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AGRONOMIC EVALUATION OF THE LEAFY (LFY) TRAIT IN MAIZE (Zea maysL.)

by

Mohamed Barre Ahmed

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ABSTRACT

AGRONOMIC EVALUATION OF THE LEAFY (LFY) TRAIT IN MAIZE (*Zea mays* L.)

by

Mohamed Barre Ahmed

Enhancement of assimilate supply through increase of leaf number at the top of the canopy may improve the grain yield in maize. Michigan State University received *Lfy* germplasm from Dr. D. L. Shaver who has a U.S. patent for use of the leafy *Lfy*, trait in maize production. Sixty-four experimental *Lfy* hybrids were compared with eight commercial non leafy hybrids in replicated yield trials in order to determine their agronomic potential. Two experiments were conducted in Cass and Saginaw Counties, Michigan in 1986. Several agronomic characteristics including leaf number above the primary ear were recorded. Leaf shading was calculated as the distance between two leaves on the same side of the stalk. Correlation analyses were used to determine the interrelationship among all agronomic characteristics for each location and over locations. Results suggested that the four "best" *Lfy* hybrids were at least equal to the best two normal hybrids and significantly better than five of the best commercial check hybrids. The Lfy hybrids were generally later in maturity and taller than non leafy hybrids. Plant height and shading effect were the most influential characteristics for grain yield as indicated by multiple regression analyses.

Dedicated to my Parents,

Barre Ahmed and Kutubei Mohamud

who provided the means and environment

to pursue my life's goals, with gratitude,

admiration, and love.

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INTRODUCTION

The improvement of grain yield in maize may be achieved through selection for characters which increase the photosynthate supply to the ear during grain formation. Limitation of assimilate supply by defoliation during the flowering period can cause a substantial yield reduction (3, 39). A grain yield decrease resulting from leaf removal at 10 or 12 days after mid silking could be related to the reduction in kernel number per plant, while grain yield decrease associated with leaf removal at 20 or more days after mid-silking was mostly related to a decline in kernel weight (30,34,48).

Several researchers have suggested increasing the assimilate supply in maize by selecting genotypes with a high rate of photosynthesis per unit of leaf area (55); by improving the efficiency of light interception and utilization (21,50); by extending the grain filling period (20); by selecting a greater leaf longevity (81). Attempts have also been made to select a higher leaf number per plant. Hybrid differences in leaf number have been reported by Chase and Nanda (14).

The position of the leaf relative to the ear affects the rate and direction of assimilate translocation and subsequently ear growth (23,82,27). Generally upper leaves contribute a greater portion of their assimilates to the ear.

Thus, an important agronomic challenge is to redesign the present maize plant in order to allow a higher production of leaves at the top of the canopy. A mutant maize plant with greater than normal leaves above the ear was observed in a single-cross hybrid (A632XM16) seed production field by Robert C. Muirhead of Hughes Hybrids, Inc., Woodstoch, Illinois. Seeds from this plant were planted in a winter nursery 1971-72 and the plants were self pollinated. Dr. D. L. Shaver, research director for Cornnuts, Inc., Salinas, California observed the progeny in 1972. Shaver has continued breeding and genetic research with this mutant for 15 years. He determined that the extra leaf trait is determined by a single dominant gene, Lfy, conditioned by modifier genes and affected by maturity of the genotype.

Muirhead and Shaver, as inventors, were issued a U.S. patent in 1985 covering the use of Lfy germplasm "to enhance the yield of maize". The patent was assigned to Cornnuts Hybrids, Inc. who has been licensing public (Michigan State University) and private agencies to conduct research and development. Several Lfy synthetics and experimental early generation Lfy inbreds were sent to Michigan State University in 1985.

Experimental single-cross hybrids were created in 1985 from these Lfy inbreds to evaluate the agronomic potential of the Lfy hybrid in replicated yield trials in Michigan.

REVIEW OF LITERATURE

Canopy Structure

The total amount of dry matter produced by the maize plant is primarily a function of the size and efficiency of the leaf area as well as its maintenance during kernel development (80). Nichiporovich (62) reported that the leaf area index (LAI) varies for different crops, but it is typically in the range between 2.0 to 5.0. Muleba (59) indicated that LAI was a determinant factor of high yield at low plant density in both a temperate and tropical environment.

High LAI can be achieved by increasing leaf area per plant and/or plant density. Leaf area per plant depends on rate of leaf development by the apical meristem and the time it takes floral initiation to trigger flowering. Extension of the preflowering period is not always acceptable, because it may result in lengthening of the interval between planting and maturity (80). However, extra-leafy maize with a modifier for earliness has a higher rate of leaf production before tasseling and it would be more desirable in short-season areas (74).

Crops differ in their response to increasing stand density. Nevertheless, maize appears to be very sensitive to thick planting. Indeed, with an increase of population density LAI increases up to the point where a mutual shading of the leaves at the time of spikelet initiation decreases the net assimilate rate (39,84), plant weight (28,29), and yield (78). Stinson and Moss, (78) suggested that low light levels within dense plantings may reduce photosynthesis in lower leaves which result in reduced yield. This suggestion is in agreement with the results of Pendelton and Hammond (66) who studied the importance of various leaf positions within the maize canopy. They found that the relative photosynthetic potential of the leaves at the top of the canopy was twice as high as the middle leaves and five times as high as the leaves at the bottom.

It is relevant to stress the simple fact that the efficiency of sunlight to penetrate a maize canopy with a given LAI depends on leaf orientation or leaf angle relative to the stem (10,50). Since vertically oriented leaves usually intercept less light at noon, they require a high LAI in order to maximize the interception of incoming radiation on that canopy (23,56). Duncan et al.(21) predicted in computer simulation studies that the upright leaf orientation types would produce a dry matter greater than horizontal leaves when the LAI is above 3.5.

In fact, some reports do not demonstrate a response to vertical leaf orientation (42,68,83), because the advantage of vertical leaf orientation for yield could be realized if narrow row spacing and high density are used (67).

It has been suggested that more vertically inclined leaves above the ear and gradually approaching more horizontal orientation at the base of the plant would further improve yield (55), and would require a LAI of 10 for maximum dry matter accumulation (24). Pendleton et al.(65) evaluated the effect of vertically oriented leaves on grain production, by mechanically supported leaves in a vertical position in a commercial hybrid. They used three treatments; first, all leaves were tied vertically; second, only leaves above the ear were tied vertically; and finally, a normal leaf arrangement. They concluded that plants with vertically inclined leaves above the ear outyielded those of the same hybrid when all leaves were vertically inclined or with a normal leaf arrangement. Shaver (75) reported that extra-leafy hybrids had the tendency for top leaves to start whorling above the ear. This trend generally reduced the shading effects resulting from the alternate arrangements of the leaves and their closeness above one another. Further, he indicated that extra-leafy maize responded strongly to thick plantings whereas the normal counterparts did not satisfactorily respond to any increase in stands above 18,000 plants per acre.

Grain Filling Period

Grain yield of maize can largely be accounted for by dry matter accumulation during the period from silking to grain physiological maturity. Johnson and Tanner (47) divided the grain filling period into three different periods of development, 1) lag period which starts at silk emergence and continues until kernels are established and reach their full growth rate. 2) Linear grain dry weight accumulation period in which more than 90% of the grain dry weight was stored in the kernels; 3) Leveling off of dry matter accumulation during which dry weight growth declines until the black layer is formed.

The importance of a lag period was pointed out by some workers (26,69) because the number of endosperm cells in the kernel is determined during this period, and it may have a pronounced influence on potential grain size. Johnson and Tanner (47) evaluated the length of filling period in four inbreds and their respective hybrids grown at the same LAI. They found that the yield difference among the material they tested was due to either the length of the initial lag period and/or in the length of the final period when dry matter accumulation was leveling off. Therefore, they suggested the use of an actual grain filling period rather than total filling period. However, the beginning of rapid linear grain growth is probably related to cytokinin activity in the endosperm of maize kernels which increases to a maximum two weeks after pollination (16,35).

In attempts to understand the differences for grain weight production among maize hybrids, considerable attention has been given to the duration and the rate of the grain filling period. Several studies of different results related to length of the filling period have been reported. Shaw and Thom (76) observed a relatively constant time interval of 51 days was required for three hybrids of divergent maturity over a period of several years. Similarly Hallauer and Russell (38) reported a relatively constant 60 day interval between silking and maturity. On the other hand, Daynard et al. (18) found differences of up to 4 days among three hybrids in their actual filling period.

The rate of dry matter production may be linked by the demand for assimilates during the grain filling period (61,35). However, the rate could be enhanced by increasing the leaf number above the ear at the time of the critical stage in the development of potential kernel number per plant (34,85).

Previous reports indicate that yield differences among maize genotypes may be accounted for by differences in the length of the period of silk emergence to grain maturity (18, 40). Hanway and Russell (40) found a significant relationship between grain yield and the length of the filling period for several hybrids at a single plant density. Corroborating the above findings, Mock and Pearce (55) included the character (long grain filling) for the development of an ideotype of maize.

An optimum grain filling period requires a continuous supply of photosynthetic products and their translocation to the ear in order to obtain the desired yield potential. However, in conditions where photosynthesis becomes inadequate to support the constant linear rate of kernel growth, assimilate stored earlier in both stalk and husk are probably utilized in kernel growth. In fact, Duncan (25) suggested that the high rate of utilization of photosynthate by the growing plant prevents the accumulation of carbohydrates during vegetative growth. Furthermore, he speculated the possibility of carbohydrates to accumulate in temporary storage tissue during the period between the cessation of vegetative growth and the initiation of rapid linear dry weight increase. Support of this idea came from the results of several researchers (3,4, 17,36), who reduced the assimilate supply either by shading or by removing the leaves during the grain filling period. They found an increase of kernel dry weight with a concomitant decrease of soluble solids in the stem. But numerous workers (12,17,52,57) have emphasized the importance of soluble solids in the stem for the improvement of standability of the maize plant. Nevertheless, Shaver (75) suggested that the overwhelming supply of metabolites in extra-leafy hybrids could be exploited by lengthening of the grain filling period through a small introgression of Cuzco germplasm. Shaver said " we estimated that for the compliment to Lfy, we need 74 days ". Since Cuzco has 150 days it is possible to get that estimate to maximize the efficiency of Lfy materials. He also indicated that the extension of the filling period would not deteriorate the strong, erect and springy stalk quality of extra-leafy maize.

