71-7282

HOPPER, Norman Wayne, 1943-

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Iowa State University, Ph.D., 1970
Agronomy

University Microfilms, Inc., Ann Arbor, Michigan

THE EVALUATION OF UPRIGHT LEAVES AND THE USE OF SUCROSE AND GLUTAMATE IN INCREASING THE YIELD OF CORN

by

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A Dissertation Submitted to the

Graduate Faculty in Partial Fulfillment of

The Requirements for the Degree of

DOCTOR OF PHILOSOPHY

Major Subject: Crop Production and Physiology

Approved:

Signature was redacted for privacy.

In Charge of Major Work

Signature was redacted for privacy.

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Signature was redacted for privacy.

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Ames, Iowa

1970

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INTRODUCTION

C. T. deWit (1967) has made the following statement: "Up to this point in man's history, photosynthesis is the only source of food on earth and its capacity may ultimately determine the number of people who can live on this planet without starvation." Presently there are about three billion people inhabiting the earth and it is predicted that by the year 2000, six to seven billion will be the population figure. The author (de Wit, 1967) concluded that at this present rate, the earth will have to support one-hundred billion people two-hundred years from now. Army and Greer (1967) have stated that man's food will continue to be produced by land-based agriculture. With these facts in mind, it can be seen that a tremendous responsibility is going to be placed on the plant scientists to develop new varieties of plants and to make more efficient the ones that are in existence today. Along this line of thinking, Army and Greer (1967) have proposed that the progress in crop production may be expected to follow four plateaus. The first plateau in increasing yields will come through the use of improved hybrids, insecticides, and herbicides. They further state that present agriculture has about passed this first plateau. The second plateau or second large jump in the yield per acre will result from the use of new plant types, bioregulators, and a new total production system for high yields. Further into the future is the third plateau in which the fundamental process of photosynthesis itself will be made more efficient. Finally, the fourth plateau, according to Army and Greer (1967), will be test tube farming. This will occur when man's knowledge of metabolism has advanced to a high degree.

Presently we are embarking upon the second plateau or phase in which new plant types will play an important role. The authors (Army and Greer, 1967) have stated that perhaps this plateau can be surpassed by extending the length of the grain-forming period and/or changing the plant shape to improve light interception. This second factor, changing the plant shape, is primarily what this author has addressed his research toward testing.

Lemon (1966) has reported that, of the total radiation striking the earth's surface, 52% is in the infrared region, 44% in the visible range, and 4% in the ultraviolet region. He also found that a corn crop in New York used 2.9% of the total incident radiation in dry matter production. When he corrected to absorbed visible radiation, his data gave a 7.3% efficiency over the most active part of the growing period. It can, therefore, be noted that 7.3% is a very low figure and that much useful radiation is being lost by striking the soil or wasted through being used inefficiently by a few of the leaves. Plants, therefore, should have a design that will enable them to absorb all or most of the incoming radiation and to distribute it uniformly over as much of the leaf area of the plant as possible.

Most of the corn hybrids currently being used have leaves that are relatively large and floppy. This being the case, relatively low plant populations have to be employed in order to reduce intra- and inter-plant competition for light. But it is well known that for the higher corn yields, relatively high populations of tolerant hybrids must be used. Therefore, to reduce intra- and inter-plant competition for light, the use of erect or upright leaves in corn has been tested. It is believed that with upright leaves incorporated into the hybrids, that higher populations can be planted and thus higher yields realized. This is thought to result from more leaves being illuminated at a lower light density, thus photosynthesizing at a higher efficiency.

Some researchers (Hageman et al., 1961 and Knipmeyer et al., 1962) believe the shading that occurs from higher populations, and consequently, the lower yields, results from the plant's reduced ability to reduce nitrate. They believe this to be more of a factor in reduced yields than lack of carbohydrate production under low light conditions.

These two aspects of production were researched to some degree and pertinent literature and data appear in the following pages.

REVIEW OF LITERATURE

Anderson (1964) has stated that "the energy of light from the sun ultimately drives all biological and meteorological processes." Therefore, if yields are to be increased to meet future needs, this light energy will need to be utilized and utilized efficiently. Several authors (Ustenko and Yagnova, 1967; Yocum et al., 1964; Loomis and Williams, 1963; and Williams et al., 1965a) have estimated and/or calculated the efficiency at which corn (*Zea mays* L.) utilized the sun's energy and generally have found that the percent efficiency is not too high. However, it should be noted that corn does utilize the sun's energy more efficiently than many other crops. Estimates for corn range from 2.9% use efficiency of the total solar radiation and 6.4% utilization of the photosynthetically active region to 12.9% use of the photosynthetically active region (Loomis and Williams, 1963; Williams et al., 1965a; and Ustenko and Yagnova, 1967). Yocum et al. (1964) have reported from their data that 5.1% of the visible (photosynthetically active) radiation was the maximum utilized at any time during the day and when averaged over the whole day 3.2% was the amount utilized. They employed corn grown in 29-inch rows at a population of 26,000 plants per acre. It can, therefore, be concluded from these studies that the solar energy is not being utilized efficiently in the process of photosynthesis. Williams et al. (1965a) believe that this percent utilization can be increased because they state that the energy-capturing capability of a corn crop is not being fully exploited.

When discussing the increased yields of crops the concept of crop growth rate (C) must be introduced. The crop growth rate is defined as the rate of dry matter production per unit of land area (Blackman, 1961; Loomis and Williams, 1969). The value of C is equal to the net assimilation rate (NAR = net increase in dry weight per unit time per unit leaf area) multiplied by the leaf area index (LAI = ratio of leaf area to land area) (Watson, 1947). It can, therefore, be noted that the maximum photosynthetic rate of a crop will be realized when the product of the efficiency of light utilization and the amount of light being intercepted is at a maximum.

As mentioned previously, to increase C the NAR and/or LAI will have to be increased. The NAR is primarily affected by the rate of respiration and by the rate of assimilation. Changes in the respiration rate do occur, but little can be done to manipulate this variable under field conditions. It is interesting to note, however, that in corn stands with a high LAI the lower shaded leaves do show an adaptation to lower light intensities by exhibiting a lower respiration rate (Chmara, 1967; Williams et al., 1965b; and Williams et al., 1968). The other factor affecting the NAR would be differences in the rate of assimilation per unit of leaf surface which in turn is due mainly to the amount of light intercepted. Blackman (1961) has stated that for all species that he investigated, a reduction in light from full to one-fourth full sunlight caused a reduction in the NAR. Light is, therefore, very important in determining the NAR and such can generally be increased with increasing light density. Some early research implied that increasing the light density only increased the rate of photosynthesis up to a point and after a certain density (saturation point) the amount of photosynthesis did not increase. Shirley (1929), in working with sunflower, found that the dry weight produced almost was directly proportional to the density of light received up to about 20% of full summer sunlight. At the higher light densities, the slope of the curve decreased. Verduin and Loomis (1944), in working with individual leaves of corn stated that about 2,500 foot-candles (ft-c) were a saturating light density. They did, however, observe that photosynthesis did continue to increase gradually up to the maximum light density that they studied (11,000 ft-c). These two authors concluded that light densities above 3,000 ft-c were of questionable value in carbon dioxide (CO_2) absorption by fully exposed leaves of corn. More recent research has indicated that perhaps the corn leaf is not saturated even at full sunlight density. Hesketh and Musgrave (1962) found that individual corn leaves were not light saturated even at 10,000 ft-c, but that the rate of change in the amount of photosynthesis was small at this light density. Hesketh (1963) noted from his research that the corn leaf had not reached a saturation point at 2.0 langleys (ly) per minute which was equivalent in quanta to 10,000 ft-c. He observed a break from linearity at 0.5 ly per minute, but no saturation point was observed. Hesketh and Moss (1963) also made the observation that they saw no evidence of a light saturation point for corn. From their studies, Baker and Musgrave (1964) stated that under field conditions of adequate moisture and CO_2, that a corn stand with an LAI greater than 0.6 would never reach light saturation.

From these studies it can be concluded that the NAR and thus photosynthesis can be increased with increasing light density even up to full sunlight. But above 2,500-3,000 ft-c the additional light is used less efficiently with each added increment (Bonner, 1962). This being the case, it would be more advantageous to spread a lesser light density over a larger leaf area. This led Watson (1952), Watson (1958), and Waggoner et al. (1963) to conclude that there was little opportunity to increase yields through increasing the NAR. It was their opinion that increasing the LAI was the most obvious means of increasing the crop growth rate or production.

Just increasing the LAI of a corn stand will not continue to increase the production of corn infinitely, however. Although corn does exhibit a critical leaf area index, a point will be reached where an increase in the LAI will not result in a corresponding increase in the crop's production. Presently, the most common way of increasing the LAI is by increasing the plant population. Concurrently with increasing the plant population, the use of narrow rows also need to be utilized, e.g., a 20-inch row spacing. The use of narrow rows has been shown to use the incoming radiation more efficiently. For example, Aubertin and Peters (1961) reported that at the same population more energy was intercepted by a crop with 20-inch rows. It also was reported by Yao and Shaw (1964) that the amount of net radiation at the ground level versus the amount of net radiation one meter above the corn crop was decreased as the row spacing decreased at any particular population. Colville (1968) reported that for 40-inch rows of mature corn that the amount of light intercepted increased as the plant population increased. As a summary, Denmead et al. (1962) estimated that possibly photosynthesis could be increased by as much as 15-20% by utilizing 24-inch rows instead of 40-inch rows and attributed this to the efficient utilization of more of the net radiation.

As mentioned previously, an LAI will be reached in corn where a further increase in the LAI will not result in a corresponding yield increase. Several authors (Monteith, 1965; Eik and Hanway, 1966; and Williams et al., 1968) have reported that maximum yields of corn were obtained when the LAI ranged from about 3 to 5. Williams et al. (1968) found an approximate proportional increase in the relative light interception up to an LAI of 3. Ek and Hanway (1966) noted that the linear relationship between grain yield and LAI did not hold above an LAI of 4. Another researcher (Monteith, 1965) found that for LAIs in excess of 5, most of the light had been intercepted and yields maximized. Therefore, to increase C by increasing the LAI above 4 or 5, the light must be spread more evenly over the entire leaf area of the plant. This means that ideally the upper leaves should absorb less light, thus allowing the lower leaves to intercept enough light such that they may contribute to the production of photosynthate. One means of doing this would be to develop corn plants with their leaves erect or upright (Monteith, 1969).

To better understand the distribution of light within the canopy, the Bouguer-Lambert Law has been used by many researchers (Loomis et al., 1967; and Hesketh and Baker, 1967). The law is as follows:

$$I = I_o e^{-KL}$$

where: I = Illumination on a horizontal surface within the canopy

I_o = Illumination on a horizontal surface above the canopy

K = Extinction coefficient

L = Cumulative leaf area index above the given level in the stand.

The two factors in the above equation that can be controlled to some extent are K and L. The factors influencing L have already been discussed. The most important components controlling K are the solar elevation, the leaf area density, and the leaf angle of the plant. Of these factors, leaf angle is one of the more easily manipulated. It might be noted here that the greater the angle the sun is from the horizontal (higher solar elevation), the more the benefit realized from upright leaves (Wilson, 1967). This is applicable when the sun's angle to the horizontal is greater than 30°.

The ideal situation, therefore, would be for the top part of the canopy to have a small K value grading to a high K value at the bottom of the canopy. In this regard, the lowest leaf of the plant should be receiving just enough light to keep it above the compensation point (the level where photosynthesis is just balancing respiration).

According to Anderson (1966) and Loomis and Williams (1969) the K value for light hitting a horizontal surface is equal to one and decreases as the leaf angle becomes more vertical. This same trend has been shown by Nichiporovich (1968). Ross (1967) has demonstrated that the value for K decreases more slowly for vertically oriented leaves than for horizontal leaves in going from the top to the bottom of the canopy. This means that less light is being removed by each additional increment of leaf area and thus more leaf area is operating and doing so more efficiently for the vertically oriented leaves.

Many of the commercial varieties now in use do not have vertically oriented leaves, thus, not much light is reaching the lower leaves of the canopy. Therefore, under these circumstances it would be of little value to increase the LAI. Denmead et al. (1962) found that some 73% of the energy exchanged within a corn canopy in 40-inch by 40-inch hills at a population of 15,700 plants per acre was done within the upper one-half of the canopy at the time of maximum leaf area development. According to Ross and Vlasova (1967), in very dense stands of corn most of the absorption of light occurred in the upper 50 cm region which contained not more than 30% of the entire leaf area. Wright and Lemon (1966) have shown that fully 53-83% of the canopy CO_2 fixation occurred in the 175-200 cm region of densely planted 220 cm tall corn, depending on the time of day. Kurbatov and Dovnar (1961) demonstrated that 56%, 36% and 8% of the total canopy photosynthesis occurred in the upper, middle, and lower layers, respectively, at a plant population of about 21,000 plants per acre. These same trends were shown by Earley (1965) in which he stated that the efficiency of grain produced per unit leaf area decreased in the order of upper to middle to lower canopy levels. Allen et al. (1964) made some theoretical calculations of potential photosynthesis and showed that the photosynthesis and the photosynthesis per LAI both decreased from the top to the bottom of the canopy. Loomis et al. (1968) also have noted that with increasing populations, more of the LAI is concentrated in the upper part of the canopy. Therefore, any attempts to increase corn production by increasing the LAI to relatively high values will have to be coupled with attempts to improve the light relations in the middle and lower canopy areas. As stated above, this may be accomplished by utilizing varieties with erect leaves.

Wilson (1960) has stated that as the leaf angle is increased, the amount of leaf area that will be illuminated will progressively increase as the secant of the angle if the angle of inclination of the leaf is to the horizontal. He further notes that the intensity of the illumination within this area will decrease as the cosine of the angle. For example, the amount of leaf area that one unit of light will cover when the leaf angle is 0° to the horizontal is one, whereas, when the leaf angle is 80°, the amount of area illuminated will be approximately 5.75 units. The intensity of illumination of each unit will be reduced from 1.0 to 0.174 for 0° and 80°, respectively. Therefore, more leaf area will be illuminated and the intercepted radiation will be used more efficiently as the leaves become more upright (Anderson, 1965).

It is important for light to penetrate deep into the canopy if these lower leaves are capable of sustaining moderately high rates of photosynthesis when additional light is supplied to them. Two reasons for such are that the leaves above the ear are important in producing and transporting photosynthate to the ear and secondly, a large amount of leaf area is concentrated in the middle and lower canopy regions which could potentially contribute to a higher yield (Palmer and Musgrave, 1966; and Ross and Nilson, 1967).

Several types of studies have been conducted to determine the importance of various canopy levels in contributing to the yield of the plant. Some of these methods have centered on measuring the CO_2 uptake at different canopy levels and by measuring the effect on yield of removing a particular strata of leaves, shading various portions of the plant, growing alternating tall and short varieties of corn in the same plot and light reflection studies.

Moss and Peaslee (1965) found that if the lower leaves of the corn plant were supplied with adequate nutrition that they could assimilate CO_2 at nearly the same rate as the upper leaves when they received an equal amount of light.

Another method of determining the contribution to yield of various canopy levels is to remove various portions of the leaves. In discussing leaf removal, two aspects are important. These are the location of leaf removal within the canopy and the stage the corn plant is in at the time of removal.

Loomis (1935) found that removing the upper 75% of the leaves versus removing the lower 75% did not cause much of a differential yield reduction. When he removed the upper 50% and lower 50%, he found that the upper 50% of the leaves yielded 71.5% of the check, whereas, the lower 50% of the leaves yielded only 59.0% of the check. Also, the upper and lower 25% of the leaves yielded 32.4% and 8.7% of the check, respectively. Hoyt and Bradfield (1962) conducted experiments where they removed the top, middle, and lower one-third of the leaf area. After partial defoliation there remained an LAI of about 3.3. They found a dry matter production ratio, when expressed on a square meter of leaf surface, of 4.0:2.2:1.0 for the top, middle, and lower canopy layers, respectively. They attributed this to the fact of decreased light within the lower canopy layers. Hammond and Pendleton (1964) and Pendleton and Hammond (1969) also have generally obtained these same results. They observed that leaf removal tended to reduce yields more on an intolerant hybrid than on a tolerant hybrid. They also postulated that the top leaves of the intolerant hybrid were the most important in grain production, whereas, the middle leaves on the tolerant hybrid were the most valuable. This again indicates the value of getting light to the middle canopy leaves in corn production when higher yields are sought by increasing the LAI and thus the population. Similar research in this area has been conducted by Tanner and Daynard (1967) on corn, by Strickler and Pauli (1961) with grain sorghum, and on wheat and oats by Womack and Thurman (1962). These researchers have generally observed the same results.

