.0	15.2	14.6
ICA L210	13.9	14.6	14.8	14.1	13.8	11.9	13.7	13.8
ICA L221	13.5	14.8	14.1	15.1	12.5	12.7	14.0	13.8
ICA L223	14.8	15.1	14.2	14.7	13.6	14.0	15.2	14.5
INV138	14.3	14.8	16.3	14.7	14.0	13.8	15.6	14.8
INV302	15.6	15.5	16.1	14.5	14.5	13.1	14.8	14.9
INV443	14.7	14.3	14.3	14.8	14.7	13.8	15.3	14.6
INV534	13.9	14.7	14.7	14.0	13.1	12.4	13.6	13.8
MIT11 DMR	15.3	14.0	14.1	15.0	13.7	12.5	14.4	14.1
Pi4243	15.0	14.8	13.9	14.9	14.2	13.2	15.4	14.5
Pi4257	16.1	15.3	14.7	15.5	14.6	15.0	16.8	15.4
Pi4283	15.6	16.7	15.6	14.3	13.8	13.0	15.7	14.9
Pi4287	13.3	14.6	13.7	13.3	13.2	14.1	15.1	13.9
SR51-F	13.3	14.9	13.0	13.1	12.3	12.4	13.1	13.2
SR52-M	12.1	13.8	12.7	12.9	11.9	11.7	12.6	12.5
Tuxpeno	13.0	12.7	13.6	14.0	11.9	12.8	13.9	13.1
Tx602	15.2	14.3	14.8	14.6	14.2	11.9	15.1	14.3
77-4407	14.0	14.7	14.6	13.7	13.4	11.9	14.7	13.8
77-4412	15.6	14.2	14.5	13.5	13.8	12.8	15.1	14.2
77-4441	14.6	16.5	14.8	13.4	14.3	13.4	16.0	14.7
77-4449	15.0	16.2	15.9	14.2	15.1	13.3	15.5	15.0
77-4544	13.7	13.9	14.9	14.2	13.4	12.2	14.2	13.8
Mean	14.3	14.8	14.3	14.4	13.5	12.8	14.5	14.1

H636 : 12.9 H650 : 14.3 H763 : 14.0 H767 : 14.3
H823 : 12.5 H824 : 13.5 X105A: 15.6 X304C: 12.8

Appendix 41. Average number of kernels/row of 225 hybrids over 2 seasons.

Male Female	Hi26	Hi28	Hi29	Hi31	Hi33	Hi34	Tx601	Mean
CIMMYT-A21	34.9	32.4	33.1	29.0	35.5	32.9	33.8	33.1
CIMMYT-T11ES	38.3	36.5	35.9	30.9	37.5	38.0	38.2	36.4
Fla.2AT-112	36.1	32.8	37.6	27.8	37.6	33.4	32.6	34.0
Fla.2AT-114	36.6	36.7	36.0	32.1	34.8	37.7	36.6	35.8
Fla.2BT-54	38.9	32.4	34.8	30.7	40.2	39.7	37.1	36.2
H632A	35.2	32.4	35.7	29.9	32.8	35.6	33.4	33.6
H632F	32.8	32.5	33.1	30.8	39.1	37.9	36.2	34.6
H632G	33.9	35.3	32.6	35.0	37.5	34.1	36.5	35.0
ICA L25	34.9	32.2	31.8	31.5	36.7	35.7	34.8	33.9
ICA L27	31.6	32.9	32.0	27.6	33.3	34.8	30.6	31.8
ICA L210	36.5	34.2	31.1	29.6	40.6	37.9	34.9	35.0
ICA L221	34.8	34.0	29.7	33.0	37.9	38.5	38.0	35.1
ICA L223	36.1	32.1	31.9	26.6	33.8	35.1	33.0	32.7
INV138	36.4	32.4	33.0	29.5	32.9	31.9	33.4	32.8
INV302	32.0	34.5	31.8	32.1	38.3	37.7	35.8	34.6
INV443	32.0	31.5	30.9	26.3	31.0	30.8	32.4	30.7
INV534	38.1	34.6	35.8	31.1	39.7	39.9	34.0	36.2
MIT11 DMR	35.7	34.4	34.8	28.3	36.3	33.2	37.1	34.2
Pi4243	35.7	38.1	35.6	27.1	40.0	39.8	36.3	36.1
Pi4257	33.4	32.5	30.8	26.6	34.8	35.4	34.7	32.6
Pi4283	28.8	34.6	32.2	28.7	34.8	34.5	30.4	32.0
Pi4287	31.6	24.4	25.8	26.3	33.9	30.6	29.2	28.8
SR52-F	37.1	34.3	34.8	30.7	34.9	36.6	37.5	35.1
SR52-M	38.3	34.9	34.3	31.8	35.9	39.8	33.1	35.4
Tuxpeno	35.8	35.0	34.1	29.7	35.9	36.0	35.3	34.5
Tx602	37.2	32.9	35.7	30.4	37.2	39.5	31.8	34.9
77-4407	38.1	39.9	35.4	25.1	39.8	31.1	36.7	35.2
77-4412	32.3	31.9	33.5	18.9	38.3	34.5	33.8	31.9
77-4441	33.8	34.5	31.2	25.8	38.3	35.0	33.2	33.1
77-4449	30.9	32.8	31.4	26.4	36.9	36.3	36.4	33.0
Mean	35.1	33.6	33.3	29.0	36.5	35.9	34.5	34.0