Finally the duration and rate of grain growth can vary substantially, depending on cultivar and environmental factors mainly temperature and photoperiod. Temperature exerts the greatest effect on the length, while both temperature and photoperiod influence the rate of growth (11,46). Wilson et al. (86) found differences in the length of the period of grain filling for two genotypes tested under three temperature regimes. Carter and Poneleit (13) observed significant year differences in number of growing degree days required to complete the period from silking to maturity. Hunter et al.(46) indicated that higher yield was associated with longer filling due to lower temperature which resulted in increased post-anthesis dry matter production. They also noted that longer photoperiod and cooler temperatures hasten the rate of grain filling and consequently increased final dry weight in the grain.

Partition of Assimilates

Development of genotypes having the number and arrangement of leaves that support a large grain yield requires knowledge of the dynamics of assimilates from the leaves to various plant parts. The photosynthate distribution pattern from different leaves is affected by the metabolic activity in the sink as well as competition for available photosynthate. The latter changes with the developmental stage of the maize plant. Thus, at the beginning of the critical period for ear development, all leaves in general contribute their assimilates to the upper stem, leaves, tassel, and the root system. Conversely, three weeks after silking, when the upper stem, leaves, and the tassel have ceased growing and the ear is growing much more rapidly, assimilate distribution patterns are shifted toward reproductive and vegetative parts of the ear (27,29,35,43, 63). Furthermore, translocation of assimilates which enhance the growth of the ear is influenced by the spatial relationship between photosyntate source and sink. From C^{14} labeling experiments conducted 20 days after silking, Eastin (27) reported that the leaves above and immediately below the ear export most of the assimilate to the developing ear, while metabolites from lower leaves are exported preferentially to the root and lower stem. Later on the direction of export from lower leaves changes from downward to upward as the ear becomes the dominant sink (82). However, the movement of carbohydrates from the lower leaves to the lower stem and roots during the early vegetative period may improve standability and root regeneration by enhancing early development of an extensive brace root system (75). At the same time, it is possible that sugars are recycled through the roots and may be converted to organic nitrogen which is translocated upward to the shoots (82).

The rate of movement of assimilate from the leaves is important in linking photosynthesis to growth. Leaves in general may translocate as much as 70 to 80% of the assimilate produced in a short time interval, depending on species and environmental conditions. However, maize and other C4 species are more efficient than C3 species, because of the specialized leaf anatomy and a greater amount of phloem in the leaves (10).

Evidence indicates that detasseling as well as the use of male sterile plants lead to a higher yield (37,20,44), and their effect may also be more pronounced when plants are in less favorable environments e.g. lack of moisture, higher plant density, and inadequate minerals. Although part of the detrimental effects of the tassel can be attributed to the reduction in the amount of light that reaches the photosynthetic surface in high stand density (20,44,50), it is also a part of diversion of metabolites to the growing tassel due to physiological dominance (60,64). The shading effect was estimated by Duncan et al. (20), who calculated maximum shading of 19% at a density of 100.000 plants per acre. Hunter et al. (44) also measured the effect of tassel shading on grain yield and found a significant reduction.

The great tendency in leafy maize for protogyny may offer a possibility of a near-elimination of these yield pernicious aspects of the tassel (72). Shaver (72) speculated that the pronounced delay of the tassel differentiation until after the flowering of ear has been established, could result in a reduction of adverse tassel shading of 10%. In addition, he estimated another 30% gain from reduction of apical dominance caused by production of more leaves above the ear during the period between the differentiation of the ear and the tassel.

Environmental Factors Affecting Leaf Number

The number of leaves per plant in maize (Zea mays L.), is correlated with plant size, leaf area, length of life cycle, and consequently, adaptation of local cultural conditions (41), particularly temperature, photoperiod, and mineral nutrition. Duncan and Hesketh (22) studied the effect of temperature regimes ranging from 15 to 36^{o}C at a constant 16 h daylength on a wide range of genotypes, and obtained an almost linear increase in average leaf number with increase in temperature. They also indicated that low temperature induced early tasseling which resulted in the development of fewer leaves, fewer nodes, and hence shorter plants. The positive relationship between higher temperature and the number of leaves has been observed by numerous workers (2,5,7,15,41,46). Chase and Nanda (14) compared the performance of 21 double cross hybrids planted in Illinois in May and Florida in September and November. They showed that winter plantings tended to reduce leaf number, and the period from seedling emergence to anthesis was much shorter in the September planting than in the other two.

As noted by Abbe and Phinney (1) the rate of leaf initiation was accelerated exponentially through consequentive plastochrones. However, shortening of the plastochrone interval between the initiation of successive leaves was attributed to warm temperature (46).

It is nevertheless suggested that while the meristematic region of the shoot remained below the soil surface level during the period of leaf initiation, the higher root zone temperature increased the rate of leaf appearance as well as the maximum number of leaves finally initiated per plant (6).

The transition period from vegetative to reproductive development is the critical phase in determining leaf number in maize (5,6,41). Arnold (5) reported that leaf number of Golden Cross Bantam was sensitive to temperature from the four-leaf stage to tassel differentiation .

Numerous studies have been made concerning the effect of photoperiod on leaf number in maize (45,49). Most genotypes showed development of more leaves, although genotypes differ in day length reaction. Bonaparte (7) examined three single cross hybrids under controlled environments, and found an appreciable increase in leaf number in a 16 h than a 12 h day length at the same temperature regime. Francis et al. (33) reported a similar effect of shortened nights on a wide variety of races of maize and also noted a difference among genotypes in their sensitivity to difference in the length of the dark period. However, development of more leaves by altering day length may delay not only tassel differentiation but also silking relative to pollen shedding (2).

It has been shown that mineral nutrients have a remarkable effect in increasing leaf area per plant (31,51). However, increasing leaf area does not necessarily produce a higher yield unless the application of the nutrients, particularly nitrogen, coincides with the developmental rhythm of the plant for maximum benefit (54). Thorne and Watson (79) observed that an application of nitrogen fertilizer to wheat in April had almost doubled the leaf area, while an application of the same amount of nitrogen at the time of heading resulted in a small increase of leaf area, but there was a nearly equal increase in yield. Eik and Hanway (31) found an increase of mean numbers of leaves formed per plant when a greater supply of nitrogen was applied at planting. In addition, they observed that a faster rate of leaf emergence and leaf area expansion were very pronounced compared to the control plots. Bonaparte and Brown (8) reached a similar conclusion, when they examined 25 hybrids at a number of locations in Canada and the United States. In contrast, Hesketh et al. (41) indicated no significant change in leaf number for plants of B14xB37 grown at different nutrient levels.

Phosphorus and potassium stimulate greater leaf area whenever they are applied in the early stages of growth. Furthermore, potassium may delay the aging process of the leaves either alone or by interacting with other essential nutrients, whereas, phosphorus may hasten leaf senescence when it is applied at a late stage of plant development (54).

Genetics Improvement of Leaf Number

Increase of leaf number above the ear for enhancing of photosynthetic supply is a principal strategy to be considered in a selection program designed to improve yield potential of maize. Although maize breeders have attempted to reduce ear height in order to improve plant standability, they lowered the physical position of the ear instead of altering the proportion of nodes and leaves above the ear (71).

Limited work has been done on the inheritance of leaf number in maize. Lorenzoni (53) studied the breeding behavior of leaf number and concluded that the character was partially dominant. Similarly Stein (77) observed dominance for leaf number. The inheritance of leaf number was further investigated by Bonaparte (9) in a diallel cross among six inbreds. He found that leaf number was partial dominance and a high proportion of the total variation was accounted for by additive gene effects. He also noted that at least one effective factor was conditioned for the expression of the trait. Shaver (73) conducted an experiment to assess the effect of mass selection for high leaf number above the ear in a synthetic which had higher leaf number. After four cycles he obtained a high frequency of barren plants and low frequency of desirable phenotypes. He concluded that the average leaf number was around 9 and selection for high leaf number in normal maize could be counterproductive. Recent discovery of maize genotypes which possess a genetic factor capable of conferring the extra-leafy character has opened a new horizon in maize breeding. The extra-leafy phenotype is conditioned by a simple dominant gene. The action of this gene (Lfy) is to change the architecture of the plant by doubling the number of leaves above the ear and by extending flowering time for at least three days (58). Since the Lfy gene arose as a mutation, Shaver examined the stability of the gene and found that Lfy was stable.

Shaver reported that Lfy could be transmitted by any conventional breeding technique, and from the beginning of his work he used early inbreds to produce good Lfy versions. So, from those materials he developed eight advanced synthetics which showed a yield advantage compared with their normal counterparts.

MATERIALS AND METHODS

The germplasm used in this study consisted of seventy two single-cross hybrids. Sixty four were experimental hybrids bearing the Lfy gene. These hybrids were produced at Michigan State University in 1985 from early generation Lfy inbreds received from Dr.D. L. Shaver and selected at M.S.U. Seven commercial single-cross hybrids were included as normal non-leafy hybrids for comparison. One of these, B73XMS71 was included as two entries, 71 and 72. Pedigrees of the hybrids is presented in Table (1).

Evaluation of the hybrids was carried out in Cass and Saginaw Counties, Michigan in the summer of 1986. The Cass County field (Oshtemo sandy loam) was planted on May 2 and the Saginaw County field (Park Hill loam) was planted on May 1st. Total fertilizer (N-P-K) amounts applied were 282-50-149 and 321-63-63 kg/ha in Cass and Saginaw counties respectively. The Cass County experiment was conducted with 13 cm of supplemental irrigation applied with a center pivot system. Growing conditions at both locations were good, resulting in relatively high yields.

The experimental design was an 8 X 9 simple rectangular lattice with two replications at each location. Single-row plots 11.1 m long with 76 cm between rows were used. Final stands were approximately 55,000 plants/ha at both locations. All trials were planted and harvested by machine without gleaning.

Grain yields were adjusted to 15.5% moisture and converted to kg/ha. Root lodging refers to percentage of plants leaning more than a 30 degree angle from vertical. Stalk lodging is the percent of plants broken below the first ear.

The following agronomic characteristics were recorded for a sample of four plants from each plot. Leaf number was recorded above the upper ear. Plant height was measured in centimeters from the base of the plant to the point of tassel branching. Ear height was measured in centimeters from the base of the plant to the node bearing the primary ear. Relative ear position was determined by the ratio of ear height and plant height.

Leaf shading was calculated as the distance between two leaves on the same side of the stalk, estimated by the following formula:

Shading effect = Ph-Eh / L no. * 2

where Ph = plant height

Eh = ear height and

L no. = number of leaves above the primary ear.

2 = Coefficient used to measure the length of two leaves (3 nodes), on the same side of the stalk.

Analyses of variance for a simple lattice design was applied to the data of all characters. Hybrid means adjusted for lattice block differences were used in the combined analyses over locations. In cases where a randomized complete design analysis was more efficient than the lattice, the unadjusted hybrid means were used for the combined analysis. Hybrids were considered fixed effects, and the two locations were considered random for determining expected mean squares. For the combined analysis over locations, a pooled average effective error was calculated by pooling the degrees of freedom and sums of squares for the error term at each experiment over all hybrids. The form of the analysis of variance including expectations of mean squares is shown in Table (2).