The time of leaf removal also is important in the reduction of grain yield. Dungan (1934) reported that the two most critical stages of leaf removal were at the tassel stage and fresh silk stage. Cornelius et al. (1961) found the period of three to four days before and after silking to be more critical than five or more days after silking with respect to the role of the upper leaves in grain production. They removed the upper four leaves at 5, 10, and 20 days after silking and reduced the grain yield by 13.8%, 8.0% and 7.0%, respectively. Hanway (1969) reported that yields were reduced most by leaf removal at stage four which is the time of tassel emergence. Therefore, removal of the upper leaves reduces yields more than does removal of lower leaves, but the potential of the lower leaves is about as high as the upper leaves. Also, the period of tassel emergence and silking were the most critical times to remove leaves.

A third method of determining the contribution of various canopy levels is to shade various strata. This method would come the closest to simulating the mutual shading that occurs in the field. Again, the two factors of amount of shading and the time that the shading treatments are imposed are important considerations. Schmidt and Colville (1967) reduced the amount of light reaching the leaves below the ear by shading them with black plastic frames at ear silk emergence. A 40-inch row spacing and a population of 16,000 plants per acre were utilized in their study. They found that when these leaves were shaded by 25%, 50%, 75%, and 100% that the corresponding yield reductions were 5%, 5%, 13%, and 14%, respectively. They also reported that removal of this same tissue instead of just shading, reduced the yield more. From this study it can be seen that the lower leaves do contribute to grain yield even though they do receive less light than the upper leaves. They further stated that the leaves below the ear leaf were equally efficient in grain production on a per unit leaf area basis.

Stinson and Moss (1960) found that varieties tolerant and intolerant to high populations react differently to shade treatments. These researchers reported that when shaded the tolerant variety was reduced in yield by 20%, whereas the intolerant variety was reduced by 42% when planted in 39-inch rows and at a population of 13,500 plants per acre. Due to this shading, the tolerant variety increased in barrenness by 5.8% and the intolerant variety showed an increase in barrenness of 21.5%. They concluded that barrenness was responsible for lower yields at higher populations also, and therefore, a parallel must exist between the yields of hybrids from shading and thick planting. Moss and Stinson (1961) also reported that the yield of intolerant hybrids was reduced more by shading than were the tolerant hybrids. Again, they attributed this to an increase in barrenness of the intolerant hybrids when shaded. They found that this increase in barrenness was related to a delay in silking and this was especially true for the intolerant varieties. McIlrath and Earley (1961) and Reichert et al. (1958) also reported similar results. They found that the rates of tasseling, anther emergence, silk emergence, and pollen shedding were all reduced due to increased shading.

Shading experiments where alternating short and tall hybrids were planted together also have been conducted. Pendleton and Seif (1962) found that when a dwarf variety of corn was bordered by normal corn in a 40-inch row spacing and at a population of 16,000 plants per acre, the yield of the dwarf was greatly reduced. When normal corn was bordered by dwarf corn, they obtained a 6% yield increase over a solid planting of normal corn. Prine (1961) alternated the planting in adjacent rows of a short, early maturing variety and a tall, late maturing variety. At 18,000 plants per acre he observed an increase in the yield of the tall variety when planted this way versus a solid planting of the tall variety. He also grew the tall, late maturing variety in a solid stand and topped alternate rows above the tenth leaf when 10% of the plants were silking. From this study he also observed a yield increase of the non-topped rows. These results were attributed mainly to a decreased competition for light.

Another technique that has been used to show that added light in the lower canopy levels is important has been light reflection studies. Prine (1961) obtained a 20% yield increase in corn at 15,000 plants per acre when he placed aluminum foil reflectors in every middle of 38-inch rows at the 12 to 14 expanded leaf stage. At 30,000 plants per acre he noted a 12% increase in yield. The reason the higher population did not respond more to the additional light was because less light reached the aluminum foil and, hence, less was reflected back into the canopy. Pendleton et al. (1967) conducted an experiment where they increased the light in the canopy by reflecting light off an aluminum foil reflector placed beside the row. They noticed a 20% increase in the grain yield per plant due to the "light rich" environment at a medium population (17,000 plants per acre). The higher population (35,300 plants per acre) was observed to benefit more from the additional light due to a more efficient production of photosynthate per unit of leaf surface. Winter and Pendleton (1970) concluded from their studies that the increased yield could not be attributed to increased light only. They noted that by cooling the air and plant temperatures by sprinkler irrigation in the reflected light plots, the yield in grams per plant was reduced by about 8.4%. Therefore, part of the additional yield from reflected light was due to increased temperature, but the majority of the response was from the additional light. Pendleton et al. (1966) placed white and black plastic beneath corn plants in an attempt to alter the yield. They got the most yield response when they placed the plastic under the corn when it was 12 inches tall rather than when it was at the tasselling stage. From a three year study, they observed a 12% yield increase at 16,000 plants per acre from the white plastic and a 7% increase at 24,000 plants per acre. Black plastic caused a 3% and a 5% yield increase at the low and high populations, respectively. This was attributed to a conservation of soil water. Therefore, the white plastic netted 9% and 2% yield increases for the low and high populations, respectively, due to more light being absorbed by the canopy.

In addition to allowing more light to penetrate into the canopy, upright leaves allow more light to be reflected from the leaves themselves down into the canopy (Verhagen et al., 1963). In this respect, it is interesting to note that corn leaves can use light equally as efficiently whether it is received from the top or bottom (Moss, 1964). This fact is very important in considering upright leaves because much light will be absorbed by the lower surfaces of many leaves. According to this author, this is because the chloroplasts are evenly distributed throughout the mesophyll, thus no excess absorption by inactive materials from the top or bottom occurs.

From the preceding studies it can be noted that the middle and lower leaves of a corn canopy can make a positive contribution to grain yield only if they can get adequate light.

In recent years much work has been done with computer models to simulate actual growing conditions. A large amount of this work has centered on the value of upright leaves in utilizing the sun's energy. These mathematical models give researchers an insight into the various processes that they are trying to simulate. They can frequently obtain answers to questions where experimental approaches are impossible or extremely expensive (Duncan, 1967).

Duncan (1967) has done much work in this area. In his computer models he has included such variables as the following: 1) leaf angle, 2) leaf area, 3) leaf position, 4) reflectivity, 5) transmissivity, 6) light-effect curve relating photosynthesis to leaf illumination, 7) brightness of the sun and sky, 8) position of the sun, and 9) respiration rate. Duncan et al. (1967a) constructed computer models for corn in which they had leaf angles of 0^o, 40^o, and 80^o, from the horizontal and LAI values of 2, 4, and 8. In their results that follow they obtained the highest "yield" around solar noon. When the leaf angle was 0^o, the yield was in the order of from highest to lowest at an LAI of 4, 8, and 2. When the leaf angle was 40^o, the LAI of 8 was only slightly higher yielding than an LAI of 4 and both of these were somewhat higher than the LAI of 2. At a leaf angle of 80^o, the LAI of 8 yielded considerably more than the LAI of 4, which in turn yielded more than the LAI of 2. It can be noted that the real advantage comes when the leaf angle is very upright. In another publication the authors (Loomis et al., 1967) proposed that below an LAI of 3 to 4, upright leaves did not have a positive effect on the crop growth rate. But as the LAI increased from this value to an LAI of 8, the value of upright leaves became very important. At an LAI of 8 their models showed a crop growth rate of about 33, 38, and 60 grams of dry matter per square meter of ground area per day for leaf angles of 0^o, 45^o, and 90^o, respectively. From their simulations they also noted that the best results could be obtained from the foliage display when the leaf angle at the top was near 90° and became progressively less until at the bottom of the canopy the leaf angle was 0°. In order of highest to lowest yield they found that as one proceeded from the top to the bottom of the canopy, the 90° to 0° yielded more than the treatment in which all leaves had an angle of 45°, which in turn yielded more than the display of 0° to 90°. Kuroiwa (1968) also has done some computer simulation work. His studies show that light for photosynthesis can be from either direct sunlight or from reflected sunlight and skylight. In all cases he obtained the highest photosynthetic rates near local noon. At an LAI of 1 he found that most of the photosynthesis resulted from direct sunlight in a canopy of flat leaves. If the leaves were vertical, the total photosynthesis was a little less than was obtained from the flat leaves and was comprised almost entirely of direct sunlight near local noon. At an LAI of 10, and again at local noon, his models showed that in the flat canopy most of the total photosynthesis resulted from skylight and reflected sunlight. But in the upright canopy structure, he noted a much higher total photosynthesis which was attributed mostly to direct sunlight. Again, this shows the value of getting sunlight deeper into the canopy.

According to Loomis et al. (1967) one disadvantage of the computer models is that they tend to overestimate the crop growth rate. But they did hasten to add that this was partly compensated for by their high values of gross photosynthesis. Some reasons for deviations between calculated and observed values might be due to wrong estimates in respiration, not accounting for tassel absorption of light, and no correction for leaves damaged by wind, insects, senescence, and disease (Duncan et al., 1967a; Duncan et al., 1967b and Hunter et al., 1969). All factors included, the models do present a reasonable and enlightening estimate of a crop's response.

The conclusions that can be drawn from these computer simulations are that it would be best to have a plant with a high LAI with very upright leaves near the top of the plant grading to a flat or horizontal leaf near the bottom. This would allow for the most efficient utilization of the incoming radiation.

The real test of any theory or any computer simulation model will come from actual field testing. The testing of upright leaves have been evaluated in the field with such crops as barley, wheat, rice, and to a lesser extent, corn.

Some of the earliest work done in this area was performed by Tanner and Gardener (1965). In a study at the Ontario Agricultural College they had six varieties of barley. Three of these varieties were high-yielding varieties and three were low-yielding varieties. The high-yielding varieties accumulated about 20% more dry matter per day than did the low-yielding ones. Upon closer examination they noted that the high-yielding ones had narrow upright leaves while a wide dropping leaf was characteristic of the low-yielding varieties. Gardener et al. (1964) noted that the reason for the high-yielding varieties being such was due to better light penetration into the open canopy which resulted in fewer leaves being below the compensation point. Tanner et al. (1966) ranked about 300 strains of wheat, oats, and barley into categories of high, medium, and low yielders only on the attributes of leaf angle and leaf width. They then compared their visually selected high-yielding varieties with the actual yield data and found that they had properly categorized them all except for two strains. Stoskopf

(1967), in working with winter wheat noted a much better yield response from varieties with narrow upright leaves than from droopy wide leaved ones when he planted them in narrow rows.

Pearce et al. (1967) conducted an experiment with barley in which flats containing the barley were inclined at different angles for a period of time. This inclination caused the leaves of the plants to grow at different angles with respect to the flats because the seedlings grew toward the light source. They obtained leaf angles from the horizontal of 90^{o}, 53^{o}, and 18^{o}. Three different populations (25, 50, and 100 grams of seed per 32 by 50 cm flat) were used and they measured such attributes as the LAI, the percent light penetration, the extinction coefficient, the amount of photosynthesis, the net assimilation rate, and the rate of respiration. As would be expected, the LAI increased with increased plant population, but it also was noted that the LAI increased more with the upright leaved plants than with the flat leaved ones. The light penetration percent decreased with increased population and more so for the horizontal leaved plants. With increased populations, the extinction coefficient also generally decreased and the higher values were observed with the more horizontal leaf types. The rate of photosynthesis increased with the higher populations and the highest rates were associated with the vertical leaf character. Values for the net assimilation rate decreased as the population increased, but more so when the leaves were horizontal. Respiration rates increased as the plant density increased, but tended to decrease as the leaf angle became more horizontal. They also noted that a higher LAI was required for 95% light interception when the leaves were more vertical. Their conclusion was that better light relations existed within the canopy when the leaves were more vertically oriented.

Work in this area also has been conducted with rice. Most of this work has been done by workers in Japan. Tanaka et al. (1969) conducted an experiment in which they had a rice community with an LAI of 7.1 and divided it into two subcommunities. One subcommunity was used as a check and it had erect leaves. The other subcommunity was transformed into a community with horizontal leaves by attaching weights to all of the leaves. They then measured the carbon assimilation and noted that the community with upright leaves expressed no light saturation point, whereas, the community with the flat leaves did reach a light saturation point. After heading they noted a 34% less increase in the weight of dry matter from the community with the curved and dropped leaves. The community that had horizontal leaves also yielded 33% less grain than the community that had the erect leaves. Chandler (1969) concluded that short and erect leaves of medium width were associated with the capacity for high yields. He also noted that the varieties that responded to high nitrogen fertilization were those with erect or upright leaves.

At the present time, not too much actual field data has been collected with corn. Pendleton et al. (1968) conducted a study in the field utilizing upright leaves. One phase of the experiment centered on utilization of an isoline of the variety C103 x Hy. This is a single cross hybrid that supposedly differs only in leaf angle due to the absence of a ligule. From these two lines of C103 x Hy, they noted a 41% yield increase from the upright versus the flat leaf arrangement at a population of 24,000 plants per acre. Both isolines had an LAI of about 4. This yield increase was attributed to a 50% reduction in barrenness. This liguleless characteristic was first reported by Emerson (1912). Brink (1933) also observed this characteristic and proposed that the two types of traits observed by himself and Emerson (1912) were caused by different genes. The isoline used by Pendleton et al. (1968) was due to the liguleless-2 gene (lg_2). Pendleton et al., (1968) also planted some Pioneer 3306, a commercial hybrid, at 24,000 plants per acre and imposed three treatments upon it. They were as follow: 1) the normal or check plots, 2) all leaves tied up, and 3) the leaves above the ear tied up. The tying up of the leaves was done with clear plastic strips to an angle of about 80° from the horizontal. From these treatments they noted that the highest yield resulted from the treatment in which just the leaves above the ear were tied up. This was accomplished with 90% of the visible light being intercepted 30 days after silking. The treatment in which all of the leaves were tied up yielded somewhat less than the previous treatment, but intercepted only 84% of the visible light. The lowest yielding treatment was the check plots which had a horizontal leaf display. These plots intercepted the most light (99%), but due to inefficient utilization, they yielded the least.

From the theoretical data collected from mathematical models and from actual field data, it can be noted that more efficient utilization of the incoming solar radiation can lead to increased yields. One mechanism of doing this is by distributing the radiation more evenly throughout the canopy by incorporating the erect leaf characteristic into the crop varieties.

Some other benefits also may be derived from the use of corn with upright leaves. Tanner et al. (1960) noted that when a corn crop is fully grown that the maximum soil evaporation may range as high as 25% to 50% of the total evapotranspiration. With the use of varieties with upright leaves, the population could be increased, thereby decreasing the amount of radiation striking the ground to cause evaporation. Shinn and Lemon (1968) observed that the upper leaves of corn had higher water potentials than the lower leaves. These authors also noted that horizontal leaves approached 30°C during midday which would have an effect on the water potential. They suggest that the development of these water potentials lead to decreased plant growth. While working with a variety of corn with horizontal leaves and leaves manipulated into a vertical position, Stevenson (1969) noted wilting to occur during high demand days in the natural plots, but not in the plots with upright leaves. He also noted that the plots with the erect leaves tended to remain green for at least one week longer. These additional attributes of erect leaves also may add to their effectiveness in increasing yield.

In the preceding paragraphs the effects of inefficient utilization of light or its poor penetration down into the canopy has been discussed in the context of reduced carbohydrate production. This reduced carbohydrate production then has been eluded to as the limiting factor in increasing the yield. In addition, work also has been done to determine the effects of poor light relations down in the canopy on nitrogen metabolism. This aspect of nitrogen metabolism also has been implicated as the limiting factor of higher yields.

Devlin (1966) has presented a scheme in which he depicts stored carbohydrates and photosynthesis as being the source of respiratory substrates. From the process of respiration carbon skeletons and energy are produced. This energy is then used to reduce nitrate to ammonia and then to combine this ammonia with the previously formed carbon skeletons to form amino acids. These amino acids are then used for protein synthesis and, hence, plant growth. Hageman et al. (1961) believe then that corn yields are determined by the level of protein reserves or protein precursor substances (e.g., glutamate) and the potential of the plant to synthesize these substances.

It is generally known that plants take up nitrogen from the soil in the nitrate form which has an oxidation number of +5. Then by successive reductive steps two electrons are added each time until the end product is ammonia which has an oxidation number of -3 (Devlin, 1966). It appears that the limiting step in the process of nitrogen metabolism is this reduction of nitrate to ammonia. A considerable amount of work has been done to determine the identity of the reducing agent and also the source of energy for this reductive process. Knipmeyer et al. (1962) have found that such energy could come directly from light energy through the process of photosynthesis or from carbohydrate metabolism. It appears that through the process of photosynthesis that nicotinamide adenine dinucleotide (NADH) and nicotinamide adenine dinucleotide phosphate (NADPH) are formed and then these compounds function to reduce nitrate to ammonia. These two compounds have been shown to be about equally effective in the reductive process, but the NADPH seems to be slightly more important (Evans and Nason, 1953 and Hageman et al., 1961). Evans and Nason (1953) noted that soybean leaf homogenates collected in the early morning showed little ability to reduce nitrate without the addition of NADPH or NADH. But if leaves were collected after they had been exposed to sunlight for a few hours, then the nitrate could be reduced without the addition of NADPH or NADH. In further experiments in which they combined the enzyme nitrate reductase, KNO_3, NADP, and grana, they noted a reduction of the nitrate only when the mixture was exposed to the light. If in the above mixture they added NADPH instead of NADP, they observed nitrate reduction in both the dark and light. They also determined that for the light to be effective that grana had to be present. It was then demonstrated that the NADPH could come from the photochemical act. It can be noted then that when poor light relations exist within the canopy, not much NADH and NADPH will be formed and, hence, very little nitrogen reduction will occur. This lowered nitrogen reduction leads to a small amount of amino acid and protein synthesis which in turn hampers growth.