H636 : 33.8 H650 : 38.4 H763 : 32.5 H767 : 26.8
H823 : 39.7 H824 : 37.1 X105A: 32.8 X304C: 37.7

Appendix 42. Average 100 kernel weight of 225 hybrids evaluated during 2 seasons.

(unit: g)

Female \ Male	Hi26	Hi28	Hi29	Hi31	Hi33	Hi34	Tx601	Mean
CIMMYT-A21	29.2	25.7	29.4	27.4	31.0	31.1	28.4	28.9
CIMMYT-T11ES	29.8	27.7	29.0	26.7	31.0	28.4	25.1	28.2
Fla.2AT-112	29.2	27.3	28.1	25.4	27.4	30.6	25.2	27.6
Fla.2AT-114	28.5	32.6	32.0	26.3	28.4	30.4	30.1	29.8
Fla.2BT-54	28.7	27.0	29.2	28.6	28.6	30.9	28.7	28.8
H632A	31.6	33.4	33.1	35.5	32.1	38.4	33.8	34.0
H632F	31.9	30.8	33.7	28.6	29.4	33.7	30.3	31.2
H632G	29.8	30.9	30.7	31.6	29.8	29.3	29.6	30.2
ICA L25	34.0	31.3	28.5	30.7	30.4	29.7	28.2	30.4
ICA L27	32.0	30.3	29.8	31.6	31.6	34.4	31.0	31.5
ICA L210	30.1	28.4	31.4	29.4	27.4	30.8	27.6	29.3
ICA L221	32.7	31.2	32.4	27.6	31.0	34.5	29.7	31.3
ICA L223	34.1	33.3	32.2	34.2	33.1	35.9	28.7	33.1
INV138	28.3	31.0	29.8	25.5	28.2	30.3	28.7	28.8
INV302	28.2	25.9	26.2	25.2	24.6	28.9	23.2	26.0
INV443	30.1	31.0	29.8	32.9	30.0	31.5	28.4	30.5
INV534	28.0	28.6	27.2	29.6	27.3	27.6	28.3	28.1
MIT11 DMR	27.2	26.9	26.5	29.6	27.8	29.8	25.7	27.6
Pi4243	20.1	26.2	27.0	18.7	25.3	26.6	24.1	24.0
Pi4257	25.7	23.6	29.4	27.3	25.6	25.1	26.6	26.2
Pi4283	27.6	28.1	30.0	28.8	30.8	29.2	26.5	28.7
Pi4287	30.1	29.4	31.3	24.5	24.4	29.5	26.1	27.9
SR52 F	34.2	30.4	32.6	33.2	31.1	33.2	29.3	32.0
SR52 M	34.1	33.5	30.8	31.1	34.8	32.2	30.9	32.5
Tuxpeno	29.9	28.3	27.1	26.8	28.9	29.0	27.3	28.2
Tx602	28.1	28.5	26.6	29.7	25.5	29.8	22.9	27.3
77-4407	27.8	25.4	27.3	24.8	26.8	28.8	28.0	27.0
77-4412	26.5	30.8	27.6	26.2	26.0	28.0	25.5	27.2
77-4441	27.0	28.3	29.5	23.9	25.6	27.3	25.4	26.7
77-4449	27.3	25.5	27.9	24.3	24.6	30.3	25.3	26.5
77-4544	29.6	28.9	29.9	27.1	32.2	37.5	25.0	30.0
Mean	29.4	29.0	29.6	28.2	28.7	30.7	27.5	29.0

H636 : 27.8 H650 : 28.7 H763 : 29.2 H767 : 29.3
H823 : 29.5 H824 : 27.5 X105A: 29.0 X304C: 27.2

Appendix 43. Barrenness of 225 hybrids in November planting.