Interrelationships among all agronomic characters for each location and over locations were determined by simple correlations. Stepwise multiple regression analysis was used to determine which character(s) contributed to grain yield.

TABLE 1. PEDIGREES OF LEAFY AND NON LEAFY HYBRIDS

ENTRY NO.	CHILE ROW NO.	PEDIGREE			
1	2151-1-1X2293-4	B73Lfysyn.	XA257)	B73Lfysyn.	XInb.337Lfy
2	2151-1-2X2252-2	"	"	"	X(101X293)
3	2151-2-1X83-c,9119	"	"	"	XInb.957Lfy/Lfy
4	2151-2-2X2252-2	"	"	"	X(101X293)
5	2152-1-1X83-c,9119	"	"	"	XInb.957Lfy/Lfy
6	2152-1-2X2252-2	"	"	"	X(101X293)
7	2152-2-1X84-c,3145	"	"	"	XInb.371Lfy
8	2152-2-2X2252-2	"	"	"	X(101X293)
9	2153-1-1X84-c3145	"	"	"	XInb.371Lfy
10	2153-1-2X2252-2	"	"	"	X(101X293)
11	2153-2-1X84-c,3145	"	"	"	XInb.371Lfy
12	2153-4-1X2252-2	"	"	"	X(101X293)
13	2154-2-1X83-c,9228	"	"	"	XInb.371Lfy/Lfy
14	2154-3-1X83-c,9228	"	"	"	"
15	2157-1-1X2254-1	[(632	LfyXA257)	632Lfy]	X(101X293)
16	2158-1-1X2254-1	"	"	"	"
17	2158-2-1X2254-2	"	"	"	"
18	2158-3-1X2230-1	"	"	"	X632Lfy C R F
19	2158-3-2X2254-2	"	"	"	X(101X293)
20	2158-4-1X2261-3	"	"	"	"
21	2158-5-1X2299-1	"	"	"	XB79Lfy
22	2158-6-1X2299-1	"	"	"	"
23	2160-1-1X83-c,9228	"	"	"	XInb.371Lfy/Lfy
24	2163-1-1X83-c,9113	[(632	LfyXA257)	637ELfy]	XInb.941Lfy/Lfy
25	2163-1-2X2254-2	"	"	"	X(101X293)
26	2163-2-1X83-c,9113	"	"	"	XInb.941Lfy/Lfy
27	2163-3-1X83-c,9113	(632	LfyXA257)	371ELfy	XINb.941Lfy/Lfy
28	2164-1-1X83-c,9113	"	"	"	"
29	2166-1-1X2254-1	(A632X637ELfy)			X(101X293
30	2166-2-1X83-c,9113	"	"		XInb.941Lfy/Lfy
31	2166-3-1X2299-1	(A632X637ELfy)			XB79Lfy
32	2266-5-1X2254-1	"	"		X(101X293)
33	2166-5-2X2299-1	"	"		XB79Lfy
34	2166-6-1X83-c,9113	"	"		XInb.941Lfy/Lfy
35	2166-1-1X2254-1	"	"		X(101X293)
36	2169-1-1X83-c,9113	(632LfyX957)			XInb.941Lfy/Lfy
37	2169-2-1X83-c,9113	"	"		"
38	2169-3-1X83-c,9113	"	"		"
39	2169-4-1X83-c,9113	"	"		"
40	2227-1-1X2261-3	(Wf9EX101Lfy)		101Lfy	X(101X293)
41	2228-2-1X2252-2	"	"		"
42	2228-3-1X2261-2	"	"	"	"

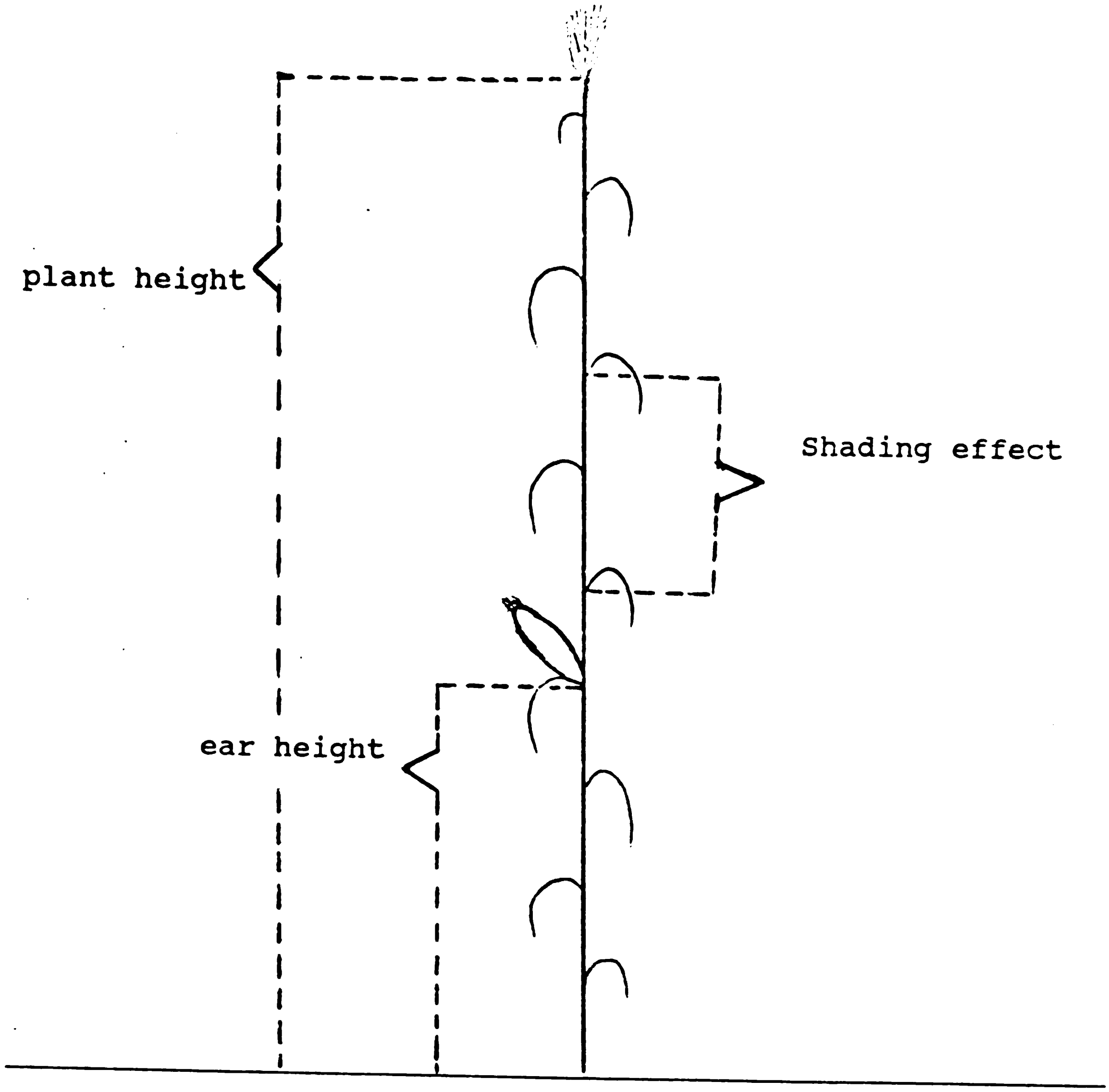
TABLE 1. Cont.

ENTRY NO.	CHILE ROW NO.	PEDIGREE	
43	2228-3-2X2294-1	(Wf9EX101Lfy)101Lfy	X337LFy
44	2228-4-1X2261-2	" " "	X(101X293)
45	2228-4-2X2294-1	" " "	X337Lfy
46	2230-1-1X2261-2	632Lfy C R F	X(101X293)
47	2230-1-2X2294-1	"	X337Lfy
48	2230-2-1X2261-2	632Lfy C R F	X(101X293)
49	2230-3-1X2261-2	"	X101X293)
50	2230-3-2X2299-1	"	XB79Lfy
51	2230-4-1X2261-1	"	X(101X293)
52	2230-5-1X2299-1	"	XB79Lfy
53	2235-1-1X2299-1	"	"
54	2235-2-1X2293-5	"	XInb.337Lfy
55	2235-3-1X2252-2	"	X(101X293)
56	2235-3-2X2261-1	"	"
57	2250-1-1X2261-1	637ELfy	"
58	2250-2-1X2261-1	"	"
59	2250-3-1X2261-1	"	"
60	2260 B-2-1X2293-3	(101LfyX293)	XInb.337Lfy
61	2260 B-3-1X84 T,109-14	" "	XB14 Lfy
62	2260 B-3-2X2293-3	" "	XInb.337Lfy
63	2265-1-1X2293-2	(101LfyXA635)A635	"
64	2265-3-1X2293-2	" " "	"
65		CB59I X LH39	
66		LH74 X LH39	
67		FR31 X FR20A	
68		A632 X CB59I	
69		LH119 X CB59I	
70		LH74 X LH51	
71		B73 X MS71	
72		" "	

Table 2. Analysis of variance used to estimate component of variance for locations and hybrids.

SOURCE OF VARIANCE	D.F.	EXPECTATIONS OF MEAN SQUARES
LOCATIONS	L-1	$\sigma^2+rh+\sigma^2L$
HYBRIDS	H-1	$\sigma^2+rl+\sigma^2H$
LOCATIONS X HYBRIDS	(L-1) (H-1)	$\sigma^2+r\sigma^2LH$
POOLED ERROR	DF1 + DF2	σ^2

σ^2L = Variance due to differences among locations.
σ^2H = Variance due to differences among hybrids.
σ^2LH = Variance due to interaction of location with hybrids.
DF1 and DF2 = degree of freedom for experiments 1 and 2 respectively.



Calculation of shading effect:

$$\text{Shading effect} = \frac{Ph - Eh}{L\ no.} * 2$$

$$= \frac{265.7 - 74.1}{9.4} * 2 = 40.8$$

Fig. 1. Plant measurements and the calculation of shading effect.

RESULTS

Means of the nine agronomic characteristics of leafy and their non-leafy (commercial) check hybrids are reported in table (3). Non-leafy hybrids were generally earlier in maturity than leafy hybrids as reflected by grain moisture content. The mean grain yield of leafy hybrids was 88% of the check non-leafy hybrids. Leafy hybrids averaged 31 cm taller and developed an avarege of four more leaves above the ear node than the check hybrids. Ear height relative to plant height was slightly lower (2.7%) for leafy hybrids. Stalk and root lodging averaged higher for leafy hybrids. Shading effect was lower for leafy hybrids.