Numerous studies have been conducted to study the effects of shade on the levels of nitrate, the enzyme nitrate reductase, and protein content. Hageman et al. (1961) noted that under good conditions of soil moisture and nitrate, the lower leaves of corn had a higher nitrate content than the upper leaves. This indicates that in the lower shaded leaves the nitrate is not being reduced to ammonia. Hageman and Flesher (1960) and Knipmeyer et al. (1962) observed that nitrate accumulated in plants grown under conditions of low light intensity and also that this could not be attributed to differences in nitrate accumulation due to varying the light density. They attributed this accumulation of nitrates to reduced light and nitrate reductase activity.

It also has been observed that the activity of the enzyme nitrate reductase is hampered by both low amounts of light and nitrate (Hageman and Flesher, 1960). Zieserl and Hageman (1962) have observed that the activity of nitrate reductase is drastically lowered by artificial shading and shading even for a brief time can lower the nitrate reductase activity

(Hageman et al., 1961 and Zierserl et al., 1963). Hageman et al. (1961) noted that corn lost approximately 50% and 90% of the nitrate reductase activity within 24 and 48 hours, respectively, after being placed in the dark.

Lang et al. (1956) have noted a decrease in the percent protein of the grain as the plant population was increased. This was probably due to a reduced amount of light in the lower canopy layers. Earley et al. (1966) also observed a decrease in grain protein associated with intermediate light levels. Researchers have observed that varieties tolerant to population stresses had somewhat higher protein contents than intolerant ones as the percent shade was increased (Hageman et al., 1961).

According to Reichert et al. (1958) and Earley et al. (1967), the rates of tassel emergence, anther emergence, and silking were all reduced due to imposed shading treatments. With all of these factors combined, the authors expected and observed a yield reduction due to shading.

From these results it appears that light is needed for the reduction of nitrogen and that this is mediated through the photochemical reduction of NADP and NAD. Once the nitrogen has been reduced it can combine with various carbon skeletons to form certain amino acids. Certain of these amino acids can transaminate to form other amino acids which can be used for protein synthesis and growth.

In conclusion, it should be noted that presently the crop plants on this planet utilize very little of the incoming solar radiation for their growth. In addition, many of these crops utilize the energy very inefficiently. This can be corrected to some degree by spreading the incoming radiation over more of the plant's leaf area. This not only increases the efficiency with which a unit of light is used but increases the amount of leaf area photosynthesizing above the compensation point. As shown by both computer models and actual field data, the use of upright leaves will accomplish this result. With the use of upright leaves it would be most efficient to have a high LAI with the leaf angle grading from 90^{o} (measured from the horizontal) at the top to 0^{o} at the base of the foliage.

It also was noted that lighting of the lower leaves can have an enhancing effect on the nitrogen metabolism of the plant. Light is necessary for the production of carbon skeletons that are the backbones of the amino acids and also necessary for the reduction of nitrogen. These carbon skeletons and reduced nitrogen form amino acids which are then utilized in protein formation and growth.

Duncan (1969) has stated that "high yielding crops come from plants that are pacifists; that concentrate on productivity and minimize rivalry."

METHODS AND MATERIALS

This study consisted of research conducted over a three year period from 1967 to 1970. Field research plots were utilized during the summers of 1967, 1968, and 1969, and were located at the Beach Avenue experimental area located about two miles south of the Iowa State University campus in Ames, Iowa. The soil type at this location consisted of a Colo silty clay loam with fine sand lenses approximately 4 to 6 feet below the surface.

The native fertility of this area was medium to low for nitrogen (N), phosphorus (P), and potassium (K) and had a soil pH of approximately 6.5. Each experimental location was fall plowed and most of the phosphorus and potassium were broadcast before the plowing operation for each of the three years. Experiment 1 received nitrogen before planting only, whereas, Experiments 2 through 9 received nitrogen preplant, as a starter at planting time, and a sidedress application during the summer. Experiments 2 through 9 also received starter applications of P and K. Shown in Table 1 is a summary of the amounts of fertilizer applied to each of the experiments.

Experiments 1 through 6 were conducted to determine the effectiveness of upright versus flat leaves of corn (_Zea mays_ L.) in the production of dry matter and grain yield. This was accomplished by utilizing different varieties and populations in most cases. In one experiment (Experiment 4) a comparison also was made between the fertile and sterile counterparts of the varieties tested. Experiments 7 and 8 were studies pertaining to nitrogen metabolism and Experiment 9 was addressed to the effects on the corn plant of leaf removal and the application of aluminum foil.

Table 1. The amounts of fertilizer (pounds/acre) applied and time of application for Experiments 1 through 9

Experiment	N			P		K	
	Preplant	Starter	Sidedress	Preplant	Starter	Preplant	Starter
1 (1967)	150			53		100	
2 (1968)	150	15	100	53	13	100	50
3 (1968)	150	15	100	53	13	100	50
4 (1968)	150	15	100	53	13	100	50
5 (1969)	130	16	143	40	13	75	50
6 (1969)	130	16	143	40	13	75	50
7 (1969)	130	16	143	40	13	75	50
8 (1969)	130	16	143	40	13	75	50
9 (1969)	130	16	143	40	13	75	50

Experiment 1967

Experiment 1

Table 2 lists the planting date, plot size, populations, and varieties utilized for Experiment 1.

A split-split-split randomized complete block design in which the main plots were randomized was utilized. The main plots were the pairs. Ten varieties were chosen to constitute five pairs. The varieties were paired as closely as possible for all characters except leaf angle. One member of each pair had erect leaves while the other member had flat or horizontal leaves, relative to each other. The subplots were the four different populations and the sub-subplots were the four harvest dates.

The seedbed was prepared using the normal cultural practices common to

Table 2. Planting date, plot size, populations, and varieties utilized for Experiment 1

Experiment	Planting Date	Plot Size Length (ft)	Width (rows)	Population[a]	Varieties[b] Upright	Flat
1	May 5	7.5	8 - 12"	14,000	Pa884P[c]	B57[c]
				19,000	H60[c]	HD2268[c]
				37,000	Hy[d]	B14[c]
				68,000	B54[c]	WF9[d]
					SX 29[e]	B14 x 577[f]

[a]Plant population in plants per acre.

[b]Upright and flat leaved counterparts of a pair are shown side by side.

[c]Seed source was Dr. W. A. Russell, Iowa State University, Ames, Iowa.

[d]Seed source was Clyde Black and Sons Seed Co., Ames, Iowa.

[e]Seed source was Pfister Associated Growers, Aurora, Illinois.

[f]Seed source was Pioneer Hybrid Seed Corn Co., Johnston, Iowa.

the Central Iowa region. The experiment was planted with a small grain V-belt oat planter in 12-inch rows. The plots were planted at 10% to 25% over the desired population to allow for reduced germination.

Weed control was accomplished by using a combination of the herbicides Atrazine and Ramrod. The herbicides were sprayed on immediately after planting. No cultivation was done due to the narrow rows (12-inch), but weed control was considered adequate.

As mentioned previously, four dry matter harvest dates were taken. Prior to each harvest date leaf area measurements were taken by selecting four plants at random within the plot and measuring the length and width (at the widest part) of each leaf. These length and width measurements of each leaf were then multiplied together and accumulated for the entire plant and the product of such multiplied by 0.75 to give the total leaf area per plant. To obtain the LAI (leaf area index), the leaf area per plant was multiplied by the number of plants per acre and then divided by the associated land area. This method was similar to the method used by Montgomery (1911) and McKee (1964). At harvest date three, leaf angle measurements also were taken. This was accomplished by measuring from the junction of the leaf sheath and blade to the crest of the ear leaf. A measurement was then taken from the crest of the leaf to the main stem or stalk of the plant. With these two measurements the leaf angle could be determined mathematically. The plots were harvested by cutting the plants off at the ground, counting, and weighing them. They were weighed on a 60 pound capacity milk scale. A small sample (7 to 10 pounds) of the harvested plants from each plot was taken and chopped into small pieces by a plot size silage grinder. These small samples were then weighed and put into an oven drier set at approximately 165°F until no further weight loss could be detected. At such time the samples were again weighed and the percent dry matter and dry matter per acre were calculated.

The four harvest dates were June 27, July 5 and 6, July 18, and August 3 and 4. The area harvested was the center six of eight rows and the center five of 7.5 feet. This comprised an area of 30 square feet or 1/1452 of an acre.

An analysis of variance was used in the statistical analysis of this experiment (Cockran and Cox, 1957; Snedecor, 1960; and Steel and Torrie, 1960). There were two types of analyses performed. One set of analysis was done on the yields of dry matter at each of the four harvest dates. The other set of analysis was done on the rate of dry matter production or accumulation between harvest dates 1 and 2, 2 and 3, and 3 and 4. Due to the variability in the LAI between members of a pair the dry matter yield was expressed on a unit LAI basis that existed at the harvest date. The dry matter production rate was expressed on a unit leaf area basis that existed between the respective harvest dates. In this case the LAI was assumed to increase almost linearly between the harvest dates. An illustration of the analysis is shown in Table 3.

Experiments 1968

Experiments 2, 3, and 4 were conducted during the summer of 1968. Experiment 2 was another dry matter test with upright and flat leaved varieties similar to Experiment 1. Experiment 3 was a grain yield test in which a short inbred variety of corn obtained from Dr. Jack Tanner of the University of Guelph was utilized and Experiment 4 was another grain yield test utilizing upright and flat leaved varieties of corn.

Again, the seedbeds were prepared for these experiments using normal cultural practices common to the Central Iowa region. All of the plots were planted at 15% to 100% over the desired population with an Allis Chalmers Model 600 minimum tillage planter modified for experimental plot work. When the plants were approximately 8 inches to 20 inches tall the plots were thinned to the desired plant populations with the interplant spacing kept as uniform as possible. Weed control was accomplished as was done in Experiment 1 by spraying with a mixture of Atrazine and Ramrod

Table 3. The sources of variation and the respective degrees of freedom for the variables analyzed for Experiment 1

Source	Analysis 1[a] d.f.	Analysis 2[b] d.f.
Blocks	2	2
Pairs (P)	4	4
Error (a)	8	8
Leaf Angle (LA)	1	1
P x LA	4	4
Error (b)	10	10
Population (Po)	3	3
P x Po	12	12
LA x Po	3	3
P x LA x Po	12	12
Error (c)	60	60
Harvest Date (D)[c]	3	2
P x D	12	8
LA x D	3	2
P x LA x D	12	8
Po x D	9	6
P x Po x D	36	24
LA x Po x D	9	6
P x LA x Po x D	36	24
Error (d)	240	160

[a]Analysis 1 was for the variables of leaf angle, LAI, and dry matter production per LAI.

[b]Analysis 2 was for the variables of average LAI and the dry matter production rate per average LAI.

[c]This source is harvest date for Analysis 1 and harvest date interval for Analysis 2.

shortly after planting. During mid-summer a sweep type cultivation was performed to control some minor weeds. Bux-ten was broadcast over the whorl of the corn plants during the cultivation operation to control the European corn borer and corn rootworm larva. Sevin, a commercial insecticide, also was applied to control the corn rootworm beetles during early silking.

Following is Table 4 which lists the dates of planting, plot sizes, populations, and varieties used for Experiments 2, 3, and 4.

Experiment 2

The design used for this experiment was a split-split-split randomized complete block design in which pairs were the main plots. For this experiment nine pairs were formed from 18 varieties of corn in which the criterion for pairing was the same as existed for Experiment 1. The subplots were composed of the four populations and the four harvest dates were the sub-subplots.

The leaf area and leaf angle measurements and harvesting procedures were done exactly as had been done for Experiment 1. For this experiment, however, the leaf angle measurements were taken at each of the four harvest dates. The four harvest dates for this experiment were July 9, July 22 and 23, August 1, and August 13. The area harvested was the center four rows for 9 linear feet. This was 60 square feet or 1/726 of an acre.

Again, an analysis of variance was performed on the dry matter production at each of the four harvest dates and on the dry matter production rate at the harvest date intervals of 0 to 1, 1 to 2, 2 to 3, and 3 to 4. Since these plots were thinned at the beginning of the season, the LAIs and average LAIs were uniform within a pair at a particular population and harvest date or harvest date interval. Therefore, the dry matter production and dry matter production rate were not expressed on a unit LAI basis. Analyses of variance also were performed on the variables of leaf angle, LAI, and average LAI. An illustration of the analysis of variance table is shown in Table 5.

Table 4. Planting dates, plot sizes, populations, and varieties utilized for Experiments 2, 3, and 4

Experiment	Planting Date	Plot Size Length (ft)	Plot Size Width (rows)	Population[a]	Varieties[b] Upright	Varieties[b] Flat
2	May 1	12.5	6-20"	10,000	B14x577[c]	SX 29[d]
				20,000	695x334[c]	3306[c]
				40,000	Hy$_2$xC103 (lg$_2$)[e]	Hy$_2$xC103 (Lg$_2$)[f]
				80,000	B73[g]	W22[g]
					B14[g]	Hy[h]
					Oh43[h]	B66[g]
					(M14xC103)[g]	A632[h]
					1517-243-129	
					B25[g]	R181B[g]
					B72[g]	B70[g]
3	May 2	50.0	6-20"	30,000	Tanner's Inbred[i]	
				60,000		
				90,000		
				120,000		
4	May 2	50.0	6-20"	13,000	695x334[c]	3306[c]
				26,000	B14x577[c]	SX 29[d]
				39,000	Hy$_2$xC103(lg$_2$)[e]	Hy$_2$xC103(Lg$_2$)[f]
				52,000		

[a]Plant population in plants per acre.

[b]Upright and flat leaved counterparts of a pair are shown side by side in the table except for Experiment 3 in which the whole experiment was planted to Tanner's inbred.

[c]Seed source was Pioneer Hybrid Seed Corn Co., Johnston, Iowa.

[d]Seed source was Pfister Associated Growers, Aurora, Illinois.

[e]Seed source was Manglesdorf Seed Co., St. Louis, Missouri.

[f]Seed source was the University of Illinois, Urbana, Illinois.

[g]Seed source was Dr. W. A. Russell, Iowa State University, Ames, Iowa.

[h]Seed source was Clyde Black and Sons Seed Co., Ames, Iowa.

[i]Seed source was Dr. Jack Tanner, University of Guelph, Ontario, Canada.

Table 5. The sources of variation and respective degrees of freedom for the variables of Experiment 2

Source	d.f.
Blocks	1
Pairs (Pa)	8
Error (a)	8
Population (Po)	3
Pa x Po	24
Error (b)	27
Leaf Angle (LA)	1
Pa x LA	8
Po x LA	3
Pa x Po x LA	24
Error (c)	36
Harvest Date (D)[a]	3
Pa x D	24
Po x D	9
Pa x Po x D	72
LA x D	3
Pa x LA x D	24
Po x LA x D	9
Pa x Po X LA x D	72
Error (d)	216

[a]For the variables of leaf angle, LAI, and dry matter production this source is the harvest date. For the variables of average LAI and dry matter production rate this source is the harvest date interval.

Experiment 3

A randomized complete block design was used for Experiment 3. This test utilized an inbred which was a short (2 to 3 feet tall) inbred with erect leaves. The purpose of the test was to determine the effect of different populations on the yield of a short erect leaved inbred. Four populations were utilized and they were 30,000, 60,000, 90,000, and 120,000 plants per acre. During this experiment no leaf area or leaf angle measurements were taken.

The plots were harvested for grain yield about the middle of October with an Allis Chalmers Model E combine fitted with a small grain head. The grain from the plots was collected in a container and weighed. At this time a small subsample of two to three pounds was taken to determine the percent moisture. The samples were dried at 165°F until a constant weight was reached and then they were weighed again. The grain yield was then computed by assuming a bushel of corn to weigh 56 pounds. Results of the grain yield were reported as bushels per acre of corn at 15.5% moisture. The area harvested was the center four rows of six and a linear distance of 40 feet. This constituted 267 square feet or 1/163 of an acre.

An illustration of the analysis of variance table is shown in the following table (Table 6).

Table 6. The sources of variation and respective degrees of freedom for Experiment 3

Source	d.f.
Blocks	3
Population	3
Error	9

Experiment 4

The design used for this experiment was a split-split-split randomized complete block design. The main plots were composed of pairs. There were three pairs and again they were paired as was done for Experiments 1 and 2. The subplots were four different populations and the sub-subplots were the fertile and sterile counterparts of each variety. The fertile and sterile cytoplasm of each variety was used except for one pair. For the pair of Hy_2 x C103 (lg_2) and Hy_2 x C103 (Lg_2) no sterile cytoplasm was available. Therefore, it was decided to mechanically remove the tassels on the plots that were to be sterile. The tassels were removed by gently pulling them out of the whorl when they were first visible. In the process usually one or two leaves were removed with the tassel on the upright leaved variety, but little leaf removal occurred when removing the tassels from the flat leaved counterparts.