(unit : %)

Male Female	Hi26	Hi28	Hi29	Hi31	Hi33	Hi34	Tx601	Mean
CIMMYT-A21	46	21	32	38	57	34	36	38
CIMMYT-T11ES	65	30	46	50	40	34	50	45
Fla.2AT-112	65	44	63	100	82	25	63	63
Fla.2AT-114	17	38	32	75	67	19	46	42
Fla.2BT-54	67	62	73	96	69	59	77	72
H632A	76	63	75	90	79	38	83	71
H632F	44	63	79	96	38	48	65	62
H632G	65	77	88	96	84	61	92	80
ICA L25	82	65	65	73	46	51	67	64
ICA L27	53	44	31	90	79	52	75	61
ICA L210	25	17	42	61	50	27	27	36
ICA L221	44	19	36	65	42	42	40	41
ICA L223	59	27	56	94	73	36	61	58
INV138	36	44	36	77	78	38	54	52
INV302	40	32	38	53	71	30	56	46
INV443	33	44	44	52	58	19	52	43
INV534	38	23	36	57	36	15	44	36
MIT11 DMR	48	33	38	79	44	29	58	47
Pi4243	52	63	96	100	86	48	92	77
Pi4257	61	59	61	96	69	40	76	66
Pi4283	75	67	84	100	79	61	75	77
Pi4287	65	75	92	94	100	67	92	84
SR52-F	77	71	90	96	63	54	80	76
SR52-M	65	82	93	94	73	59	83	78
Tuxpeno	42	63	90	96	88	17	79	68
Tx602	44	63	52	84	77	61	92	68
77-4407	89	46	67	96	80	46	55	68
77-4412	73	52	67	98	65	42	48	64
77-4441	23	63	73	100	71	42	79	64
77-4449	32	53	57	100	73	25	53	56
77-4544	65	52	63	96	76	48	71	67
Mean	54	50	61	78	68	41	65	60

H636 : 61   H650 : 52   H763 : 61   H767 : 90

H823 : 28   H824 : 34   X105A: 32   X304C: 40

Appendix 44. Analysis of variance for filled ear length and number of kernel rows of 225 hybrids in different seasons.

Source	df	Mean squares			
		Filled ear length		Number of kernel rows	
		March	May	March	May
Replication	1	13.54	0.17	2.56	1.32
Hybrid (Unadj.)	224	4.99	5.49	2.68	3.02
Block within rep. (Adj.)	28	2.67*	1.72	0.74	0.62
Intra-block error	196	1.47	1.66	0.58	0.63
Randomized complete block error	224	1.62	1.67	0.60	0.63

* Significant at 5 % probability level.

Appendix 45. Analysis of variance for number of kernels/row and 100 kernel weight of 225 hybrids in different seasons.

Source	df	Mean squares			
		Number of kernels per row		100 kernel weight	
		March	May	March	May
Replication	1	94.85	9.97	4.25	25.43
Hybrid (Unadj.)	224	28.10	33.66	20.13	20.03
Block within rep. (Adj.)	28	11.55*	11.29	13.85**	3.83
Intra-block error	196	6.69	8.75	4.11	3.78
Randomized complete block error	224	7.30	9.06	5.33	3.78

* Significant at 5 % level. ** Significant at 1 % level.

Appendix 46. Average days to tasseling, plant and ear height, LAI, and rust rating of a 7-entry diallel.

Hybrids	Days to tasseling (day)	Plant Height (cm)	Ear height (cm)	LAI	Rust (1-7)
Hi26 x Hi28	56.4	233	97	3.97	2.6
Hi26 x Hi29	57.2	228	91	4.00	3.1
Hi26 x Hi31	56.8	219	84	3.98	4.5
Hi26 x Hi33	55.8	225	83	4.10	4.0
Hi26 x Hi34	59.3	232	94	4.40	2.3
Hi26 x Tx601	58.3	241	94	4.01	3.3
Hi28 x Hi29	56.4	227	97	4.07	3.3
Hi28 x Hi31	55.8	230	98	3.95	3.6
Hi28 x Hi33	54.3	213	83	3.59	3.8
Hi28 x Hi34	57.7	222	103	4.38	2.7
Hi28 x Tx601	58.3	239	105	3.97	3.3
Hi29 x Hi31	56.3	230	91	3.92	4.8
Hi29 x Hi33	55.3	217	82	3.54	4.0
Hi29 x Hi34	57.9	224	101	4.52	2.8
Hi29 x Tx601	58.9	251	104	3.80	3.4
Hi31 x Hi33	55.2	216	78	3.48	5.3
Hi31 x Hi34	57.8	222	90	4.16	4.1
Hi31 x Tx601	58.7	238	93	3.82	4.1
Hi33 x Hi34	55.5	209	84	4.01	3.8
Hi33 x Tx601	57.2	234	92	3.94	3.8
Hi34 x Tx601	60.2	238	100	4.48	2.6
Mean	57.1	228	93	4.00	3.6

Appendix 47. Estimates of SCA and GCA effects for plant height and ear height of 7-entry diallel over 3 different seasons.