Table 4 and 5 present means for the nine characteristics for each of the 72 hybrids at two locations. Growing conditions produced good yields (9530 and 9304 kg/ha) at both locations. Plant height (269.6 vs 249.4 cm) and ear height (84.6 vs 78.0 cm) averaged slightly higher at Cass County than in Saginaw County. Stalk lodging (10.1 vs 2.4%) and root lodging (7.7 vs 0.7%) averaged higher in Cass plots.

Means for both locations combined are presented in Table 6. Four of the best yielding *Lfy* hybrids (entries 36, 4,34,30) were at least equal to the best commercial check hybrids (entries 72,71,70). Moisture content was slightly higher for these four *Lfy* hybrids. There was no significant difference in stalk and root lodging. These four *Lfy* hybrids averaged 3.4 more leaves above the ear node than the checks (table 7).

In table 8. the four "best" Lfy hybrids (36,4,34,30) averaged 12,614.0 kg/ha (Table 6) while five commercial check hybrids (65,66,67,68,69) averaged 9,364.1 kg/ha, a difference of 34.7% for these four Lfy hybrids. In this comparison, the Lfy hybrids were later in maturity averaging 24.8% in moisture compared to 21.3% for the five checks. Average leaf numbers were 9.4 vs 6.2. Stalk lodging was 4.5% and 4.4%, root lodging was 2.7% and 0.4%, plant height was 260.5 and 224.8 cm and ear height was 74.3 and 71.3 cm for Lfy and check averages in this comparison.

Analyses of variance for nine characteristics for each location and for locations combined are given in the Appendix, tables 10-12. The source of variance due to differences among hybrids was highly significant at both locations for all characteristics except root lodging which was significant at 5% level in Saginaw County.

The mean values for nine morphological and physiological characteristics of seventy two hybrids grown at both Cass and Saginaw counties are presented in tables (4 and 5) respectively.

The grain yield of the hybrids grown in Cass county ranged from 4768 to 13523 kg/ha. The highest yield was produced by No. 36, while the lowest yield was produced by No. 18, even though both hybrids had an average of 9 leaves above the primary ear. The former one exhibited a greater distance between leaves on the same side. At Saginaw, the grain yield was in the range between 5459 and 13196 kg/ha. The best performing hybrid was No. 71, which had an average of 6 leaves above the primary ear. In contrast, the poorest performing hybrid was No. 61, with an average of 13 leaves above the primary ear. Leaf number above the primary ear ranged from 6 to 14 in Cass County, and from 5 to 14 in Saginaw County. At both locations the non-leafy hybrids had developed fewer leaves but they had longer internodes above the primary ear compared to their leafy counterparts. Plant height ranged from 205.8 to 309.1 cm, and from 194.5 to 287.9 cm at both locations respectively. Ear height was 61.9 to 112.1 cm and 60.1 to 98.1 cm at both locations. The range of stalk and root lodging at Saginaw County was 0.0 to 6.5 and 0.0 to 15.5% respectively, with an average of 0.7% for stalk lodging and 2.4% for root lodging. However, most of the hybrids showed a higher rate of lodging in Cass County and the range of stalk lodging was between 0.0 to 33.4% with an average of 10.1%. For root lodging, the range was 0.0 to 51.9% with an average of 7.7%.

The combined location analysis of variance showed highly significant differences among hybrids and locations for all characteristics except for ear position and root lodging.

These two characteristics were non significant among locations and hybrids respectively (table 12). The interactions between hybrids and locations were highly significant for grain yield, moisture content, ear height, root lodging and ear position. The interactions did not differ significantly for leaf number, plant height, stalk lodging and shading effect.

The interrelationships among grain yield, moisture percentage, leaf number, plant and ear height, stalk and root lodging, ear position as well as shading effect are presented in table (9) There was considerable variation in the correlation coefficients between all characters studied. The small negative correlation coefficient between grain yield and leaf number indicated that there is little relationship between grain yield and leaf number above the primary ear. Similarly there were limited negative relationships between grain yield and both stalk and root lodging. A significant positive correlation existed between leaf number above the primary ear and maturity which was indirectly determined by grain moisture content. The leaf number also had a good relationship with plant and ear height as well as stalk and root lodging. A substantial association existed between maturity and plant height, but a slight association was found between maturity and ear height. There was a negative correlation between shading effect and all characters, except grain yield in which the improvement of shading effect increased grain yield.

The regression analysis indicated that plant height and shading effect were the most influential characteristics for grain yield.

TABLE 3. MEANS OF NINE MORPHOLOGICAL AND PHYSIOLOGICAL CHARACTERISTICS OF LEAFY AND COMMERCIAL CHECK HYBRIDS AVERAGED OVER LOCATIONS

	TYPE OF HYBRID		
Characteristics	Leafy	Commercial check	Difference
Grain yield	9281.1	10510.4	-1229.3
Moisture %	25.1	22.5	2.6
Leaf number	9.9	6.2	3.7
Plant height	262.7	231.8	30.9
Ear height	81.8	78.7	3.1
Stalk lodging	6.6	4.4	2.2
Root lodging	4.7	0.6	4.1
Ear position	31.2	33.9	-2.7
Shading effect	36.9	49.9	-13.0

TABLE 4. MEAN VALUES FOR NINE MORPHOLOGICAL AND PHYSIOLOGICAL CHARACTERISTICS OF SEVENTY TWO HYBRIDS AT CASS COUNTY

ENTRY NO.	GRAIN YIELD KG/Ha	MOIST URE %	LEAF NO.	PLANT HT cm	EAR HT cm	STALK LODG. %	ROOT LODG. %	EAR POS. %	Shading Effect cm
36	13522.7	24.5	8.6	273.5	78.0	12.2	7.6	28.5	45.5
34	12786.5	22.9	8.6	264.7	77.0	2.9	0.0	29.1	43.7
4	12700.8	27.1	10.1	257.1	71.2	4.6	9.6	27.7	36.8
3	12658.9	27.0	9.7	281.7	83.0	5.1	3.1	29.5	41.0
72	12302.2	24.5	6.3	251.2	86.9	5.6	2.9	34.6	51.8
11	12269.6	26.3	9.9	285.5	73.9	6.0	3.9	25.9	42.5
1	12247.6	24.6	10.6	255.6	79.1	2.4	31.2	30.9	33.3
71	12075.4	24.5	5.8	250.9	93.7	11.4	0.0	37.3	53.7
33	12037.8	23.4	10.3	287.2	80.1	4.5	7.8	27.9	40.4
30	11867.1	21.7	9.9	279.3	82.9	8.9	4.8	29.7	39.9
17	11797.3	23.0	10.6	280.6	112.1	15.2	10.9	40.0	31.8
9	11623.4	27.8	9.9	276.6	76.4	9.5	5.6	27.6	40.6
54	11607.7	28.4	11.9	277.6	92.9	12.0	10.0	33.5	31.2
70	11467.9	23.5	6.1	253.9	101.2	2.2	2.7	39.9	50.1
7	11408.3	27.5	8.7	264.4	74.9	7.1	2.0	28.3	43.6
10	11249.6	24.8	11.1	285.0	89.6	5.6	13.6	31.4	35.2
58	11198.4	23.5	11.7	299.4	86.4	11.6	7.1	28.9	36.4
45	11052.6	23.3	11.7	283.0	99.2	25.0	26.7	35.0	31.4
59	11016.2	25.6	11.4	305.2	96.7	7.4	0.3	31.7	36.7
31	10938.4	22.3	7.9	273.4	87.8	4.3	0.0	32.1	46.7
35	10326.5	23.8	9.9	263.0	93.4	11.6	1.0	35.5	34.4
60	10303.4	27.4	12.9	299.7	102.9	22.6	37.1	34.3	30.6
38	10278.3	23.4	9.9	276.2	80.8	9.9	7.2	29.3	39.7
12	10082.0	24.5	12.2	281.3	81.3	2.6	26.6	28.9	32.8
23	10052.4	23.3	8.9	297.2	112.1	33.4	1.9	37.7	41.8
53	10034.5	27.5	11.0	307.2	94.1	7.5	1.7	30.6	38.7
67	10017.9	20.4	6.0	248.1	72.3	6.6	0.0	29.1	58.6
32	9940.4	24.7	9.9	255.7	85.3	12.5	1.1	33.3	34.3
27	9904.7	23.7	10.4	267.8	68.7	13.8	4.3	25.7	38.5
15	9734.4	23.5	10.9	269.7	87.6	4.6	13.5	32.5	33.6
50	9714.8	25.4	7.6	280.4	93.4	6.1	0.4	33.3	49.2
44	9677.5	24.0	11.4	276.8	95.4	18.9	7.3	34.5	32.0
28	9548.9	23.7	10.4	303.8	76.1	29.6	0.0	25.1	44.0
20	9527.8	27.6	12.7	288.3	94.3	18.5	1.5	32.7	30.6
29	9505.3	25.9	10.4	288.0	94.8	17.3	11.6	32.9	37.3
19	9468.9	23.2	9.9	278.4	109.7	17.0	0.6	39.4	33.9
37	9430.3	26.3	9.1	278.0	72.7	0.0	1.0	26.2	45.1
26	9385.6	23.5	10.4	284.4	70.9	22.7	3.0	24.9	40.9

TABLE 4. cont.