It might be noted here that no leaf angle or leaf area measurements were taken. However, these varieties were used in Experiment 2 and a general idea of their values may be obtained from noting the tables of Experiment 2.

The plots were harvested for grain yield about the middle of October with an Allis Chalmers Model E combine and the yield per acre were calculated as was done for Experiment 3. The harvested area was again the middle four rows of six for a distance of 40 linear feet. This represented 267 square feet or 1/163 of an acre.

Also in this experiment a small dry matter sampling was taken from the pair of Hy_2 x C103 (lg_2) and Hy_2 x C103 (Lg_2) (Experiment 4a). The harvestable plot was four rows wide and 10 linear feet long. This of course reduced the grain harvestable area for this pair, but adjustments were made in calculating the grain yield of this pair in Experiment 4. Again, no leaf area or leaf angle measurements were taken. The dry matter harvest was taken in late September.

Table 7 depicts the analysis of variance for the grain yield of Experiment 4 and the dry matter yield of Experiment 4a.

Table 7. The sources of variation and respective degrees of freedom for the variables in Experiments 4 and 4a

Experiment 4		Experiment 4a	
Source	d.f.	Source	d.f.
Blocks	3	Blocks	3
Pairs (Pa)	2	Leaf Angle (LA)	1
Error (a)	6	Error (a)	3
Leaf Angle (LA)	1	Population (Po)	3
Pa x LA	2	LA x Po	3
Error (b)	9	Error (b)	18
Population (Po)	3	Fert:Ster. (F:S)	1
Pa x Po	6	LA x F:S	1
LA x Po	3	Po x F:S	3
Pa x LA x Po	6	LA x Po x F:S	3
Error (c)	54	Error (c)	24
Fert:Ster. (F:S)	1		
Pa x F:S	2		
LA x F:S	1		
Pa x LA x F:S	2		
Po x F:S	3		
Pa x Po x F:S	6		
LA x Po X F:S	3		
Pa x LA x Po x F:S	6		
Error (d)	72		

Experiments 1969

Experiments 5 through 9 were conducted during the 1969 summer growing season. The seedbeds were again prepared using those practices common to this area. The plots were planted and thinned by the same methods used in 1968. The plots were planted on May 9 and 10 and a final population of 40,000 plants per acre was obtained. Experiments 5, 7, and 9 were planted with the variety XL-45 and Experiments 6 and 8 were planted with DL-11 (DeKalb Hybrid Seed Corn Co., DeKalb, Illinois).

Weed control was accomplished by spraying a mixture of Atrazine and Ramrod onto the plots shortly after planting. A mid-summer cultivation also was performed. Bux-ten and Sevin also were applied as was done in 1968 to control field insects.

Data collected included the silking dates, silking interval, grams of grain per plant, grain yield per acre, percent barrenness, and the number of nubbins and ears per plot.

The silking dates for Experiments 5 through 9 were determined by entering the plots every day or every second day and randomly selecting 20 consecutive plants and recording the number of plants having ears with silks exposed. The number of plants silking was then plotted as a function of days from planting and the 15%, 25%, 50%, and 75% silking dates were determined to the nearest one-half day.

Silking intervals represented the time between 25% and 75% silking for the experiments with XL-45 and between 15% and 50% silking for those experiments containing DL-11.

The number of ears and nubbins and percent barrenness were determined at harvest time. A nubbin was defined as an ear with less than 25% of the cob surface being occupied by grain kernels. Barrenness was defined as those harvested plants that did not produce an ear or produced a nubbin. The grams of grain per plant was calculated by dividing the amount of grain per plot by the number of plants within the plot that produced an ear.

Grain yield was determined by collecting all of the ears and nubbins from a plot and drying them in a drier at 165^{o}F until no further weight loss was noted. The yield in bushels per acre was then calculated by assuming that a bushel of ear corn weighed 70 pounds. The yield in bushels per acre was adjusted to 15.5% moisture.

Experiments 5 and 6

These two experiments were utilized to study the effects of mechanically manipulating the leaves above the ear leaf into an erect position at various times in relation to anthesis. Experiment 5 was conducted on a population-tolerant hybrid (XL-45) and Experiment 6 utilized a population-intolerant hybrid (DL-11). Otherwise, the two experiments were treated identically.

The positioning of the leaves into a more erect position was accomplished by putting a cluster of four rubber bands (Hodgman no. 12) over the unrolled leaves of the whorl above the ear leaf when about seven leaves were expanded. Every day or second day the rubber bands were rolled down the whorl as the plants were growing. The rubber bands were then rolled up to hold the leaves above the ear leaf erect at three different dates. The dates were 1 week and 0 weeks before anthesis, and 1 week after anthesis. A fourth set of plots constituted a control. The experimental design was a randomized complete block design.

The date of 1 week before anthesis was determined by counting the number of expanded leaves from the base of the plant and by observing tassel emergence from the whorl. It was found that when the tassel was still rolled inside the last leaf that it was about 1 week before anthesis. At the respective times of rolling the rubber bands up, a closer approximation of the ear leaf could be made by observing a bulge beneath the ear leaf sheath. The positioning of the leaves above the ear leaf into an erect position could then be done with a high degree of accuracy.

The plot size was four 20-inch rows 25 feet long. The area harvested was the center two of four rows for a distance of 20 linear feet. This represented 66.67 square feet or 1/653 of an acre. The plots were harvested during the last week of October.

Table 8 shows how the statistical analysis was broken down.

Table 8. The sources of variation and respective degrees of freedom for the variables measured for Experiments 5 and 6

Source	d.f.
Blocks	2
Treatment	3
Error	6

Experiments 7 and 8

Experiment 7 was planted to XL-45 and Experiment 8 consisted of DL-11. The purpose of these experiments was to study the effects on the previously mentioned variables of applying sodium glutamate (sodium salt of glutamic acid), sucrose, and a combination of glutamate and sucrose. Glutamate was applied at two rates (Gl-1 and Gl-2), sucrose at one rate (Suc), and the combination of glutamate and sucrose at one rate (Gl-2 + Suc). Gl-1 was 0.2 grams of glutamate per plant (8,000 grams glutamate per acre or 1.46 pounds of N per acre) while Gl-2 was 1.0 grams of glutamate per plant (40,000 grams glutamate per acre or 7.30 pounds N per acre). Suc was applied at 1.0 grams per plant (40,000 grams sucrose per acre) and the combination treatment was a combined mixture of the high rate of glutamate (Gl-2) and the above sucrose rate. The chemicals were applied using small plastic atomizer bottles that put out a fine spray mist when pumped. The spray was directed over the entire leaf that was to be sprayed. The amount of chemical added to each plant was carried in 2 ml of water. The compounds were applied to the plots in two applications. One-half of the desired final rate was sprayed onto the plant at 1 week before anthesis with the remaining one-half being applied at the time of anthesis. These times were determined as was done for Experiments 5 and 6.

The compounds were sprayed at different positions on the plants. These positions on the plant were the second leaf above the ear leaf (2A), the ear leaf (E), and the second leaf below the ear leaf (2B). A control (C) also was included with each series of positions. These respective leaves were located by feeling or looking for the ear beneath a leaf sheath. Once found, the leaf subtending the ear was denoted as the ear leaf.

The plot consisted of one row 25 feet long. These plots were hand harvested during the last week of October and the yield and other variables calculated as previously mentioned. The actual area harvested was the center 22.21 linear feet of 25 feet for the one row. This represented 37.01 square feet or 1/1177 of an acre.

The experimental design for these experiments was a split plot randomized complete block design. The main plots were the different chemicals sprayed onto the leaves and the subplots were the various positions upon which the chemicals were sprayed.

Table 9 shows the various sources of variation and respective degrees of freedom for the measured variables for Experiments 7 and 8.

Table 9. The sources of variation and respective degrees of freedom for the measured variables for Experiments 7 and 8

Source	d.f.
Blocks	2
Chemical (C)	3
Error (a)	6
Position (P)	3
C x P	9
Error (b)	24

Experiment 9

Experiment 9 was comprised of XL-45. The purpose of the experiment was to note the effects on the above mentioned variables due to leaf removal (LR), leaf removal and the application of aluminum foil (LR + Al foil) and the application of aluminum foil only (Al foil) when imposed at 1 and 0 weeks before anthesis. Therefore, the six treatments were leaf removal at 1 and 0 weeks before anthesis (LR 1 and LR 0), leaf removal and application of aluminum foil at 1 and 0 weeks before anthesis (LR + Al foil 1 and LR + Al foil 0), and the application of aluminum foil at 1 and 0 weeks before anthesis (Al foil 1 and Al foil 0).

When a leaf was removed it was the second leaf above the ear leaf (2A), the ear leaf (E), or the second leaf below the ear leaf (2B). Leaf removal was accomplished by mechanically tearing the desired leaf off at the junction of the blade and sheath. When aluminum foil was applied to the plant, small 2-inch by 18-inch strips of Kaiser heavy duty foil were wrapped around the stalks between the leaves from the 2A, E, or 2B leaf positions to the tassels of the plants. The LR + Al foil 1 and LR + Al foil 0 treatments were a combination of the above mentioned leaf removal and aluminum foil application descriptions. A control (C) also was included in each treatment.

The above mentioned times (1 and 0 weeks before anthesis) and leaves (2A, E, or 2B) were determined using the same methods described in Experiments 5 and 6.

A split plot randomized complete block design was used in which treatments were the main plots and the positions of treatment were the subplots.

The same variables and methods of measurement as used for Experiments 5, 6, 7, and 8 were conducted for Experiment 9.

A plot size of one row 25 linear feet long was utilized here. The area harvested during the last week of October for grain yield was the center 22.21 feet of 25 feet for the one row. This was 37.01 square feet or 1/1177 of an acre.

Located in Table 10 is an illustration of the statistical breakdown of the analysis of variance for Experiment 9.

The LSD (least significant difference) as described by Steel and Torrie (1960) and Duncan's new multiple-range test as presented by Duncan (1955) were utilized to establish meaningful difference levels. The LSD was used where applicable for Experiments 1, 2, and 4, while the test developed by Duncan was employed in Experiments 3, 6, 7, 8, and 9 where applicable.

Table 10. The sources of variation and respective degrees of freedom for the variables analyzed for Experiment 9

Source	d.f.
Blocks	2
Treatments (T)	5
Error (a)	10
Position (P)	3
T x P	15
Error (b)	36

One further note may be made concerning the measurements of the leaf angles for Experiments 1 and 2. Some error may have been introduced due to differing positions of the leaf crests. For example, those varieties with leaves which had no crest may have been biased to a more flat leaf angle. The leaf area beyond the crest was not considered when determining the leaf angles. This additional leaf area could have contributed to a considerable amount of mutual shading.

EXPERIMENTAL RESULTS

Experiment 1967

The environmental growing conditions during the summer of 1967 were somewhat unfavorable for producing high yields of corn. During June approximately 5 to 6 inches of rain above the average fell, making for wet conditions during these stages of growth. Although the 1967 data were in the form of dry matter yield, a moisture stress during the pollination-fertilization period also was evident. During the growing season, however, the mean monthly temperature was 2 to 4 degrees below normal.

Experiment 1

Ten varieties of corn were chosen to constitute five pairs. Within a pair one variety was chosen for its upright leaf character and the other member of the pair for its flat leaf character. The members of each pair were matched as closely as possible for other characters such as plant height, maturity date, etc. These five pairs were planted at four population levels and they were 14,000, 19,000, 37,000, and 68,000 plants per acre. Four dry matter harvest dates were taken and at each harvest date the LAI was measured and at the third harvest date the actual leaf angle (measured in the field as degrees from the horizontal) was determined. From these data the dry matter per LAI and the dry matter production rate (rate of dry matter accumulation between harvest dates) per average LAI (average LAI between the respective harvest dates) was calculated. These mean plant responses and their associated analyses of variance are shown in Appendix Tables 46 and 47, respectively.

Table 11 illustrates the mean leaf angles for the upright and flat

Table 11. The leaf angle for the upright and flat leaved varieties at four populations and at harvest date 3 for Experiment 1

Population[a] (x 10^3)	Upright Harvest date 3[b]	Flat Harvest date 3[b]	Mean
14	54.7	48.7	51.7
19	56.1	53.4	54.8
37	59.5	54.3	56.9
68	62.5	57.2	59.9
	Mean = 58.2	Mean = 53.4	

[a]Population in plants per acre.

[b]Leaf angle measurements were only taken at harvest date 3 and were expressed in degrees from the horizontal.

leaved varieties when measured at harvest date 3. From Appendix Table 47, it can be observed that the main effects of leaf angle and population were highly significant in affecting the actual leaf angle of the five pairs.

The designated upright and flat leaved varieties appear to have been assigned correctly. By noting the mean for the upright and flat leaved varieties, averaged across populations, it may be observed that the leaves of upright leaved varieties were about 5 degrees (9%) more erect than the leaves of the flat leaved varieties. This also was the case at each population level in which the more erect leaves were associated with the upright leaved varieties.

As the population was increased from 14,000 to 68,000 plants per acre, the leaves became more erect. When the upright and flat leaved varieties were averaged together there was an 8.2 degree (16%) increase in the actual leaf angle. The upright leaved varieties increased in leaf angle by 7.8 degrees (14%) and the flat leaved varieties increased in leaf angle by 8.5 degrees (17%) as the population was increased from 14,000 to 68,000 plants per acre.

Since no thinning was done in 1967, somewhat variable populations existed within a specified population level. Consequently, this resulted in measurable differences in the LAI within a pair. Appendix Table 47 shows that the important effects that caused significant or highly significant changes in the LAI were leaf angle, population, harvest date, leaf angle by harvest date, and population by harvest date.

It was not surprising that most of the above sources of variation caused significant changes in the LAI, but it was surprising to note that leaf angle had an effect. If the variation in population had been randomly distributed between the upright and flat leaved varieties the variable of leaf angle probably would not have significantly affected the LAI. By noting the means for the upright and flat leaved varieties in Table 12, it can be seen that the flat leaved varieties had 0.39 (17%) more LAI than the upright leaved varieties when averaged across populations and harvest dates. It also may be noted that in every case except one (population 37,000 plants per acre and harvest date 4) that the flat leaved varieties had a higher LAI than the upright leaved varieties. For this reason it was decided to express the dry matter production on a unit leaf area basis in order to make a standard comparison between the upright and flat leaved varieties.

As mentioned previously, the population and harvest date effects also significantly affected the LAI. As would be expected, as the population

Table 12. The LAI for the upright and flat leaved varieties for four populations and four harvest dates for Experiment 1

Population[a] (x 10^3)	Upright Harvest date 1	2	3	4	Flat Harvest date 1	2	3	4
14	0.43	0.86	1.47	1.81	0.49	0.96	2.03	2.39
19	0.53	1.05	1.94	2.23	0.71	1.40	2.22	2.48
37	1.15	2.30	3.68	3.90	1.24	2.47	4.98	3.85
68	1.56	3.11	5.51	5.39	1.96	3.92	6.25	5.77
		Mean = 2.31[b]				Mean = 2.70[b]		

[a]Population in plants per acre.

[b]LSD (0.05) = 0.178.

increased from 14,000 to 68,000 plants per acre, the LAI also increased when averaged across all varieties. With advancing harvest dates the LAI increased through harvest date 3 and a slight decline was noted for harvest date 4.

Leaf angle by harvest date was a significant factor in influencing the LAI. With the upright leaved varieties there was a steady increase in the LAI with advancing harvest dates, but for the flat leaved varieties the increase continued through harvest date 3 at which time a slight decrease was observed for harvest date 4.

Population by harvest date was another significant factor influencing the LAI. For populations of 14,000 and 19,000 plants per acre, the LAI increased steadily from harvest date 1 through 4. For the two higher populations (37,000 and 68,000 plants per acre) the LAI increased up through harvest date 3 and then declined slightly at harvest date 4. It might be noted here that when leaf angle is not mentioned, these means are figured from combining the upright and flat leaved varieties together.

The other factors of pairs, pairs by leaf angle, pairs by population, pairs by harvest dates, and pairs by leaf angle by harvest date also were significant, but since pairs were confounded with the other effects and due to the diversity of the pairs, they were not discussed.

Appendix Table 47 shows that the main effects of leaf angle, population, and harvest date were highly significant in altering the dry matter production per LAI. The interaction of population by harvest date also was highly significant. These results are summarized in Table 13 and in Figure 1.

The effect of leaf angle was highly significant in altering the dry matter production per LAI (Table 13). The means when averaged across populations and harvest dates indicate a 75 pound per acre (8%) advantage for the upright over the flat leaved varieties.