Inbreds	SCA effects						GCA effects
	Hi28	Hi29	Hi31	Hi33	Hi34	Tx601	
Hi26	3.62 1.17	-4.14 -1.12	-8.48 -2.07	6.36 3.65	6.11 0.62	-3.46 -2.25	1.95 -2.48
Hi28		-1.53 -2.90	5.06 4.40	-3.44 -4.30	-1.19 1.58	-2.51 0.05	-0.84 5.55
Hi29			2.96 0.37	-1.96 -1.92	-1.79 3.22	6.47 2.35	1.85 2.25
Hi31				0.96 0.55	1.29 -1.40	-1.78 -1.85	-2.65 -4.38
Hi33					-3.79 -1.85	1.89 3.87	-10.74 -10.51
Hi34						-0.61 -2.17	-4.15 3.19
Tx601							14.58 6.39

Upper and lower values are plant height and ear height, respectively.

Appendix 48. Estimates of SCA and GCA effects for filled ear length and number of kernel rows of a 7-entry diallel evaluated during 3 different seasons.

Inbreds	SCA effects						GCA effects
	Hi28	Hi29	Hi31	Hi33	Hi34	Tx601	
Hi26	-0.43	-0.03	0.09	0.35	0.44	-0.42	0.13
	0.61	-0.51	-0.22	-0.89	0.48	0.52	0.03
Hi28		-0.04	0.95	0.03	-0.08	-0.42	0.44
		0.18	0.45	-0.73	-0.68	0.16	1.16
Hi29			-0.07	-0.17	0.50	-0.18	0.07
			-0.33	0.66	0.20	-0.20	0.30
Hi31				0.09	-1.21	0.14	-1.23
				0.43	0.09	-0.43	-0.84
Hi33					-0.41	0.12	0.10
					0.24	0.28	-0.76
Hi34						0.76	0.14
						-0.34	-0.06
Tx601							0.49
							0.17

Upper and lower values are filled ear length and number of kernel rows, respectively.

Appendix 49. Estimates of SCA and GCA effects for number of kernels per row and 100 kernel weight of a 7-entry diallel evaluated during 3 different seasons.

Inbreds	SCA effects						GCA effects
	Hi28	Hi29	Hi31	Hi33	Hi34	Tx601	
Hi26	-1.20 0.74	0.11 -1.15	-1.23 0.97	1.52 0.86	1.54 -0.97	-0.74 -0.46	0.31 0.26
Hi28		0.03 -0.18	2.53 1.28	-1.38 0.74	0.11 -1.82	0.10 -0.77	1.04 0.59
Hi29			-0.43 1.02	0.03 0.11	0.58 0.54	-0.33 0.36	-0.77 -0.65
Hi31				1.31 -1.56	-1.42 -1.12	-0.78 -0.60	-4.05 1.14
Hi33					-2.12 0.51	0.63 -0.66	0.57 -1.58
Hi34						1.30 2.85	1.79 1.09
Tx601							1.11 -0.84

Upper and lower values are number of kernels per row and 100 kernel weight, respectively.

Appendix 50. Combined analysis of combining ability for filled ear length and number of kernel rows of 7-entry diallel evaluated in 3 different seasons.

Source	df	Mean squares	
		Filled ear length	Number of kernel rows
GCA	6	4.98**	6.89**
SCA	14	0.92**	0.95**
Season (S)	2	351.19	123.17
GCA x S	12	1.30**	6.05**
SCA x S	28	0.58*	0.59**
Error	60	0.33	0.24

Appendix 51. Combined analysis of combining ability for number of kernels per row and 100 kernel weight of a 7-entry diallel evaluated in 3 different seasons.

Source	df	Mean squares	
		Number of kernels per row	100 kernel weight
GCA	6	57.35**	16.39**
SCA	14	6.01**	5.39**
Season (S)	2	2641.43	969.73
GCA x S	12	7.33**	3.63**
SCA x S	28	3.54	1.47
Error	60	2.09	0.94

* Significant at 5 % probability level.

** Significant at 1 % probability level.

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