57	9326.0	26.4	11.7	295.8	86.2	4.6	9.7	29.2	35.8
56	9251.6	24.6	11.9	282.7	90.4	11.9	10.0	32.0	32.5
39	9217.5	22.9	9.1	282.2	87.5	13.4	2.2	31.0	42.8
6	8924.2	25.8	10.4	269.2	80.3	0.0	1.3	29.8	36.2
16	8857.5	24.8	10.3	271.4	95.3	14.8	3.7	35.1	34.4
49	8855.6	23.1	6.8	233.1	79.8	6.0	1.8	34.2	45.4
68	8778.0	20.6	6.7	234.4	75.1	6.1	0.5	32.0	47.6
24	8772.6	26.3	10.4	272.2	71.1	12.7	7.0	26.1	38.9
42	8672.5	22.6	10.9	256.1	83.1	8.4	21.5	32.5	31.9
47	8635.2	24.7	13.1	274.7	95.1	9.4	18.9	34.6	27.4
8	8632.2	27.3	8.4	262.5	76.9	4.7	12.3	29.3	44.5
63	8619.9	20.7	6.6	205.8	63.8	3.9	4.5	31.0	43.0
65	8586.9	20.5	6.1	225.0	76.4	6.0	1.6	34.0	48.7
48	8516.6	23.4	7.1	233.7	84.4	7.8	6.4	36.1	42.0
2	8438.9	25.1	11.1	284.3	90.0	5.6	14.1	31.6	35.0
21	8280.8	25.1	9.5	280.9	85.0	7.8	5.8	30.3	41.2
66	8257.2	20.4	6.8	229.4	77.1	4.3	0.6	33.6	44.5
69	8090.0	21.5	6.3	222.9	61.9	13.2	0.5	27.7	51.5
55	8040.7	26.6	10.7	258.7	93.0	16.0	6.7	35.9	31.0
5	7888.5	28.5	10.3	309.1	84.2	2.2	10.2	27.3	43.9
25	7884.7	25.5	11.1	303.4	107.5	30.0	18.9	35.4	35.3
13	7874.5	25.6	8.4	275.4	80.1	7.1	7.7	29.1	46.2
22	7844.2	26.4	10.3	295.8	94.3	11.9	0.8	31.9	39.3
61	7745.8	27.9	13.9	286.3	72.7	0.0	4.5	25.4	30.8
62	7706.6	29.5	14.4	298.4	88.8	3.3	51.9	29.8	29.2
41	7498.4	25.3	10.4	234.9	67.0	12.3	13.9	28.5	32.1
14	7190.5	25.5	8.5	274.1	80.3	5.8	6.5	29.3	45.6
51	7151.4	23.5	7.5	234.5	83.5	7.7	3.1	35.6	40.3
64	6997.1	21.0	6.8	224.4	74.8	7.4	4.4	33.3	43.7
46	6969.0	26.5	6.4	216.8	78.7	14.2	1.9	36.3	42.8
40	6770.5	22.1	12.1	272.8	90.4	23.0	5.1	33.1	30.1
43	6308.5	24.2	11.4	282.4	90.3	18.4	24.1	32.0	33.6
52	6061.5	25.5	7.3	267.0	80.9	7.3	1.1	30.3	50.6
18	4767.9	24.0	8.6	246.1	77.1	9.1	2.4	31.3	39.3
MEAN	9530.2	24.6	9.7	269.6	84.6	10.1	7.7	31.4	39.6
RANGE	13522.7	29.5	14.4	309.1	112.1	33.4	51.9	40.0	58.6
	4767.9	20.3	5.9	205.8	61.9	0.0	0.0	24.9	27.4
LSD	814.5	1.7	1.8	18.7	14.5	19.0	19.0	5.0	7.3
LSD$^{(0.01)}$	626.5	1.3	1.4	14.3	11.2	14.6	14.6	3.9	5.6
C.V.$^{(0.05)}$	3.3	2.6	7.0	2.7	6.6	72.2	94.7	6.2	7.1

TabLE 5. MEAN VALUES FOR NINE MORPHOLOGICAL AND PHYSIOLOGICAL CHARACTERISTICS OF SEVENTY TWO HYBRIDS AT SAGINAW COUNTY

ENTRY NO.	GRAIN YIELD KG/Ha	MOIST URE %	LEAF NO.	PLANT HT cm	EAR HT cm	STALK LODG. %	ROOT LODG. %	EAR POS. %	Shading Effect cm
71	13195.7	25.0	6.0	243.1	82.8	1.4	0.0	34.1	53.3
72	13017.6	25.0	6.0	229.8	88.3	3.9	0.0	38.4	47.3
36	12856.4	27.0	10.2	257.9	70.1	0.9	0.0	27.2	36.9
30	12695.5	24.5	10.2	269.0	75.6	2.3	0.0	28.1	37.8
70	12466.3	24.2	5.9	231.5	93.8	1.6	0.0	40.5	47.1
4	12404.6	24.7	9.0	241.4	68.3	1.1	0.0	28.3	38.4
34	12078.0	25.7	8.6	240.7	70.3	2.7	0.0	29.2	39.6
3	11834.2	27.7	9.5	249.2	76.3	2.3	2.4	30.6	36.6
33	11590.3	25.1	11.0	259.4	62.7	6.0	0.0	24.2	35.8
54	11366.2	27.5	12.0	259.6	85.1	1.8	2.5	32.8	29.0
17	11248.6	24.1	9.8	260.1	85.3	0.2	0.0	32.8	35.5
67	11176.4	21.6	5.4	226.3	75.6	2.2	0.0	33.4	56.1
13	11093.0	23.9	8.8	258.1	82.2	1.2	0.0	31.8	40.2
11	11035.8	27.8	9.1	249.8	71.8	0.5	0.0	28.8	38.9
37	10969.2	27.1	9.3	257.1	71.3	1.0	0.0	27.7	39.8
58	10959.4	25.3	11.5	270.1	73.9	0.3	0.0	27.4	34.1
45	10877.7	25.4	11.4	273.9	95.3	0.3	0.0	34.8	31.2
23	10848.9	23.1	8.8	255.3	90.3	0.8	0.0	35.4	37.3
20	10696.9	25.5	12.1	274.7	80.6	1.8	0.0	29.3	32.2
9	10676.3	28.1	11.2	259.5	72.5	3.3	0.0	27.9	33.4
31	10664.5	25.1	8.8	256.2	70.9	1.2	0.0	27.7	42.1
38	10611.7	26.2	9.0	254.7	72.8	3.5	0.0	28.6	40.6
1	10598.9	26.2	10.3	253.1	83.9	0.0	2.0	33.2	33.0
59	10501.5	25.2	11.0	268.9	70.3	9.4	0.0	26.1	36.1
65	10354.5	23.1	6.1	212.6	69.4	0.2	0.0	32.7	47.3
69	10262.7	21.4	6.0	210.8	60.8	2.3	1.0	28.8	49.7
12	10024.0	21.7	10.4	246.1	77.3	0.6	0.9	31.4	32.4
35	9881.3	25.6	9.3	242.2	77.6	4.3	0.9	32.0	35.4
27	9855.4	23.5	9.2	253.8	71.3	1.9	1.3	28.1	39.6
15	9743.2	26.5	10.8	244.5	75.7	1.5	0.0	31.0	31.3
2	9727.2	24.6	9.0	237.0	70.3	0.6	0.0	29.7	37.2
10	9673.6	26.8	9.3	265.2	82.6	5.4	0.0	31.2	39.1
7	9417.8	27.3	8.9	258.3	73.9	0.2	3.1	28.6	41.4
68	9227.5	20.0	6.7	213.2	71.1	0.4	0.0	33.3	42.2
16	9113.5	24.0	8.9	241.1	81.6	3.7	1.1	33.8	36.0
50	9098.6	28.4	7.7	246.5	73.3	2.0	1.0	29.7	44.8
28	8948.3	24.6	10.2	269.6	60.1	4.5	0.0	22.3	41.0
21	8920.9	26.7	9.2	260.7	93.9	0.0	0.0	36.	36.4

TABLE 5. cont.

26	8918.6	24.7	9.6	266.9	68.6	4.2	0.0	25.7	41.1
32	8895.9	26.7	10.2	225.6	65.4	1.3	0.0	29.0	31.4
66	8890.1	23.0	6.3	224.7	73.3	2.7	0.0	32.6	47.9
8	8766.8	24.2	8.7	236.1	78.5	0.0	0.0	33.2	36.1
24	8743.8	23.2	10.4	249.5	82.2	1.5	0.0	33.0	32.3
55	8546.6	30.0	9.8	218.3	79.5	4.2	0.9	36.4	28.2
5	8508.5	25.5	10.3	287.9	85.8	3.7	1.4	29.8	39.3
60	8468.2	30.7	13.6	284.1	89.8	2.0	6.3	31.6	28.6
39	8431.4	27.2	9.1	271.3	81.7	2.9	0.0	30.1	41.6
44	8357.2	27.6	10.6	255.2	86.2	1.2	6.5	33.8	32.0
57	8345.7	24.2	11.2	285.6	83.8	15.5	2.0	29.4	36.0
49	8338.4	22.8	6.8	228.8	80.0	4.8	0.0	35.0	43.8
29	8306.4	26.6	10.5	261.8	89.9	4.8	0.0	34.4	32.8
25	8305.7	26.6	10.8	279.1	98.1	1.9	2.2	35.1	33.7
53	8293.0	27.3	10.1	276.5	81.2	2.6	0.0	29.4	38.6
22	8207.0	24.7	9.8	261.6	82.6	2.3	0.0	31.6	36.6
47	8118.3	24.3	11.8	260.1	88.7	0.4	3.4	34.1	29.2
63	7918.5	23.8	6.3	194.5	61.9	3.0	0.0	31.9	42.1
48	7892.4	24.1	7.4	214.1	73.3	0.6	0.0	34.3	37.9
42	7727.9	26.2	10.8	242.2	78.9	2.0	0.0	32.6	30.4
19	7440.7	24.0	9.0	251.0	82.6	2.4	1.0	32.9	37.4
14	7372.8	24.5	8.9	251.5	77.6	3.0	0.0	30.9	39.2
62	7365.5	25.5	13.3	269.0	79.3	6.2	1.9	29.5	28.5
56	7317.3	26.7	12.1	255.5	82.9	1.5	2.0	32.5	28.6
6	7125.2	27.4	10.7	244.8	77.6	3.4	0.0	31.7	31.3
41	6777.8	28.5	10.3	231.6	79.1	1.7	3.6	34.2	29.7
40	6738.8	22.7	12.0	249.1	84.7	3.4	0.0	34.0	27.3
64	6582.0	24.5	7.2	197.0	62.5	0.0	0.0	31.7	37.4
52	6386.0	24.5	8.2	255.0	75.3	1.9	0.0	29.6	43.8
46	6178.1	24.1	6.6	198.2	71.3	4.2	0.0	35.9	38.5
43	6074.0	23.8	11.5	260.6	86.6	4.1	2.4	33.2	30.2
51	5770.9	26.6	7.3	223.1	79.3	2.0	1.4	35.6	39.3
18	5695.6	20.9	8.7	230.4	83.6	2.2	0.0	36.3	33.8
61	5459.0	27.1	13.2	268.3	72.2	0.0	0.0	26.9	29.8
MEAN	9304.0	25.3	9.4	249.4	78.0	2.4	0.7	31.4	37.4
RANGE	13195.6	30.7	13.6	287.9	98.1	15.5	6.5	40.5	56.1
	5459.0	20.0	5.4	194.5	60.1	0.0	0.0	22.3	27.3
LSD (0.01)	750.9	1.2	1.6	25.8	17.5	6.3	4.3	6.5	7.9
LSD (0.05)	577.6	0.9	1.2	19.9	13.4	4.8	3.3	5.0	6.1
C.V.	3.1	1.8	6.5	4.0	8.6	98.8	232.5	7.9	8.1