By referring to the overall mean (Table 13), the effect of population on the dry matter production per LAI may be noted. As the population was increased from 14,000 to 68,000 plants per acre, there was a steady decline in the production per LAI. There was a 490 pound per acre (41%) decline from the lowest to the highest population. This same trend was exhibited by both the upright and flat leaved varieties. The upright leaved varieties showed a 582 pound per acre (45%) decrease and the flat leaved varieties showed a 399 pound per acre (36%) decrease.

As harvest dates progressed the dry matter production per LAI increased (statistically highly significant). When averaged across all populations and harvest dates there was a 972 pound per acre (157%) increase. The same

Table 13. Dry matter production per unit of leaf area for the upright and flat leaved varieties for four populations and four harvest dates for Experiment 1

Population[a] (x 10^3)	Upright Harvest date 1	2	3	4	Mean	Flat Harvest date 1	2	3	4	Mean	Overall Mean
14	727[b]	934	1261	2273	1299	733	871	1074	1756	1108	1203
19	769	884	1173	1848	1169	606	786	1099	1971	1116	1142
37	547	835	958	1434	944	550	802	749	1475	894	919
68	499	693	715	964	717	501	627	725	985	709	713
Mean	636	836	1027	1630		597	771	912	1547		
	Mean = 1032[c]					Mean = 957[c]					

[a]Population in plants per acre.

[b]Data in pounds per LAI.

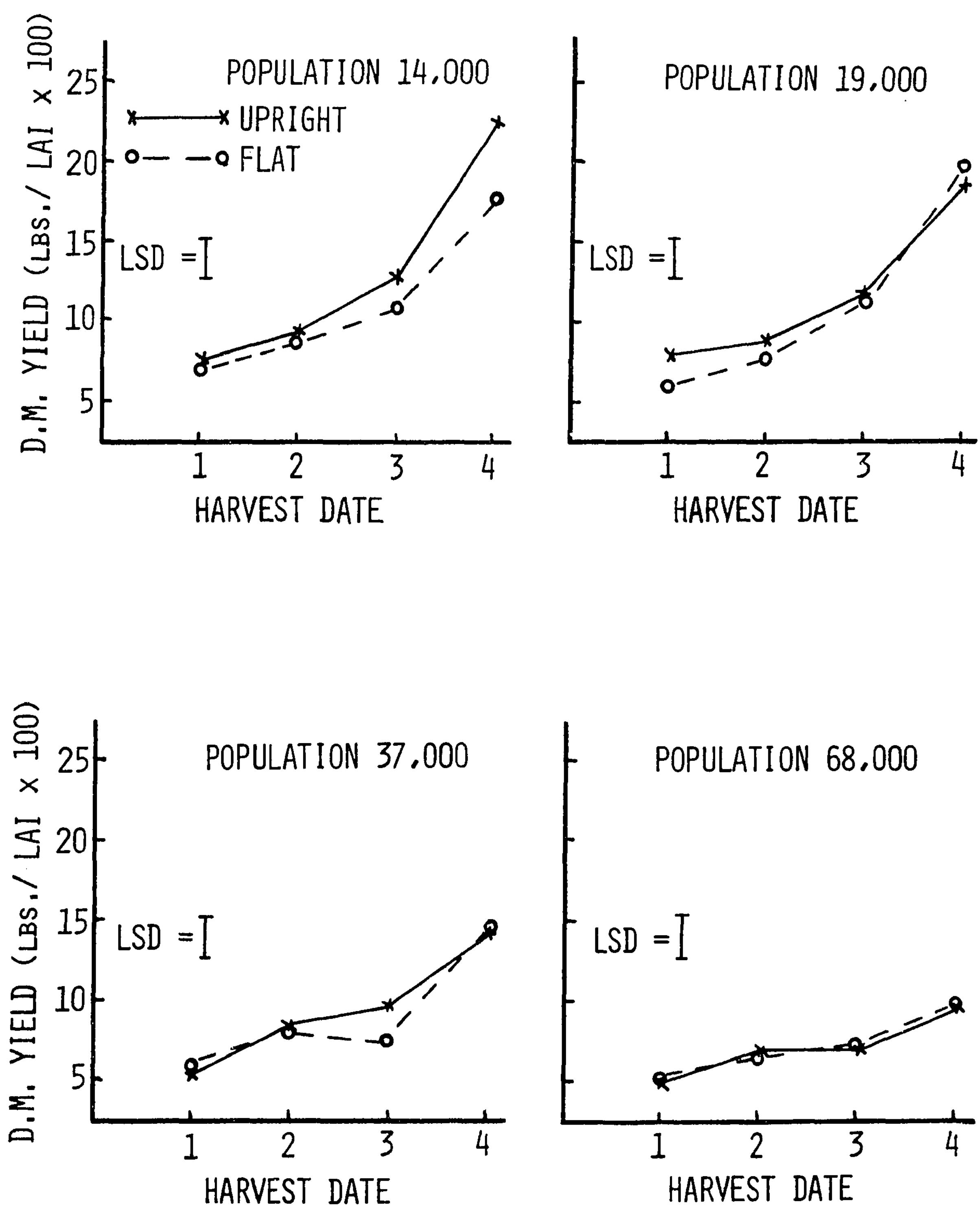
[c]LSD (0.05) = 45.

trend was observed for the upright and flat leaved varieties with an increase of 994 pounds per acre (156%) and 950 pounds per acre (159%) respectively.

The population by harvest date interaction was highly significant. At all populations, as the harvest date was advanced, the amount of dry matter produced per unit LAI also increased. The significant interaction arises from the fact that the increase in dry matter production per LAI was more dramatic at the lower population levels as the harvest dates were progressed (Table 13).

Figure 1 depicts graphically the effects of leaf angle, population, and harvest date on the dry matter yield. It may be noted that in only

Figure 1. Dry matter production yield per unit of leaf area for the upright and flat leaved varieties as a function of harvest date for four populations (plants per acre) for Experiment 1



D.M. YIELD (LBS./ LAI x 100)
POPULATION 14,000
UPRIGHT
FLAT
LSD =
HARVEST DATE
POPULATION 19,000
LSD =
HARVEST DATE
D.M. YIELD (LBS./ LAI x 100)
POPULATION 37,000
LSD =
HARVEST DATE
POPULATION 68,000
LSD =
HARVEST DATE

one instance did the upright leaved varieties ever significantly yield more dry matter per LAI and that was at a population of 14,000 plants per acre and harvest date 4. This particular population and harvest date also had the highest absolute dry matter production per LAI.

The factors affecting the average LAI (LAI between harvest dates) may be noted in Appendix Table 47. In addition to the factors that influenced the LAI, the average LAI was significantly altered by the pair by leaf angle by population interaction. Since pairs were involved and due to the diversity of pairs, no interpretative value was placed on this interaction. Also, the interactions of leaf angle by date and pairs by leaf angle by date were significant in influencing the LAI but were not for the average LAI.

The important factor to note here is that in every case the flat leaved varieties had a higher average LAI than did the upright leaved varieties at comparable populations and harvest date intervals (Table 14). Therefore, it was decided to express the dry matter production rate (dry matter production between harvest dates) on an average LAI basis.

Referring to Appendix Table 47, it may be noted that the effects of leaf angle, population, and population by harvest date interval all had a highly significant effect on the dry matter production rate per average LAI.

The effects of leaf angle, population, and harvest date interval may be noted in Table 15 and Figure 2.

The leaf angle effect was statistically highly significant in favor of the upright leaved varieties. By comparing the means for the upright and flat leaved varieties, when averaged across populations and harvest date intervals, a 100 pound per acre (16%) advantage may be noted for the upright

Table 14. The average LAI[a] for the upright and flat leaved varieties for four populations and three harvest date intervals for Experiment 1

Population[b] (x 10^3)	Upright Harvest date interval[c]			Flat Harvest date interval		
	1-2	2-3	3-4	1-2	2-3	3-4
14	0.65	1.17	1.64	0.73	1.50	2.21
19	0.79	1.50	2.09	1.06	1.81	2.35
37	1.73	2.99	3.79	1.86	3.73	4.42
68	2.34	4.32	5.45	2.94	5.09	6.02
		Mean = 2.37[d]			Mean = 2.81[d]	

[a]The average LAI was the LAI between the harvest dates.

[b]Population in plants per acre.

[c]Harvest date interval was the time between the harvest dates.

[d]LSD (0.05) = 0.184.

leaved varieties (Table 15).

Changes in population caused highly significant changes in the dry matter production rate per average LAI. By referring to the overall mean column in Table 15, it may be observed that as the population increased from 14,000 to 68,000 plants per acre, a 491 pound per acre (55%) decline in the production rate occurred. The upright leaved varieties declined by 539 pounds per acre (56%) and the flat leaved varieties declined by 442 pounds per acre (54%).

The last factor having a statistically significant effect (highly significant) was population by harvest date interval. At 14,000 plants per acre the dry matter production rate per average LAI increased as the harvest

Table 15. Dry matter production rate[a] per average unit of leaf area[b] for the upright and flat leaved varieties for four populations and three harvest date intervals[c] for Experiment 1

Population[d] (x 10^3)	Upright Har. date interval 1-2	2-3	3-4	Mean	Flat Har. date interval 1-2	2-3	3-4	Mean	Overall Mean
14	753[e]	896	1240	963	664	919	857	813	888
19	658	962	844	821	652	738	761	717	769
37	747	600	522	623	701	469	428	533	578
68	590	412	271	424	501	380	230	371	397
Mean	687	718	719		629	627	569		
	Mean = 708[f]				Mean = 608[f]				

[a]Dry matter production rate was the amount of dry matter produced between the harvest dates.

[b]Average LAI was the LAI between the harvest dates.

[c]Harvest date intervals were the time between the harvest dates.

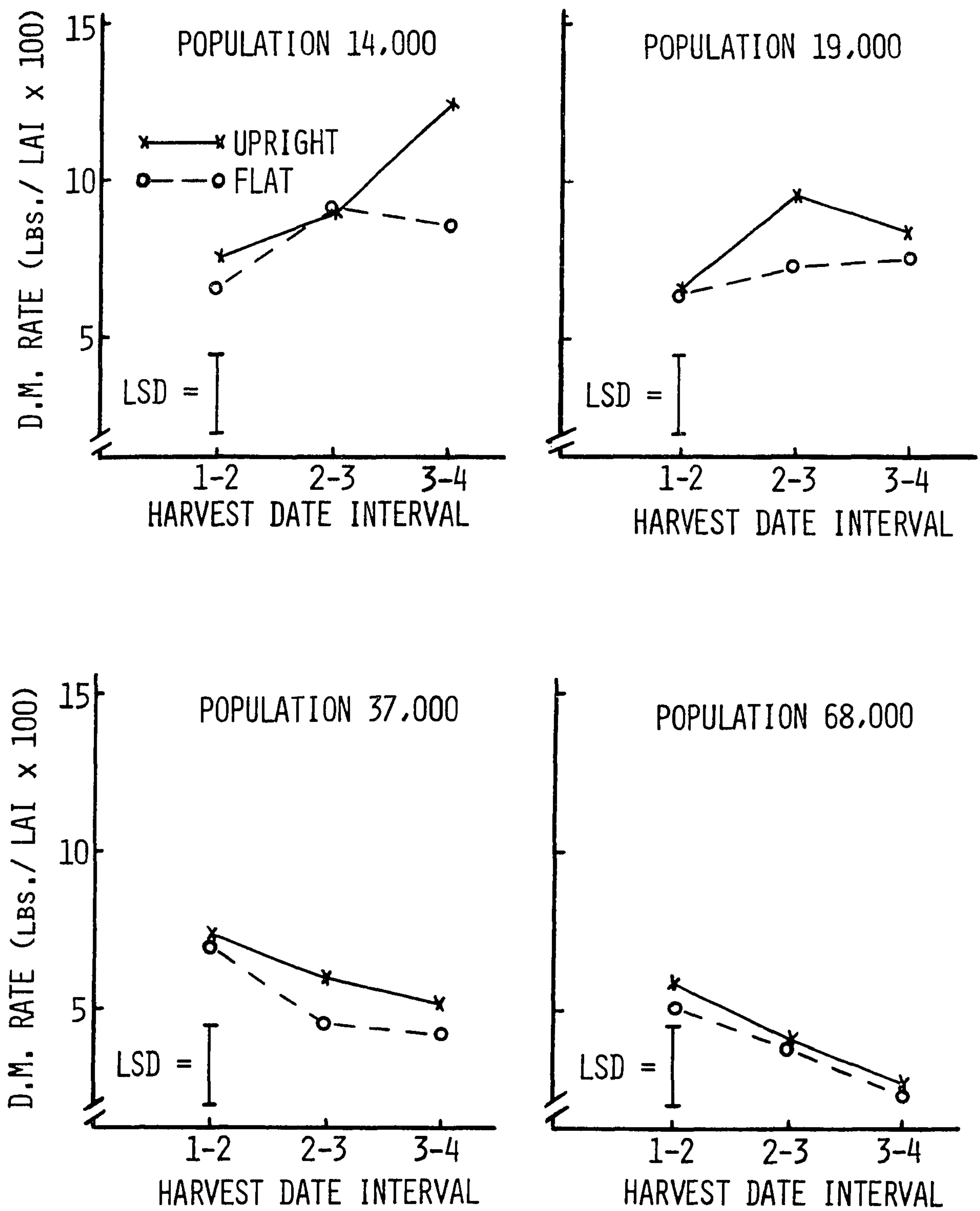
[d]Population in plants per acre.

[e]Dry matter in pounds per average LAI.

[f]LSD (0.05) = 43.

date interval advanced (note Figure 2 as if a line were drawn representing the average of the upright and flat leaved varieties). For the population of 19,000 plants per acre the production rate per average LAI increased up to harvest date interval 2-3 and then declined at harvest date interval 3-4. For the two higher populations (37,000 and 68,000 plants per acre) the dry matter production rate per average LAI steadily declined with advancing harvest date interval.

Figure 2. Dry matter production rate per average unit of leaf area for the upright and flat leaved varieties as a function of harvest date interval for four populations (plants per acre) for Experiment 1


D.M. RATE (LBS./ LAI x 100)
15
10
5
POPULATION 14,000
UPRIGHT
FLAT
LSD =
1-2
2-3
3-4
HARVEST DATE INTERVAL
POPULATION 19,000
LSD =
1-2
2-3
3-4
HARVEST DATE INTERVAL
D.M. RATE (LBS./ LAI x 100)
15
10
5
POPULATION 37,000
LSD =
1-2
2-3
3-4
HARVEST DATE INTERVAL
POPULATION 68,000
LSD =
1-2
2-3
3-4
HARVEST DATE INTERVAL

By referring to Figure 2 it may be noted that at nearly every comparable population and harvest date interval that the upright leaved varieties had a higher dry matter production rate per average LAI than the flat leaved varieties. A significant difference between the upright and flat leaved varieties occurred only once and that was at 14,000 plants per acre and harvest date interval 3-4. In this instance the upright leaved varieties yielded more than the flat leaved varieties and this also was the highest absolute yield.

Experiments 1968

The growing conditions during the 1968 growing season were favorable to corn growth and grain production. Generally, the moisture conditions were considered adequate and the average monthly temperatures were about normal, except for July. During July the mean monthly temperatures were about 2 to 3 degrees below normal.

Experiment 2

In this experiment 18 varieties of corn were selected to constitute nine pairs. As was done in 1967, the members of a pair were paired as to most characters except leaf angle, in which one member had a more upright leaf display than the other member. The nine pairs were planted at 10,000, 20,000, 40,000, and 80,000 plants per acre. Four dry matter harvest dates were taken and at each harvest date leaf area and leaf angle measurements also were taken. From this data the dry matter production for each harvest date and the dry matter production rate for the harvest date interval were the yield characteristics studied. These mean plant responses and the analyses of variance appear in Appendix Tables 48 and 49, respectively.

Actual leaf angle measurements were taken in the field at each harvest date. By referring to Appendix Table 49, it can be seen that the main effects of pairs, population, leaf angle, and harvest date all significantly affected the actual leaf angle as well as the interactions of pairs b by leaf angle, pairs by harvest date, leaf angle by harvest date, and pairs by leaf angle by harvest date.

Table 16 contains the actual leaf angle measurements for the upright and flat leaved varieties at the various populations and harvest dates. First, it may be noted that population had a significant effect on the actual leaf angle. By referring to the means listed under the column of overall mean it can be noted that as the population increased, there was an increase in the leaf angle. There was a 7.8 degree (20%) increase in leaf angle as the population was increased from 10,000 to 80,000 plants per acre. The upright leaved varieties increased by 8.7 degrees (21%) and the flat leaved varieties increased by 6.7 degrees (19%) their leaf angles as the population was increased from 10,000 to 80,000 plants per acre when averaged across the harvest dates.

Leaf angle also was highly significant in influencing the actual leaf angle. Located at the bottom of Table 16 the mean of the upright and flat leaved varieties averaged across all populations and harvest dates may be observed. The leaves of the upright leaved varieties were 6.9 degrees (18%) more erect than the leaves of the flat leaved varieties.