TABLE 6. MEAN VALUES FOR NINE MORPHOLOGICAL AND PHYSIOLOGICAL CHARACTERISTICS COMBINED OVER LOCATIONS

ENTRY NO.	GRAIN YIELD KG/Ha	MOISTURE %	LEAF NO.	PLANT HT cm	EAR HT cm	STALK LODG. %	ROOT LODG. %	EAR POS. %	Shading Effect cm
36	13189.6	25.8	9.4	265.7	74.1	6.6	3.8	27.9	40.8
72	12659.9	24.8	6.2	240.5	87.6	4.7	1.5	36.4	49.6
71	12635.5	24.7	5.9	247.0	88.3	6.4	0.0	35.7	53.5
4	12552.7	25.9	9.6	249.3	69.8	2.9	4.8	28.0	37.6
34	12432.3	24.3	8.6	252.7	73.7	2.8	0.0	29.2	41.6
30	12281.3	23.1	10.0	274.2	79.3	5.6	2.4	28.9	38.8
3	12246.5	27.3	9.6	265.4	79.6	3.7	2.8	30.0	38.8
70	11967.1	23.9	6.0	242.7	97.5	1.9	1.4	40.2	48.6
33	11814.1	24.3	10.6	273.3	71.4	5.2	3.9	26.1	38.0
11	11652.7	27.0	9.5	267.7	72.9	3.2	1.9	27.2	40.8
17	11522.9	23.5	10.2	270.3	98.7	7.7	5.5	36.5	33.6
54	11486.9	27.9	11.9	268.6	89.0	6.9	6.2	33.1	30.1
1	11423.2	25.4	10.4	254.3	81.5	1.2	6.6	32.1	33.1
9	11149.9	27.9	10.5	268.0	74.4	6.4	2.8	27.8	36.8
58	11078.9	24.4	11.6	284.8	80.2	5.9	3.6	28.2	35.3
45	10965.2	24.4	11.6	278.4	97.3	2.7	3.4	34.9	31.3
31	10801.4	23.7	8.4	264.8	79.4	2.7	0.0	30.0	44.3
59	10758.9	25.4	11.2	287.1	83.5	8.4	0.2	29.1	36.4
67	10597.2	21.0	5.7	237.2	73.9	4.4	0.0	31.2	57.4
10	10461.6	25.8	10.2	275.1	86.1	5.5	6.8	31.3	37.0
23	10450.7	23.2	8.8	276.3	101.2	7.1	1.0	36.6	39.6
38	10445.0	24.8	9.4	265.5	76.8	6.7	3.6	28.9	40.1
7	10413.0	27.4	8.8	261.4	74.4	3.7	2.6	28.5	42.5
37	10199.8	26.7	9.2	267.6	72.0	0.5	0.5	26.9	42.4
20	10112.4	26.6	12.4	281.5	87.4	0.1	0.8	31.1	31.3
35	10103.9	24.7	9.6	252.6	85.5	8.0	1.0	33.8	34.9
12	10053.0	23.1	11.3	263.7	79.3	1.6	3.8	30.1	32.6
27	9880.0	23.6	9.8	260.8	70.0	7.9	2.8	26.9	39.0
15	9738.8	25.0	10.8	257.1	81.6	3.1	6.7	31.7	32.4
13	9483.8	24.8	8.6	266.8	81.2	4.2	3.9	30.4	43.1
65	9470.7	21.8	6.1	218.8	72.9	3.1	0.8	33.3	48.0
32	9418.1	25.7	10.1	240.7	75.4	6.9	0.6	31.3	32.8
50	9406.7	26.9	7.7	263.5	83.3	4.1	0.7	31.6	47.0
60	9385.8	29.0	13.2	291.9	96.4	2.3	1.7	33.0	29.6
28	9248.6	24.1	10.3	286.7	68.1	7.1	0.0	23.8	42.5
69	9176.4	21.5	6.1	216.9	61.3	7.7	0.8	28.3	50.7
53	9163.8	27.4	10.6	291.8	87.7	5.0	0.8	30.0	38.7
26	9152.1	24.1	10.0	275.7	69.8	3.4	1.5	25.3	41.0

TABLE 6. cont.

2	9083.1	24.9	10.0	260.6	80.2	3.1	7.1	30.8	36.0
44	9017.3	25.8	11.0	266.0	90.8	10.0	6.9	34.1	32.0
68	9002.7	20.3	6.7	223.8	73.1	3.2	0.3	32.7	44.9
16	8985.5	24.4	9.6	256.3	88.4	9.3	2.4	34.5	35.1
29	8905.9	26.2	10.4	274.9	92.4	11.0	5.8	33.6	35.1
57	8835.8	25.3	11.5	290.7	85.0	10.0	5.9	29.3	35.9
39	8824.5	25.0	9.1	276.8	84.6	8.1	1.1	30.6	42.2
24	8758.2	24.7	10.4	260.8	76.6	7.1	3.5	29.4	35.6
8	8699.5	25.7	8.5	249.3	77.7	2.3	6.1	31.2	40.2
21	8600.8	25.9	9.3	270.8	89.5	3.9	2.9	33.0	38.9
49	8597.0	23.0	6.8	231.0	79.9	5.4	0.9	34.6	44.6
66	8573.7	21.7	6.6	227.1	75.2	3.5	0.3	33.1	46.1
19	8454.8	23.6	9.5	264.7	96.2	9.7	0.8	36.3	35.6
47	8376.8	24.5	12.4	267.4	91.9	4.9	11.2	34.4	28.2
55	8293.6	28.3	10.3	238.5	86.2	10.1	3.8	36.2	29.7
56	8284.5	25.6	12.0	269.1	86.7	6.7	6.0	32.2	30.5
63	8269.2	22.3	6.4	200.1	62.9	3.4	2.3	31.4	42.6
48	8204.5	23.7	7.3	223.9	78.9	4.2	3.2	35.2	39.9
42	8200.2	24.4	10.8	249.2	81.0	5.2	10.8	32.5	31.1
5	8198.5	27.0	10.3	298.5	85.0	3.0	5.8	28.5	41.6
25	8095.2	26.1	10.9	291.3	102.8	15.9	10.5	35.3	34.5
22	8025.6	25.5	10.0	278.7	88.5	7.1	0.4	31.7	38.0
6	8024.7	26.6	10.6	257.0	78.9	1.7	0.6	30.7	33.7
62	7536.0	27.5	13.8	283.7	84.1	4.7	26.9	29.6	28.9
14	7281.7	25.0	8.7	262.8	79.0	4.4	3.2	30.0	42.3
41	7138.1	26.9	10.4	233.3	73.1	7.0	8.8	31.3	30.9
64	6789.6	22.7	7.0	210.7	68.6	3.7	2.2	32.6	40.4
40	6754.7	22.4	12.1	260.9	87.6	1.2	2.6	33.6	28.7
61	6602.4	27.5	13.5	277.3	72.5	0.0	2.3	26.1	30.3
46	6573.5	25.3	6.5	207.5	75.0	9.2	0.9	36.1	40.7
51	6461.2	25.0	7.4	228.8	81.4	4.8	2.2	35.6	39.8
52	6223.8	25.0	7.8	261.0	78.1	4.6	0.5	29.9	47.0
43	6191.2	24.0	11.5	271.5	88.4	11.2	13.3	32.6	31.9
18	5231.8	22.4	8.6	238.3	80.4	5.7	1.2	33.7	36.5
MEAN	9417.7	24.9	9.5	259.3	81.4	6.3	4.2	31.5	38.4
RANGE	13189.6	29.0	13.8	298.5	102.3	17.1	26.9	40.2	57.4
	5231.8	20.3	5.7	200.1	61.3	0.0	0.0	23.8	28.2
LSD$_{(0.01)}$	812.5	1.5	1.7	23.1	16.5	14.5	13.2	5.8	7.6
LSD$_{(0.05)}$	610.9	1.1	1.3	17.3	12.4	10.9	9.9	4.3	5.7
C.V.	2.3	1.6	4.8	2.4	5.4	60.9	83.2	4.9	5.3

Table 7. Comparison of best *Lfy* hybrids with 3 best Commercial check hybrids.

	TYPE OF HYBRID		
Characterisics	Lfy	Commercial check	Difference
Grain yield	12614.0	12420.8	193.2
Moisture %	24.8	24.5	0.3
Leaf number	9.4	6.0	3.4
Plant height	260.5	243.4	17.1
Ear height	74.2	91.1	-16.9
Stalk lodging	4.5	4.3	0.2
Root lodging	2.7	1.0	1.7
Ear position	28.5	37.4	-8.9
Shading effect	39.7	50.6	-10.9

Table 8. Comparison of best *Lfy* hybrids with 5 Commercial check hybrids.

	TYPE OF HYBRID		
Characterisics	Lfy	Commercial check	Difference
Grain yield	12614.0	9364.1	3249.9
Moisture %	24.8	21.3	3.5
Leaf number	9.4	6.2	3.2
Plant height	260.5	224.8	35.7
Ear height	74.2	71.3	2.9
Stalk lodging	4.5	4.4	0.1
Root lodging	2.7	0.4	2.4
Ear position	28.5	31.7	-3.2
Shading effect	39.7	49.4	-9.7

TABLE 9. VARIETY CORRELATION COEFICIENTS AMONG CHARACTERS OVER LOCATIONS.

Character	2	3	4	5	6	7	8	9
Grain yield	-0.078 ns	0.070 ns	0.188 ns	0.021 ns	-0.120 ns	-0.108 ns	-0.142 ns	0.241 ns
Leaf number	---	0.535 **	0.730 **	0.325 **	0.279 *	0.415 **	-0.277 *	-0.873 **
Moisture %		---	0.498 **	0.225 ns	-0.005 ns	0.239 *	-0.174 ns	-0.430 **
Plant height			---	0.466 **	0.326 **	0.215 ns	-0.348 **	-0.385 **
Ear height				---	0.411 **	0.117 ns	0.664 **	-0.352 **
Stalk lodging					---	-0.051 ns	0.159 ns	-0.260 *
Root lodging						---	0.070 ns	-0.570 **
EAR POSITION							---	-0.040 ns
Shading effect								---

** = highly significant at 0.01% of probability level.
* = significant at 0.05% of probability level.
ns = non significant at 0.01 and 0.05% of probability level.

DISCUSSION

The number of leaves of a determinate species such as maize is correlated with plant height, flowering date and grain moisture content at harvest (14,23). The development of new leaves on the main stalk ceases after the initiation of the terminal inflorescence. Therefore, earlier induction of flowering results in fewer leaves, fewer nodes and hence shorter plants. It appears that within the limits of hybrids included, that leafy hybrids are tall, late and possess more leaves above the primary ear (fig. 3,4).

The results herein also elucidate that an increase in leaf number increases root lodging. This statement confirms the expectation that higher leaf number above the primary ear may cause an imbalance of weight of upper and lower parts of the plant. This imbalance causes the plant to lodge at the base during wet stormy weather. Root lodging was highly correlated with leaf number and shading effect (table 9), but the latter has a negative trend. This implies that lodging can be decreased either through a decrease of leaf number or enhancement of photosynthetic activity of the leaves by better canopy structure (fig.8 and 10). As a matter of fact, leafy hybrids which have as one of their parents either inbreds 941 Lfy or 371 Lfy are resistant to root lodging. These hybrids have low ear placement, low shading effect and moderate leaf number (9-10) above the ear (tables 1 and 6). Similarly, Shaver

(73) mentioned the merit of these inbreds in his memmo in 1985 and said "I do recommend using 941 Lfy Inbred as one tester ,....... I think every hybrid having this as one parent can hardly fail to be beautifully low eared, and have ramrod stiff stalks". He also indicated that the original lfy 941 was similar to 371 lfy. In contrast, hybrids originated from inbred 337Lfy had the highest score of root lodging (Tables 1 and 6). These hybrids were characterize by high leaf number, high ear position, high shading effect and low yielding. Data in the literature generally suggest that the reduction of carbohydrates in the lower portion of the stalk could be related to a decrease of assimilate supply from the lower leaves (12,17,52,57). This reduction could be the result of low photosynthetic activity because of insufficent light penetration to the lower leaves. However, when the effect of low carbohydrates is imminent, it may impair the development of a strong brace-root system which can support the pressure of the extra leaves above the ear.

Plant and ear height are two other morphological characteristics which influence the standability of maize. Tall plants are more susceptible to stalk breakage than short ones, especially if the ear placement is high. In this study stalk lodging has a significant positive relationships with both plant and ear height (table 9). These relationships are weak and have a negative tendency in non-leafy hybrids. Thus, leafiness and tallness as well as high ear placement together contribute substantially to stalk lodging in maize (fig. 5, 8, and 9) .

For grain yield the results obtained do not clearly indicate an apparent relationship between leaf number above the primary ear and grain yield with a stand density of 55,000 plants per hectare. This correlation would be higher under more severe competition as a consequence of high plant density. There are however, several leafy hybrids (36,4,34,30, and 3) which had high yields. The range of their average yield was 12246.5 to 13189.6 kg/ha. These hybrids came from very productive leafy inbreds [941 Lfy and (B73Lfy syn.XA25) B73] which had tall plants with low ear placement, smaller shading effect and moderate to relatively high leaf number (9-11 leaves) (tables 1 and 6). Furthermore, the prediction equation of stepwise multiple regression analysis showed that the combined effects of plant height and shading effect contributed significantly to the variation in grain yield.

$Y = - 2512.0460 + 25.555390 + 146.66910$.

No information has been reported on the correlation between leaf number and shading effect evaluated as the distance between two leaves on the same side. Shading effect has a high negative correlation with leaf number and other characteristics except yield (table 9). The interpretation of the relationship between leaf number and shading effect, could be visualized in terms of the efficiency of a maize plant, for which yield must be considered jointly. In this respect, the negative coefficients between leaf number and yield and leaf number and shading effect must be taken into account. They are indicative (fig. 2 and 7) that the most efficient maize plants must have higher leaf number above the primary ear and smaller shading effect (It means a longer distance between leaves on the same side). This can be achieved by incorporation of leafy hybrids with the character of upright leaf orientation as predicted by Duncan et al. in 1967 computer simulation studies. They found that when LAI of a plant canopy is above 3.5 the vertically oriented leaves would produce a higher yield than horizontal leaves. Several authors (23,82,27) reported that upper leaves of the maize plant are the major contributors of metabolites to the ear and severe shading of these leaves during the critical period could drastically decrease the yield. Duncan, W. G. and Hesketh, J. D. 1968 pointed out that vertically oriented leaves above the primary ear and leaves gradually approaching a horizontal orientation at the lower portion of the plant would enhance the efficiency of the leaves and increase grain yield. For example, table (6) the comparison between lines 61, 62, and 70, 71 demonstrates typical cases of hybrids which possess high leaf number and high shading effect and low leaf number and low shading effect. Numbers 61 and 62 exhibited a combined response to reduce grain yield. The average yield of No. 61 was 6602.4 and No. 62 was 7536.0 kg/ha. No 70 and 71 (71 and 72 are the same pedigree but for better evaluation was included twice in the study) since they developed only 6 leaves above the ear, they had smaller shading effect and thus had an average yield of 11967.1 and 12552.7 kg/ha respectively.

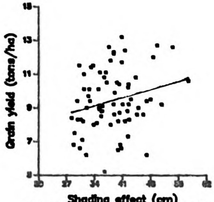


fig.2. relationship between shading effect and grain yield

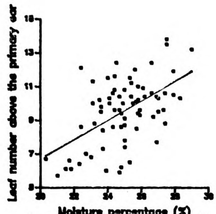


fig.3. relationship between moisture percentage and leaf number above the ear

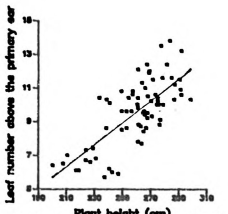


fig.4. relationship between plant height and leaf number above the ear

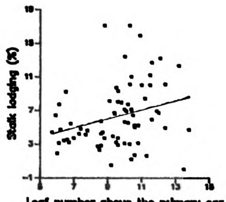


fig.5. relationship between leaf number above the ear and stalk lodging

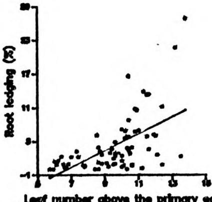


fig.6. relationship between leaf number above the ear and root lodging

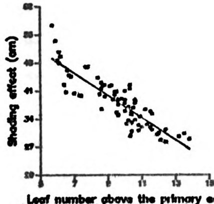


fig.7. relationship between leaf number above the ear and shading effect

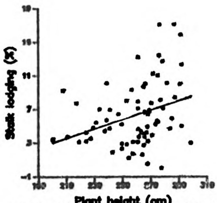


fig.8. relationship between plant height and stalk lodging

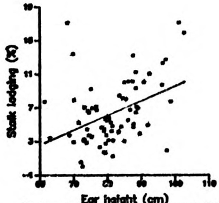


fig.9. relationship between ear height and stalk lodging

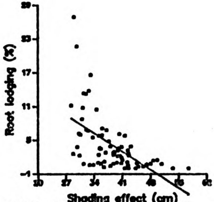


fig.10. relationship between shading effect and root lodging

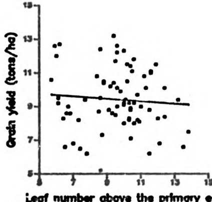


fig.11. relationship between leaf number above the ear and grain yield

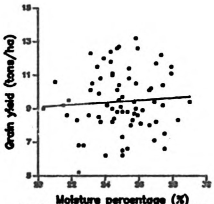


fig.12. relationship between moisture percentage and grain yield

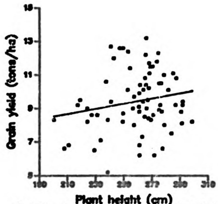


fig.13. relationship between plant height and grain yield

Conclusions

Yield of four of the "best" leafy, Lfy, hybrids were at least equal to the best commercial check hybrids and significantly better than five of the normal check hybrids. Moisture content was slightly higher with no real difference in lodging. Plant and ear heights were similar for the best selections compared to the two best check hybrids. However, improvement of shading effect of Lfy hybrids through incorporation of upright leaf orientation trait may enhance the efficiency of their photosynthetic surface and therefore reduce lodging effect.

Many, best not all, of the experimental Lfy hybrids were later in maturity with considerably more root and stalk lodging, higher plant and ear height.

Yield differences for Lfy hybrids did not approach those (30-100%) obtained in California by Shaver. However, it is significant that the best experimental Lfy hybrids produced and tested in the first cycle of breeding in Michigan were very competitive with commercial hybrids with normal leaf number.

With a research effort comparable to that devoted to the development of current commercial hybrids, significant yield improvement might be obtained with leafy Lfy germplasm.

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APPENDIX

Table 10. MEAN SQUARES FROM ANALYSIS OF VARIANCE OF DATA COLLECTED IN CASS COUNTY IN 1986.

Source of variation

	Total	Replications	Hybrids	block (adj.)	Error
D.F.	143	1	71	16	1/ 71 or 55
Grain yield		139065.20	6723387.28**	----	110825.40
Moisture %		0.06	8.98**	----	0.42
Leaf number		0.08	8.34**	----	0.45
Plant height		1681.04	1198.53**	149.90	51.47
Ear height		785.61	240.06**	68.09	31.26
Stalk lodging		29.19	106.27**	93.05	53.46
root lodging		0.04	182.86**	76.50	53.26
Ear position		31.65	26.09**	4.98	3.77
Shading effect		16.41	93.78**	----	7.70

** = significant at 0.01% of probability level.
* = significant at 0.05% of probability level.
1/ = 71 and 55 are D.F. of the Error term for Randomized Complete Block Design and Lattice Design respectevely.

Table 11. MEAN SQUARES FROM ANALYSIS OF VARIANCE OF DATA COLLECTED IN SAGINAW COUNTY IN 1986.

Source of variation

	Total	Replications	Hybrids	block (adj.)	Error
D.F.	143	1	71	16	1/ 71 or 55
Grain yield		198664.65	7386360.93**	28877.10	83399.21
Moisture %		0.13	8.23**	0.30	0.20
Leaf number		1.90	7.32**	0.45	0.38
Plant height		116.29	888.42**	225.30	98.82
Ear height		1.13	141.02**	----	44.03
Stalk lodging		18.45	11.54**	9.74	5.79
root lodging		1.43	3.69*	----	2.47
Ear position		5.52	21.70**	----	5.51
Shading effect		15.12	76.57**	----	8.87

** = significant at 0.01% of probability level.
* = significant at 0.05% Of probability level.
1/ = 71 and 55 are D.F. of the Error term for Randomized Complete Block Design and Lattice Design respectively.

TABLE 12. MEAN SQUARES FROM COMBINED ANALYSIS OF VARIANCES FOR VARIOUS CHARACTERS.

	Source of variance		
	Location	**Hybrid**	**Loc X Hyb**
Grain yield	38.56**	11.80**	11.66**
Leaf number	8.52**	34.27**	1.06ns
Moisture %	99.37**	3.29**	12.54**
Plant height	391.92**	21.22**	1.10ns
Ear height	85.55**	4.62**	1.68**
Stalk lodging	122.97**	3.19**	0.51ns
Root lodging	122.18**	1.28ns	2.80**
Ear position	0.09ns	5.49**	1.54**
Shading effect	45.29**	18.71**	1.01ns

** = highly significant at 0.01% of probability level.
* = significant at 0.05% of probability level.
ns = non significant at 0.01 and 0.05% of probability levels.