The actual leaf angle also was significantly affected by the harvest date. There appeared to be a general decline in the actual leaf angle as the harvest date advanced. The actual leaf angle declined from 42.9 degrees at harvest date 1 to 40.1 degrees at harvest date 4. It may be

Table 16. The leaf angle of the upright and flat leaved varieties at four populations and at the four harvest dates for Experiments 2

Population[a] (x 10^3)	Upright Harvest date 1	2	3	4	Mean	Flat Harvest date 1	2	3	4	Mean	Overall Mean
10	39.3	41.4	40.7	41.0	40.6	39.6	32.6	35.8	33.1	35.3	37.9
20	44.1	40.9	44.3	42.9	43.0	38.4	33.8	34.6	34.6	35.4	39.2
40	47.2	45.1	45.2	43.9	45.4	40.1	37.6	39.2	36.2	38.3	41.8
80	49.1	49.9	48.9	49.4	49.3	45.7	41.0	41.3	39.8	42.0	45.7
Mean	44.9	44.3	44.8	44.3		40.9	36.2	37.7	35.9		
	Mean = 44.6[b]					Mean = 37.7[b]					

[a]Population in plants per acre.

[b]LSD (0.05) = 0.8.

observed from Table 16 that the means of harvest date, averaged across populations, declined more for the flat leaved varieties than it did for the upright leaved varieties, thus accounting for the highly significant leaf angle by harvest date interaction.

The other significant effects of pairs, pairs by leaf angle, pairs by harvest date, and pairs by leaf angle by harvest date might be expected to be significant due to the diverse pairs used in the experiment. Nevertheless, they would be of little importance because they each contain the factor of pairs which means that they were averaged across the upright and flat leaved varieties. The purpose of this study was to separate out the effects of leaf angle. However, it can be noted from Table 16 that in every case except one (population 10,000 and harvest date 1) that the upright leaved varieties had more erect leaves at comparable populations and harvest dates than did the flat leaved varieties.

During the early part of the 1968 growing season the research plots were thinned to constant populations. Due to this procedure, no differences in the LAI between the upright and flat leaved varieties would be expected or was observed (Appendix Table 49 and Table 17). The data in Table 17 indicates that at comparable populations and harvest dates that the LAIs were not very different. The comparison of the means of the upright and flat leaved varieties, averaged across all populations and harvest dates, differed only by 0.01 of an LAI.

The variables of population and harvest date would be expected to significantly affect the LAI and such was the case. Population increases caused a corresponding increase in the LAI from 1.3 at 10,000 plants per acre to 6.4 at 80,000 plants per acre. There was an increase in the LAI

Table 17. The LAI for the upright and flat leaved varieties for four populations and four harvest dates for Experiment 2

Population[a] (x 10^3)	Upright Harvest date				Flat Harvest date			
	1	2	3	4	1	2	3	4
10	1.11	1.35	1.31	1.23	1.17	1.44	1.44	1.36
20	2.07	2.54	2.36	2.58	2.12	2.63	2.39	2.15
40	3.71	4.80	4.30	3.66	3.84	4.61	3.85	3.55
80	6.25	7.09	6.48	5.32	6.58	7.40	6.36	5.35
		Mean = 3.51				Mean = 3.52		

[a]Population in plants per acre.

of from 3.4 to 4.0 from harvest date 1 to harvest date 2. Then the LAI declined to 3.2 at harvest date 4.

The above mentioned trend for harvest date also was the case for the four harvest dates at each of the four population levels, but the variation appeared more pronounced at the higher population levels. This then gave a significant population by harvest date interaction.

In addition, the effects of pairs, pairs by population, pairs by leaf angle, and pairs by harvest date also were significant in altering the LAI. But since pairs were involved in each, little emphasis was placed on the results of such effects.

Therefore, since at comparable populations and harvest dates there existed very similar LAIs, the dry matter production per acre was not expressed on a unit leaf area basis as was done in Experiment 1.

The dry matter production per acre was significantly affected by population, leaf angle, harvest date, population by harvest date, and leaf angle by harvest date. The effects of pairs, pairs by leaf angle, pairs by harvest date, pairs by population by harvest date, and pairs by leaf angle by harvest date were significant also, but were omitted due to the confounding effects of pairs (Appendix Table 49).

As mentioned previously, population, leaf angle, and harvest date all significantly affected the dry matter production. As the population was increased from 10,000 to 80,000 plants per acre, the dry matter production increased 5,408 pounds per acre (164%). This was true for both the upright and flat leaved varieties (Table 18 and Figure 3). The upright leaved varieties showed a 5,276 pound per acre increase (168%) while the flat leaved varieties showed a 5,540 pound per acre (159%) increase in dry matter production with the above mentioned population increase. Leaf angle had a significant effect on the dry matter production. It may be noted in Table 18 that a comparison of the leaf angle means, averaged across all populations and harvest dates, shows a 505 pound per acre (8%) advantage for the flat leaved varieties over the upright leaved varieties. With advancing harvest dates the dry matter production increased from 3,121 pounds per acre at harvest date 1 to 8,682 pounds per acre at harvest date 4. This represented a 5,561 pound per acre (178%) increase. The same general trend of increasing dry matter production with advancing harvest dates existed within both the upright and flat leaved varieties. In the upright leaved varieties there was a 5,141 pound per acre (168%) increase, while the flat leaved varieties showed a 5,982 pound per acre (188%) increase with advancing harvest date. This larger increase exhibited by the flat leaved varieties with advancing harvest dates led to a significant leaf angle by

Table 18. Dry matter production per acre for the upright and flat leaved varieties for four populations and for four harvest dates for Experiment 2

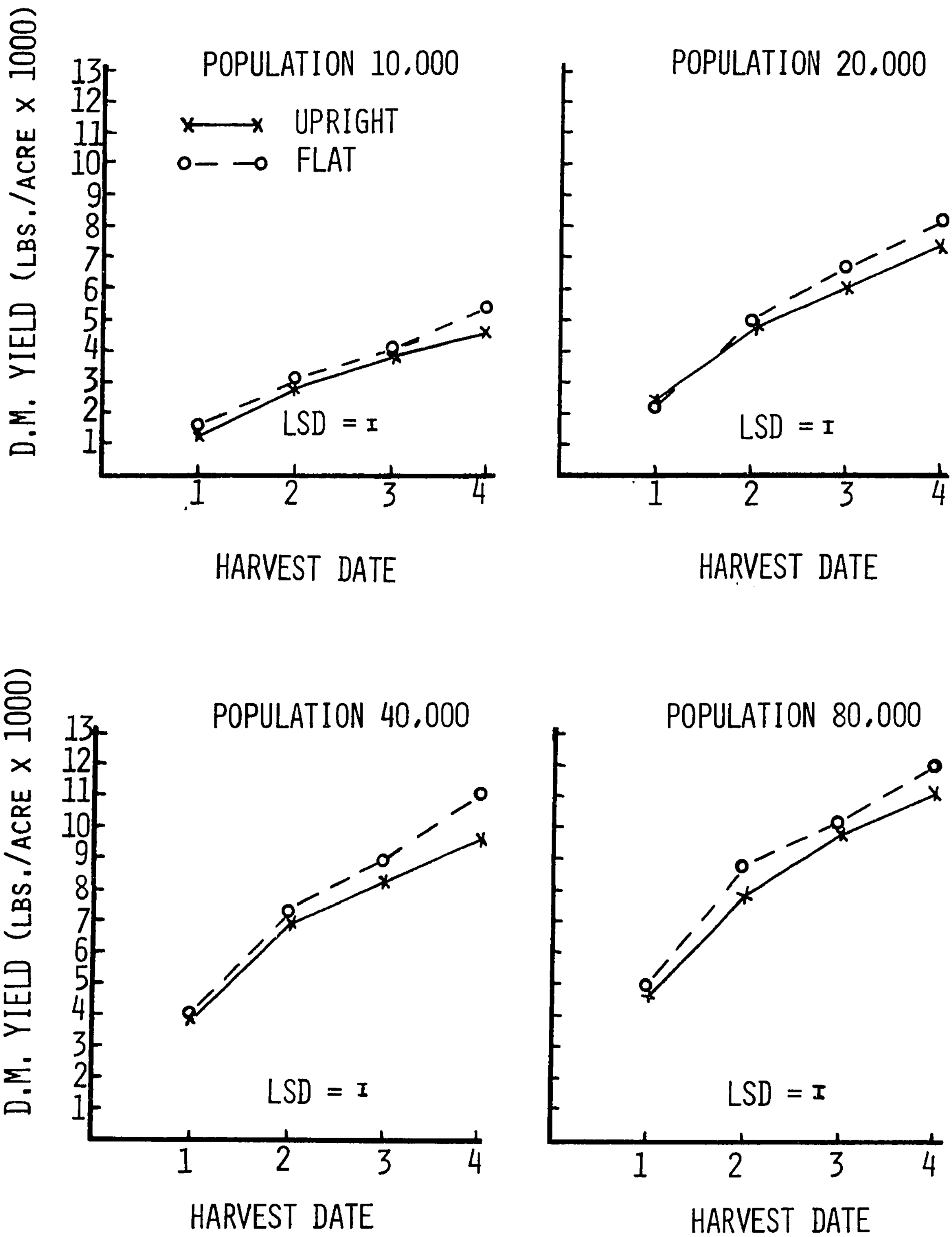
Population[a] (x 10^3)	Upright Harvest date 1	2	3	4	Mean	Flat Harvest date 1	2	3	4	Mean	Overall Mean
10	1323[b]	2759	3824	4617	3131	1502	3066	3983	5327	3470	3300
20	2434	4801	6071	7418	5181	2416	5119	6680	8233	5612	5397
40	3803	6911	8183	9605	7125	3819	7267	8963	11039	7772	7449
80	4693	7962	9799	11174	8407	4975	8777	10245	12040	9010	8708
Mean	3063	5608	6969	8204		3178	6057	7468	9160		
		Mean = 5961[c]					Mean = 6466[c]				

[a]Population in plants per acre.

[b]Data in pounds per acre.

[c]LSD (0.05) = 135.

Figure 3. Dry matter production (yield) per acre for the upright and flat leaved varieties as a function of harvest date for four populations (in plants per acre) for Experiment 2


POPULATION 10,000
UPRIGHT
FLAT
LSD = I
HARVEST DATE
D.M. YIELD (LBS./ACRE x 1000)
POPULATION 20,000
LSD = I
HARVEST DATE
POPULATION 40,000
LSD = I
HARVEST DATE
D.M. YIELD (LBS./ACRE x 1000)
POPULATION 80,000
LSD = I
HARVEST DATE

harvest date interaction.

The population by date interaction was highly significant. It was noted for each population level that as the harvest date was advanced, the dry matter production increased. However, the percentage increase in dry matter production as the harvest date was advanced was less at the higher population levels. For instance, the percent increase in dry matter production was 252% at the lowest population (10,000 plants per acre) and 140% at the highest population (80,000 plants per acre) as the harvest date was advanced from harvest date 1 to harvest date 4.

The average LAI (LAI between the harvest dates) was affected by the same effects as the LAI. Therefore, a detailed discussion of the significant effects will not be reported here. The explanations put forth while discussing the LAI have the same interpretations for the average LAI. Let it suffice to note that at comparable populations and harvest date intervals the average LAIs were very similar for the upright and flat leaved varieties (Table 19). Therefore, the dry matter production rate (dry matter produced between harvest dates) was not compiled on a unit leaf area basis.

A breakdown of the dry matter production rate by leaf angle, population, and harvest date interval are shown in Table 20 and Figure 4. By noting Appendix Table 49 it can be observed that the effects of population, leaf angle, harvest date interval, and population by harvest date interval, all significantly affected the dry matter production rate.

As the population increased from 10,000 to 80,000 plants per acre the dry matter production rate increased from 1,256 to 2,902 pounds per acre. This represented 131% increase. This same trend was exhibited by both the

Table 19. The average LAI[a] for the upright and flat leaved varieties for four populations and four harvest date intervals[b] for Experiment 2

Population[c] (x 10^3)	Upright: Harvest date interval 0-1	1-2	2-3	3-4	Flat: Harvest date interval 0-1	1-2	2-3	3-4
10	0.56	1.23	1.34	1.27	0.59	1.31	1.44	1.41
20	1.04	2.31	2.45	2.37	1.06	2.38	2.51	2.28
40	1.86	4.26	4.55	3.99	1.92	4.23	4.23	3.70
80	3.13	6.67	6.79	5.90	3.29	7.00	6.88	5.89
		Mean = 3.11				Mean = 3.13		

[a]The average LAI was the LAI between the harvest dates.

[b]Harvest date interval was the time between the harvest dates.

[c]Population in plants per acre.

upright and flat leaved varieties. The upright leaved varieties showed a 1,626 pound per acre (139%) increase while the flat leaved varieties exhibited a 1,663 pound per acre (123%) increase. Since both the upright and flat leaved varieties responded similarly at each of the population levels there was no significant population by leaf angle interaction.

The main effect of leaf angle was significant (Table 20). By noting the leaf angle means, averaged across all populations and harvest date intervals, it can be seen that the flat leaved varieties had a higher dry matter production rate than did the upright leaved varieties. There was a 237 pound per acre (12%) advantage associated with the flat leaved varieties.

With advancing harvest date intervals there was a general decline in

Table 20. Dry matter production rate[a] per acre for the upright and flat leaved varieties for four populations and four harvest date intervals[b] for Experiment 2

Population[c] (x 10^3)	Upright Harvest date interval 0-1	1-2	2-3	3-4	Mean	Flat Harvest date interval 0-1	1-2	2-3	3-4	Mean	Overall Mean
10	1323[d]	1492	1065	793	1168	1502	1624	917	1344	1347	1256
20	2434	2372	1269	1390	1866	2416	2703	1561	1553	2058	1962
40	3803	3108	1272	1422	2401	3819	3449	1695	2077	2760	2581
80	4693	3270	1837	1375	2794	4975	3802	1468	1795	3010	2902
Mean	3063	2560	1361	1245		3178	2895	1410	1692		
		Mean = 2057[e]					Mean = 2294[e]				

[a]Dry matter production rate was the amount of dry matter produced between the harvest dates.

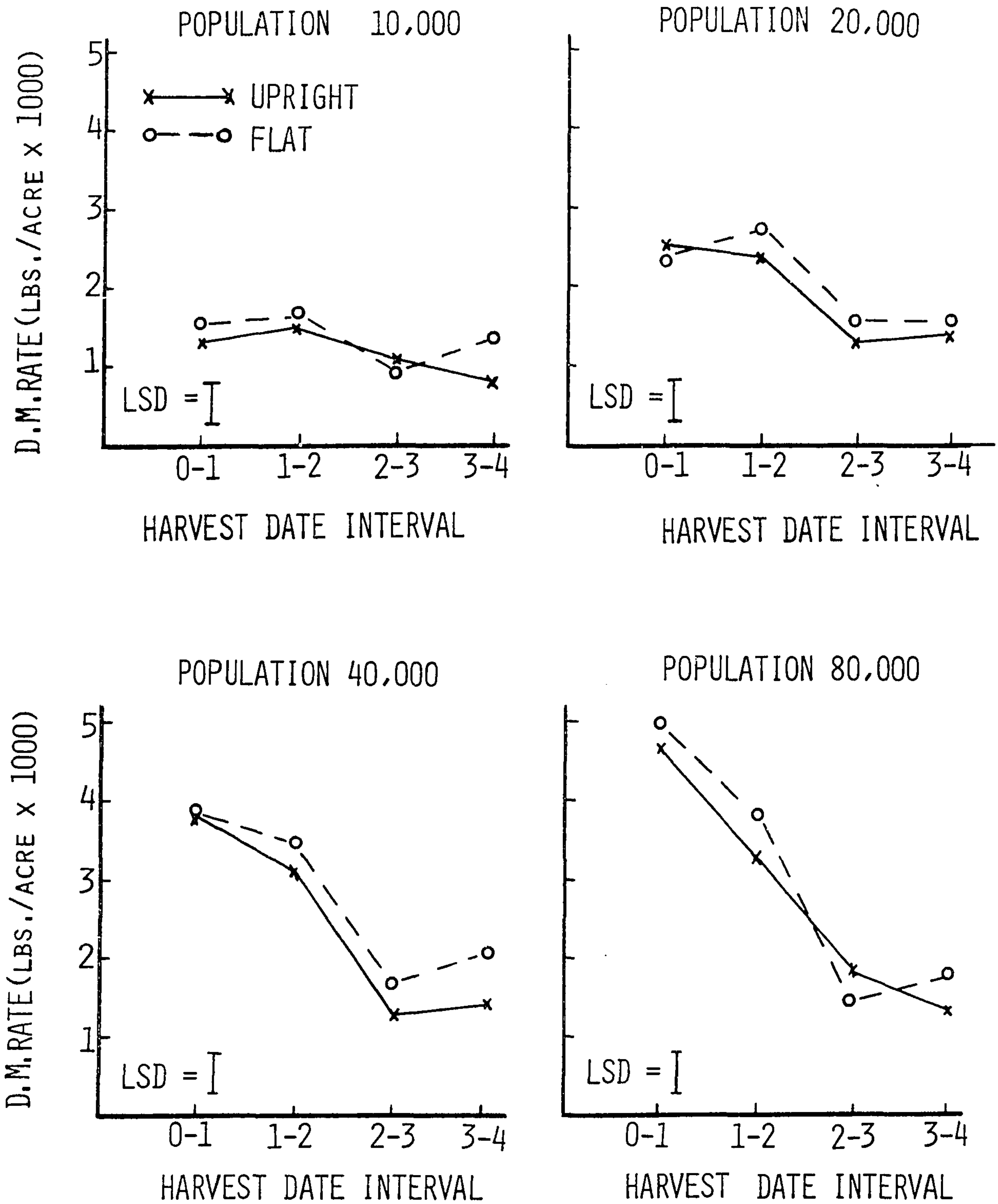
[b]Harvest date intervals were the time between the harvest dates.

[c]Population in plants per acre.

[d]Data in pounds per acre.

[e]LSD (0.05) = 57.

Figure 4. Dry matter accumulation (rate) per acre for the upright and flat leaved varieties as a function of harvest date interval at four population levels (in plants per acre) for Experiment 2


POPULATION 10,000
POPULATION 20,000
POPULATION 40,000
POPULATION 80,000
UPRIGHT
FLAT
D.M.RATE(LBS./ACRE x 1000)
LSD =
0-1
1-2
2-3
3-4
HARVEST DATE INTERVAL
1
2
3
4
5

the dry matter production rate per acre, thus accounting for its significant effect. This same general trend was the case for the upright leaved varieties in which they declined in dry matter production rate until harvest date interval 3-4. The flat leaved varieties showed a general decline to harvest date interval 2-3 but a slight increase was evident at harvest date interval 3-4. However, there was no significant leaf angle by harvest date interval interaction.

Population by harvest date interval was a highly significant interaction affecting the dry matter production rate. Generally, at 10,000 and 20,000 plants per acre there was an increase in the dry matter production rate as the harvest date interval advanced from harvest date interval 0-1 to 1-2. Then a general decline was evident for harvest date intervals 2-3 and 3-4. At the higher populations (40,000 and 80,000 plants per acre) there was a general decline in the dry matter production rate from harvest date interval 0-1 through 3-4. At populations of 10,000, 40,000, and 80,000 plants per acre there was a slight increase in the dry matter production rate of harvest date interval 3-4 as compared with 2-3. Due to unequal harvest date intervals these results will need to be viewed with caution. The important comparison to note is the difference between the upright and flat leaved varieties at a particular harvest date interval.

Experiment 3

This experiment was designed to test the population tolerance of an early inbred which reaches a height of about 3 feet and has erect leaves. No actual height or leaf angle measurements were taken, but the plots were harvested for grain yield.

The yield response at the various population levels and the analysis of variance may be noted in Tables 21 and 22, respectively. The yield data as a function of population is shown graphically in Figure 5. It may be noted that the variable of population was highly significant statistically and generally the yield increased as the population increased up to 120,000 plants per acre.

Table 21. The yield response of an inbred variety supplied by Tanner at four populations for Experiment 3

	Population (plants per acre x10^3)			
	30	60	90	120
Yield[a] (bu/acre)	30.62a	41.35b	39.52b	43.52b

[a]Yields followed by same letter are not significantly different at the 0.05 level of probability.

Table 22. The mean squares associated with the yield of an inbred variety supplied by Tanner for Experiment 3

Source	d.f.	Yield
Blocks	3	12.00
Population	3	128.24**
Error	9	13.09

**Statistically significant at the 0.01 level of probability.

Experiment 4

This experiment was composed of six varieties which were formed into three pairs. Again, the members of a pair were matched for most characters

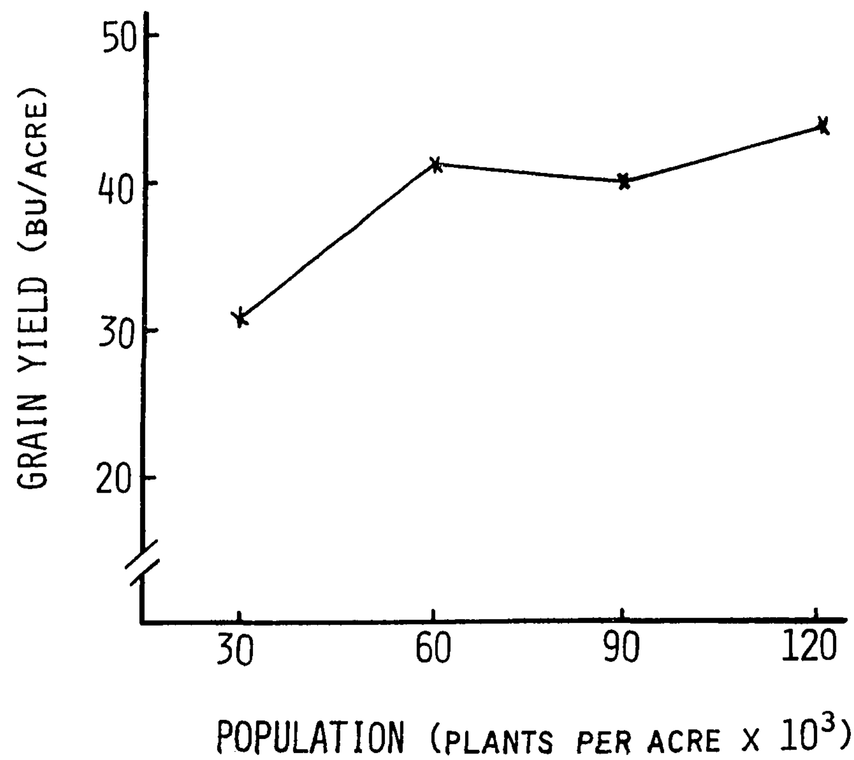


Figure 5. Grain yield as a function of four populations for the inbred supplied by Tanner for Experiment 3

except leaf angle. The plots were planted to have four final populations (13,000, 26,000, 39,000, and 52,000 plants per acre). In addition, the fertile and sterile counterparts of each variety were used. The mean yield response and the analysis of variance are shown in Appendix Tables 50 and 51, respectively.

From Appendix Table 51 it may be noted that the main effects of pairs, population and fertile:sterile all had a statistically highly significant influence on the grain yield and leaf angle was statistically significant at the 5% level. The interactions of pairs by leaf angle, pairs by population, leaf angle by population, pairs by leaf angle by population, pairs by fertile:sterile, leaf angle by fertile:sterile, pairs by leaf angle by fertile:sterile, population by fertile:sterile, and leaf angle by population by fertile:sterile were all significant or highly significant in affecting the grain yield.

As mentioned above, the factor of leaf angle did significantly affect the grain yield. When the yields were averaged across the components of pairs, population, and fertile:sterile, it may be noted that the flat leaved varieties yielded about four bushels per acre (4%) more than did the upright leaved ones (Table 23). Figure 6 depicts the effects of leaf angle across populations for the fertile and sterile.

Population also significantly affected the yield. The populations of

Table 23. Yield of the upright and flat leaved varieties for the fertile and sterile counterparts at four population levels for Experiment 4

	Upright					Flat					Overall
	Pop. (plants per acre x10^3)					Pop. (plants per acre x10^3)					Mean
	13	26	39	52	Mean	13	26	39	52	Mean	
Fertile	107[a,b]	111	96	89	101	123[a]	110	80	70	96	99[d]
Sterile	112	114	108	98	108	130	136	116	105	122	115[d]
Mean	109	113	102	93		126	123	98	87		
	Mean = 104[c]					Mean = 108[c]					

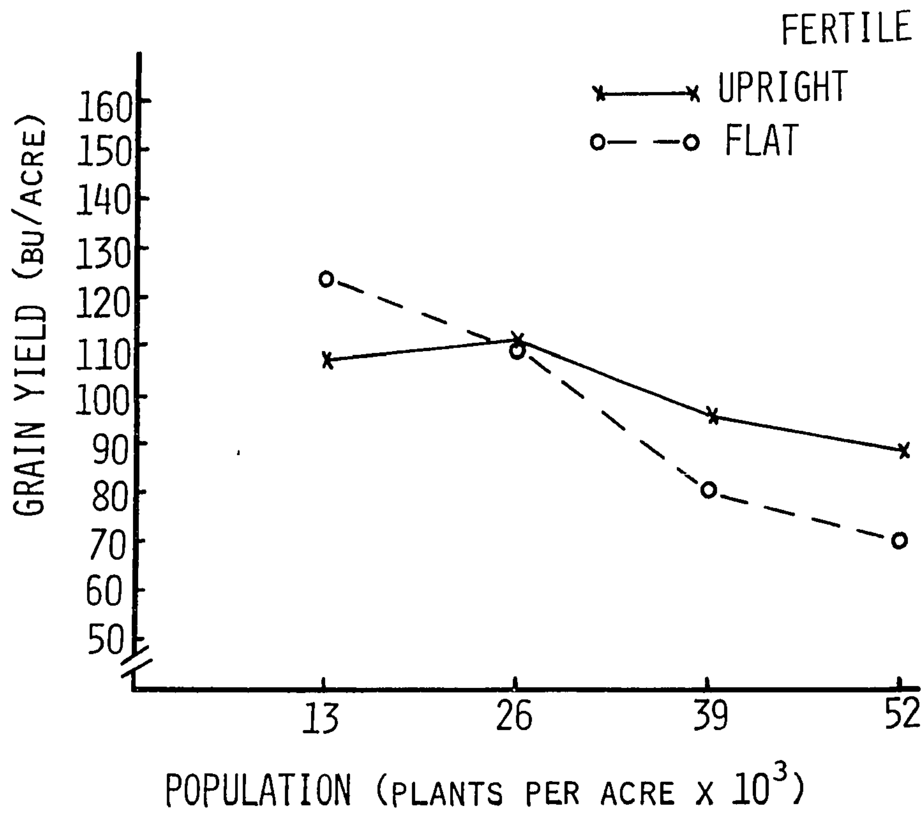
[a]LSD (0.05) = 6.2.

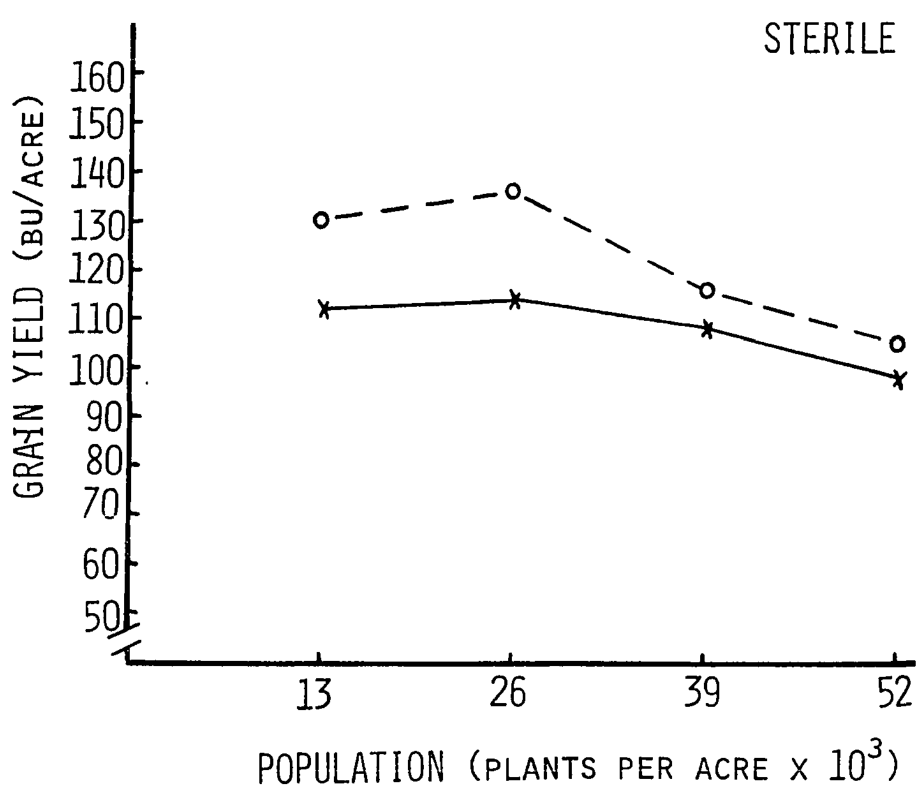
[b]Data in bushels per acre.

[c]LSD (0.05) = 3.6.

[d]LSD (0.05) = 2.2.

Figure 6. Grain yield as a function of population for six varieties (three pairs) with the fertile and sterile counterparts for Experiment 4


FERTILE
UPRIGHT
FLAT
GRAIN YIELD (BU/ACRE)
160
150
140
130
120
110
100
90
80
70
60
50
13
26
39
52
POPULATION (PLANTS PER ACRE X 10^3)


STERILE
GRAIN YIELD (BU/ACRE)
160
150
140
130
120
110
100
90
80
70
60
50
13
26
39
52
POPULATION (PLANTS PER ACRE X 10^3)

13,000 and 26,000 plants per acre yielded about 118 bushels per acre, whereas, the populations of 39,000 and 52,000 plants per acre yielded 100 and 90 bushels per acre, respectively when averaged across the fertile:sterile component. This represented a 28 bushel per acre (24%) yield decrease in going from a lower population (13,000 or 26,000 plants per acre) to a higher population (52,000 plants per acre) for the varieties used here.

The leaf angle by population interaction also was significant in affecting a yield response. When averaged across the fertile and sterile, the highest yield for the upright leaved varieties was at 26,000 plants per acre (113 bushels per acre) and the lowest yield was at 52,000 plants per acre (93 bushels per acre) (Table 23). This represents a 20 bushel per acre or 18% decrease in yield for the upright leaved varieties as populations were increased from 26,000 to 52,000 plants per acre. The flat leaved varieties, averaged across the fertile and sterile, had the highest yield at 13,000 plants per acre and decreased by 39 bushels per acre (30%) as the population was increased to 52,000 plants per acre. The significant interaction here is due to the much more rapid yield decline for the flat leaved varieties as populations were increased.

In all cases, imparting sterility to the varieties caused a yield increase as indicated by Appendix Table 51 and Table 23. The mean yield for all of the fertile varieties was 99 bushels per acre and for the sterile varieties the mean yield was 115 bushels per acre. This represents a 16% increase in yield due to the incorporation of the sterile nature into the varieties.

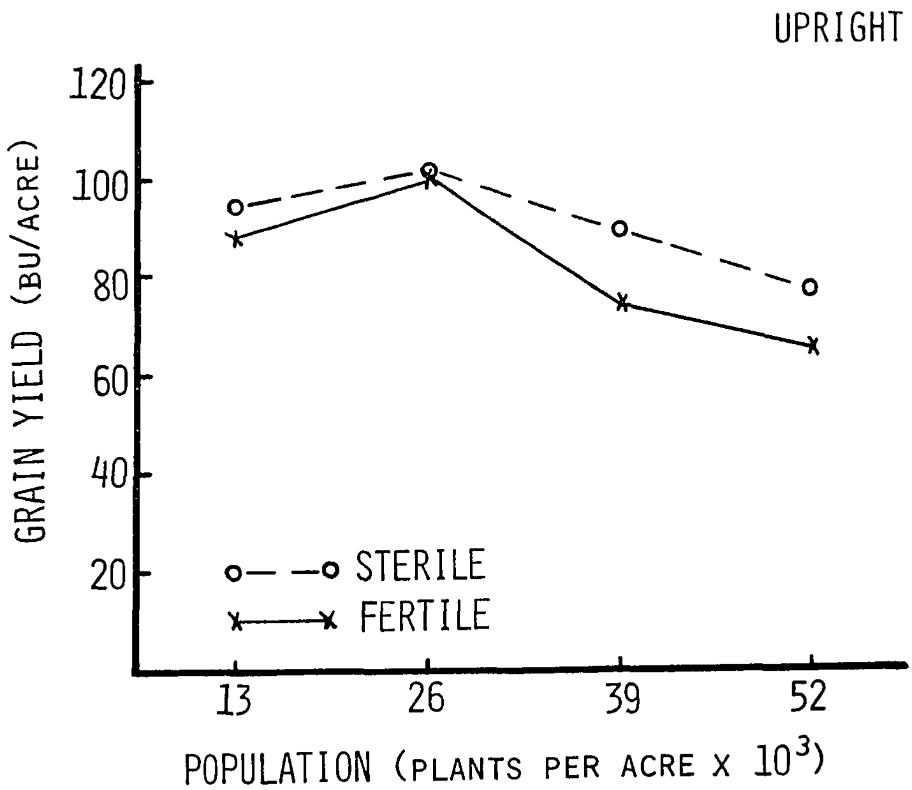
The fertile:sterile variable also was significant when combined in a two-way interaction with leaf angle. When averaged across populations, the sterility imparted a seven bushel per acre (7%) yield increase to the upright leaved varieties, whereas, the sterility was responsible for a 26 bushel per acre (27%) increase in the flat leaved varieties.