TABLE 13. CORRELATION COEFICIENTS AMONG CHARACTERS IN CASS County

Character	2	3	4	5	6	7	8	9
Grain yield	0.033 ns	0.030 ns	0.226 ns	0.104 ns	-0.101 ns	-0.010 ns	-0.500 ns	0.076 ns
Leaf number	---	0.475 **	0.648 **	0.266 *	0.234 *	0.470 **	-0.174 ns	-0.868 **
Moisture %		---	0.452 **	0.102 ns	-0.049 ns	0.268 *	-0.204 ns	-0.322 **
Plant height			---	0.486 **	0.244 *	0.201 ns	-0.172 ns	-0.298 *
Ear height				---	0.333 **	0.110 ns	0.774 **	-0.321 **
Stalk lodging					---	0.008 ns	0.184 ns	-0.246 *
Root lodging						---	-0.025 ns	-0.442 **
EAR POSITION							---	-0.140 ns
Shading effect								---

** = highly significant at 0.01% of probability level.
* = significant at 0.05% of probability level.
ns = non significant at 0.01 and 0.05% of probability levels.

TABLE 14. CORRELATION COEFICIENTS AMONG CHARACTERS IN SAGINAW County.

Character	2	3	4	5	6	7	8	9
Grain yield	-0.189 ns	0.011 ns	0.081 ns	-0.065 ns	-0.116 ns	-0.150 ns	-0.132 ns	0.340 **
Leaf number	---	0.426 **	0.685 **	0.217 ns	0.164 ns	0.287 *	-0.303 **	-0.838 **
Moisture %		---	0.342 **	0.138 ns	-0.029 ns	0.308 **	-0.121 ns	-0.355 **
Plant height			---	0.414 **	0.273 *	0.183 ns	-0.335 **	-0.269 *
Ear height				---	0.021 ns	0.238 *	0.716 **	-0.256 *
Stalk lodging					---	0.058 ns	-0.171 ns	-0.015 ns
Root lodging						---	0.100 ns	-0.273 *
EAR POSITION							---	-0.054 ns
Shading effect								---

** = highly significant at 0.01% of probability level.
* = significant at 0.05% of probability level.
ns = non significant at 0.01 and 0.05% of probability levels.

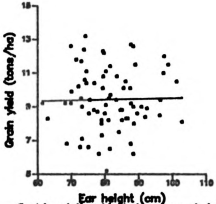

fig.14. relationship between ear height and grain yield

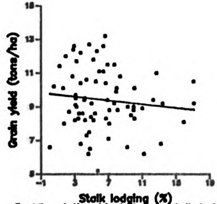

fig.15. relationship between stalk lodging and grain yield

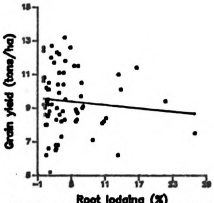

fig.16. relationship between root lodging and grain yield

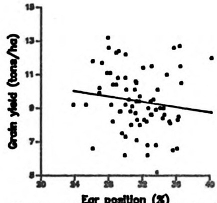

fig.17. relationship between ear position and grain yield

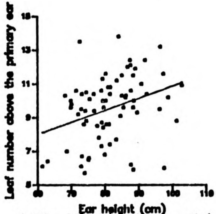

fig.18. relationship between ear height and leaf number above the ear

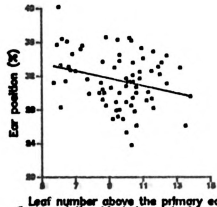

fig.19. relationship between leaf number above the ear and ear position

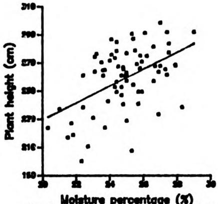

fig.20. relationship between moisture percentage and plant height

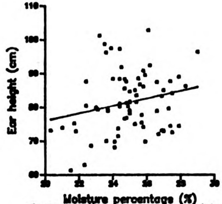

fig.21. relationship between moisture percentage and ear height

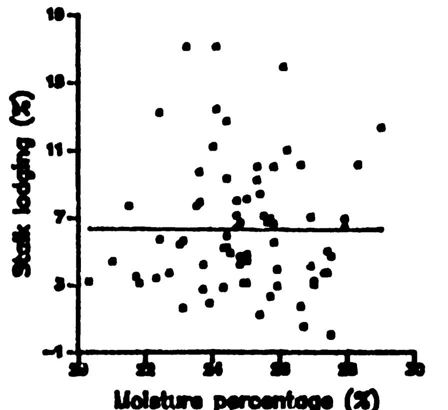

fig.22. relationship between moisture percentage and stalk lodging

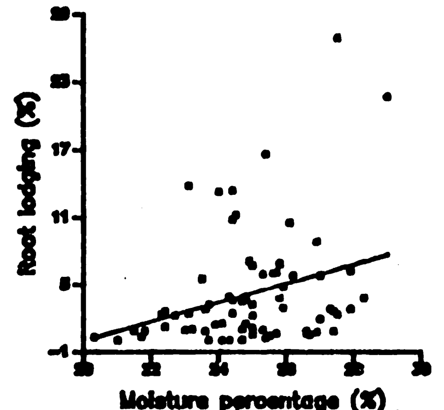

fig.23. relationship between moisture percentage and root lodging

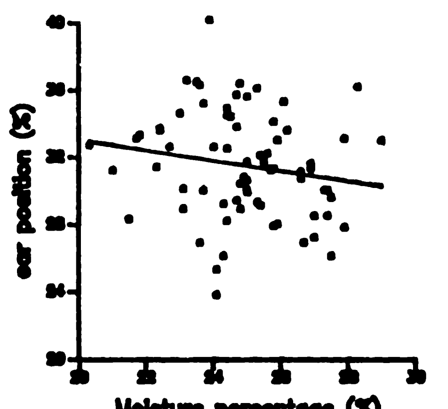

fig.24. relationship between moisture percentage and ear position

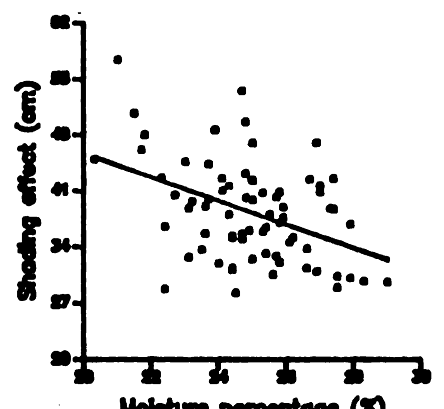

fig.25. relationship between moisture percentage and shading effect

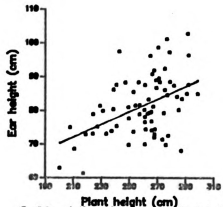

fig.26. relationship between plant height and ear height

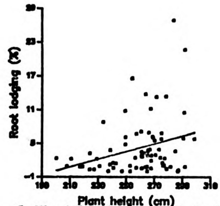

fig.27. relationship between plant height and root lodging

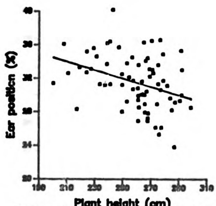

fig.28. relationship between plant height and ear position

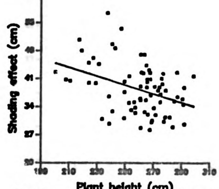

fig.29. relationship between plant height and shading effect

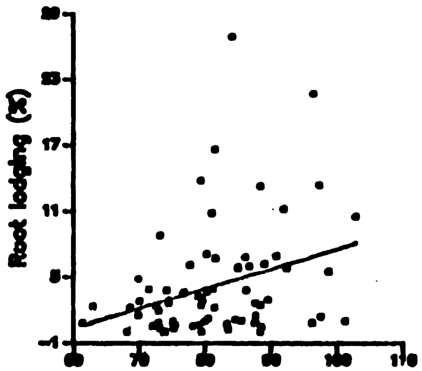

fig.30. relationship between ear height and root lodging

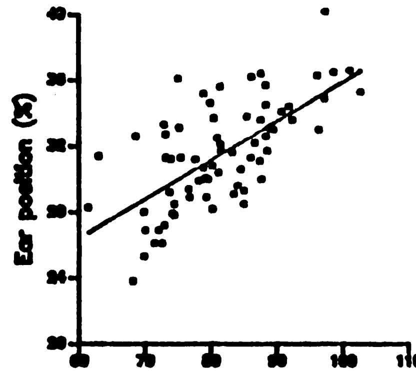

fig.31. relationship between ear height and ear position

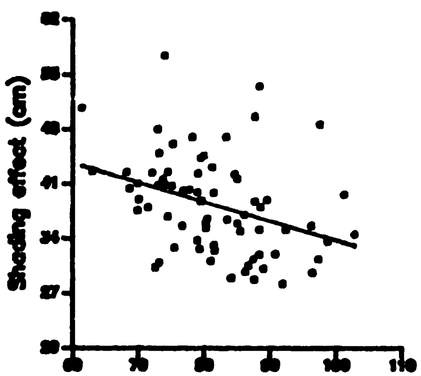

fig.32. relationship between ear height and shading effect

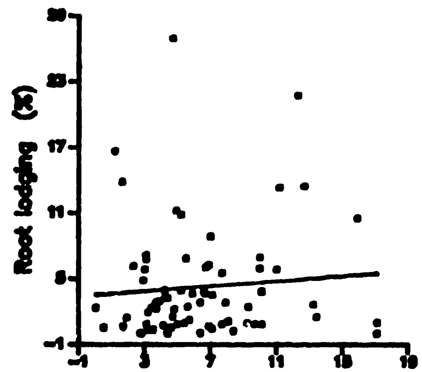

fig.33. relationship between stalk lodging and root lodging

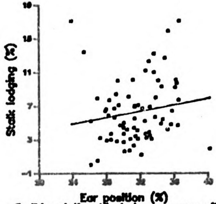

fig.34. relationship between ear position and stalk lodging

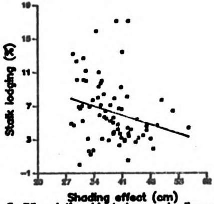

fig.35. relationship between shading effect and stalk lodging

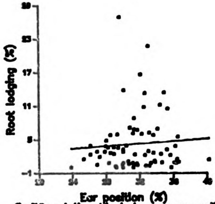

fig.36. relationship between ear position and root lodging

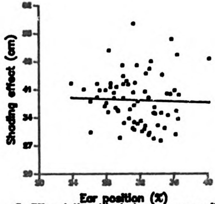

fig.37. relationship between ear position and shading effect