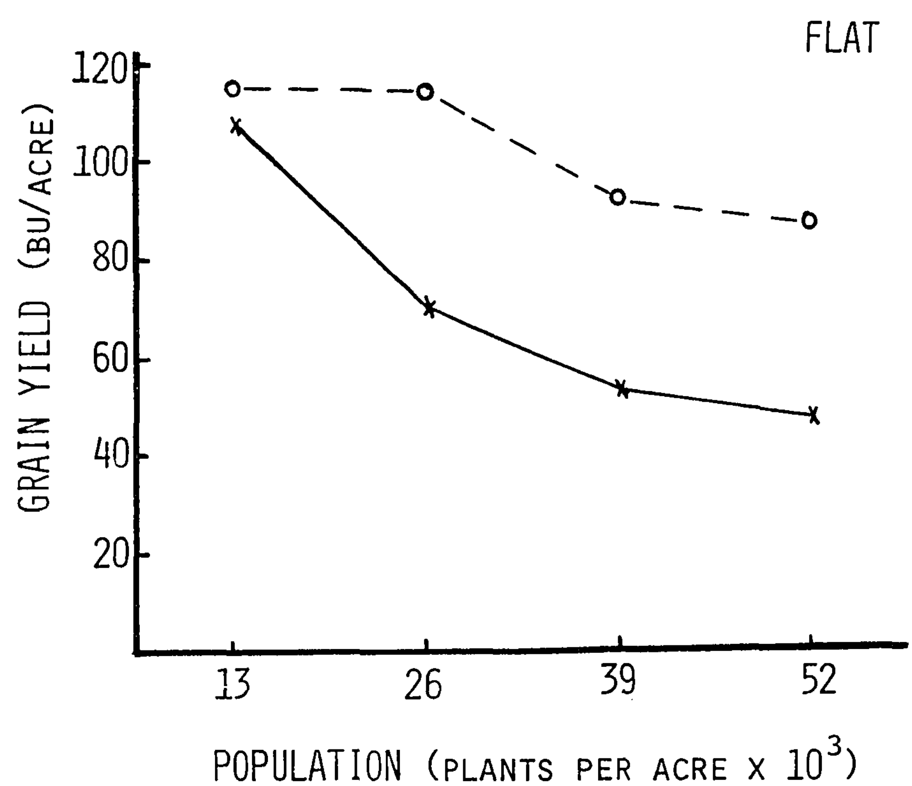
The significant population by fertile:sterile interaction was due to the more population tolerance imparted by the sterility. As the population was increased from 13,000 to 52,000 plants per acre for the fertile, there was a gradual decline in the yield from 115 to 80 bushels per acre. The sterile increased in yield from 121 to 125 bushels per acre as the population was increased from 13,000 to 26,000 plants per acre and then declined to 102 bushels per acre at 52,000 plants per acre. The sterile had a higher optimum population for yield and after such was passed, the yield declined more slowly than was the case for the fertile varieties.

The three-way interaction, leaf angle by population by fertile:sterile also was highly significant. By noting Table 23 it may be noted that as the population increased there was generally an increasing yield advantage of the sterile over the fertile. This was evident for both the upright and flat leaved varieties. The yield advantage attributed to the sterility was more pronounced for the flat leaved varieties than was the case for the upright leaved varieties, thus giving a significant interaction for this three-way interaction. Figure 7 depicts this graphically for the Hy_2 x C103 pair.

The other significant effects or interactions contained the variable of pairs. Due to the diversity of the pairs, it might be expected that these effects or interactions would be significant, but of little importance to the main theme of leaf angle in this study.

Figure 7. Grain yield as a function of population for Hy_2 x C103 (lg_2) and Hy_2 x C103 (Lg_2) with the fertile and sterile counterparts for Experiment 4


UPRIGHT
120
100
80
60
40
20
GRAIN YIELD (BU/ACRE)
STERILE
FERTILE
13
26
39
52
POPULATION (PLANTS PER ACRE X 10³)


FLAT
120
100
80
60
40
20
GRAIN YIELD (BU/ACRE)
13
26
39
52
POPULATION (PLANTS PER ACRE X 10³)

Experiment 4a

One of the pairs utilized for grain yield in Experiment 4 was selected for a small dry matter sampling experiment. The pair chosen consisted of Hy_2 x C103 (lg_2) and Hy_2 x C103 (Lg_2). As in Experiment 4, the pair was split into two leaf angles (upright and flat), four populations, and the last split consisted of the fertile and sterile counterparts of the two varieties. The mean plant yield response and the analysis of variance can be found in Tables 24 and 25, respectively.

From Table 25 it may be noted that population had a statistically highly significant effect on the dry matter production and that the interaction of population by fertile:sterile had a statistically significant effect.

The factor of leaf angle was not statistically significant, but when averaged across all populations and the fertile:sterile component, the upright leaved variety yielded 0.380 of a ton per acre (6%) more dry matter than did the flat leaved variety.

As the population was increased from 13,000 to 26,000 to 39,000 to 52,000 plants per acre the dry matter production increased from 6.056 to 7.097 to 7.104 to 7.743 tons per acre. This represented a 27% increase in dry matter per acre as the population was increased from 13,000 to 52,000 plants per acre and was highly significant.

The leaf angle by population interaction was not significant, but by observing the means averaged across the fertile:sterile component it may generally be seen that as the population was increased the dry matter production also increased for both the upright and flat leaved varieties (Table 24 and Figure 8). The most notable exception was the mean for the

Table 24. The dry matter production of the upright and flat leaved counterparts of Hy_2 x C103 at four population levels and with the fertile and sterile counterparts for Experiment 4a

	Upright Pop. (plants per acre x10^3)					Flat Pop. (plants per acre x10^3)					Overall Mean
	13	26	39	52	Mean	13	26	39	52	Mean	
Fertile	6.340[a]	7.453	6.545	8.331	7.167	6.534	5.903	6.893	7.009	6.585	6.876
Sterile	5.703	7.498	7.425	8.225	7.213	5.646	7.534	7.550	7.406	7.034	7.123
Mean	6.022	7.475	6.985	8.278		6.090	6.719	7.222	7.208		
		Mean = 7.190					Mean = 6.810				

[a]Tons per acre.

Table 25. Dry matter yield variable of the upright and flat leaved counterparts of Hy_2 x C103 at four population levels and for the fertile and sterile counterparts with the associated mean squares for Experiment 4a

Source	d.f.	Yield
Blocks	3	0.75
Leaf Angle (LA)	1	2.31
Error (a)	3	0.86
Population (Po)	3	7.80**
LA x Po	3	1.60
Error (b)	18	0.87
Fert:Ster. (F:S)	1	0.98
LA x F:S	1	0.65
Po x F:S	3	2.20*
LA x Po x F:S	3	0.74
Error (c)	24	0.47

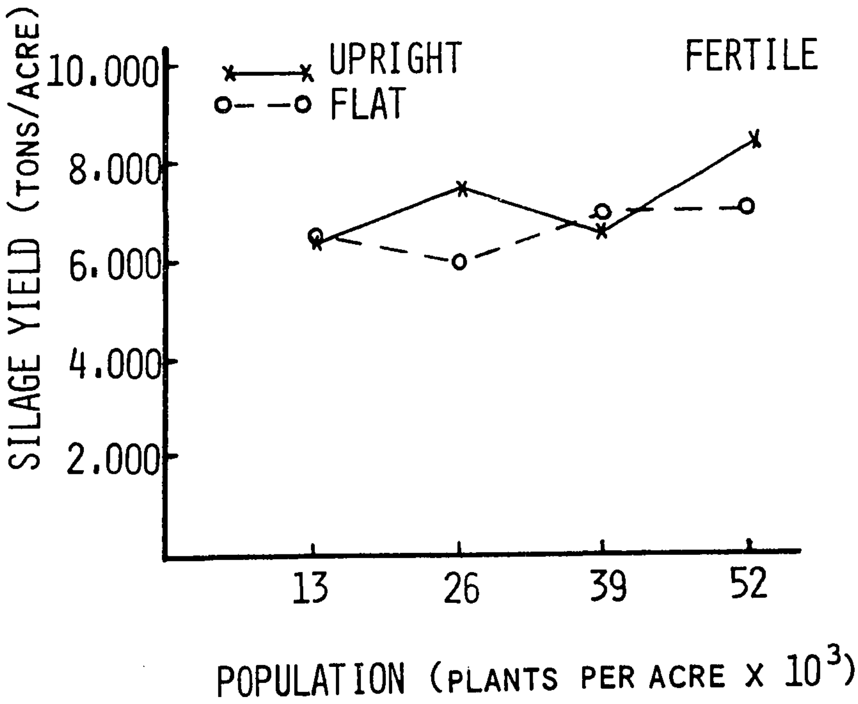
*Statistically significant at the 0.05 level of probability.

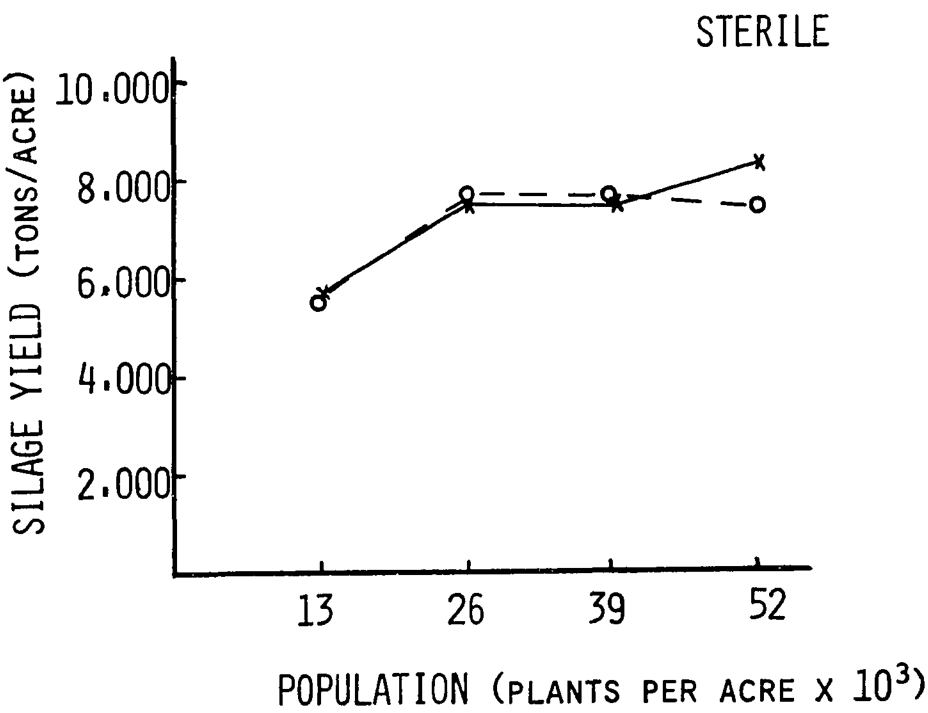
**Statistically significant at the 0.01 level of probability.

upright leaved variety at 39,000 plants per acre. Although not statistically significant, the upright leaved variety tended to increase in dry matter yield at a faster rate than did the flat leaved variety as the population was increased.

The leaf angle by fertile:sterile interaction was not statistically significant, but sterility was associated with a yield increase when averaged over all populations. The sterility component imparted a 0.6% and

Figure 8. Yield as a function of population for both the upright and flat leaved counterparts of Hy_2 x C103 with the fertile and sterile counterparts of both varieties for Experiment 4a


SILAGE YIELD (TONS/ACRE)
10.000
8.000
6.000
4.000
2.000
UPRIGHT
FLAT
FERTILE
13
26
39
52
POPULATION (PLANTS PER ACRE X 10^3)


STERILE
SILAGE YIELD (TONS/ACRE)
10.000
8.000
6.000
4.000
2.000
13
26
39
52
POPULATION (PLANTS PER ACRE X 10^3)

6.8% yield increase to the upright and flat leaved varieties, respectively.

Population by fertile:sterile also caused an upward trend in yield and was significant at the 0.05 level of probability. Generally as the population was increased, the dry matter production also increased. This was usually the case for both the fertile and sterile counterparts, but seemed to be more pronounced for the sterile counterparts.

The three-way interaction, leaf angle by population by fertile:sterile, was non-significant. Figure 9 shows that there was no consistent divergence of the fertile and sterile yields as population was increased for either the upright or flat leaved variety. There was a slight suggestion that at the higher populations the sterile may have caused some increase in yield for both the upright and flat leaved varieties, but not consistently.

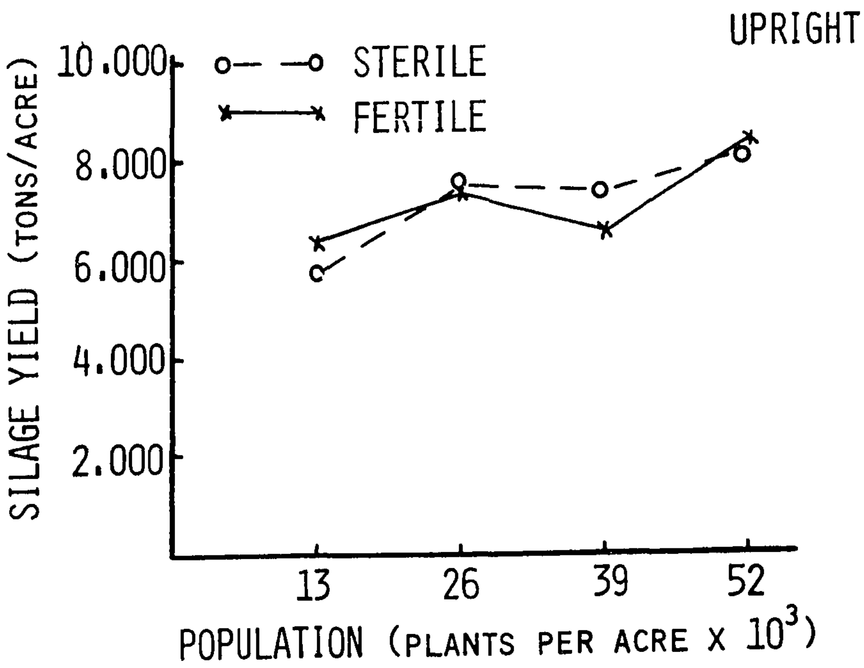
Experiments 1969

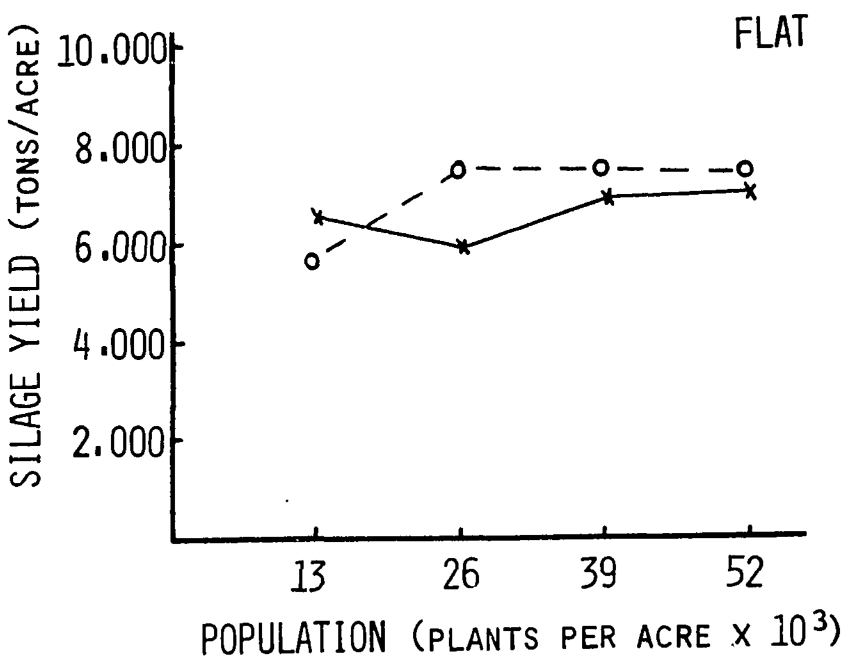
Experiments 5 and 6

Experiments 5 and 6 were identical experiments with the exception that Experiment 5 had the variety XL-45 and Experiment 6 consisted of the variety DL-11. In both of these experiments only one population of 40,000 plants per acre was utilized. The four treatments utilized were the tying up of the leaves above the ear leaf at 1 and 0 weeks before anthesis and 1 week after anthesis. The fourth treatment was a control.

The variables studied were harvest plants per plot, grams of grain per plant (figured only on those plants having an ear), grain yield, percent barrenness, number of ears per plot, number of nubbins per plot, the silking dates (15%, 25%, 50%, and 75%), and the silking intervals (days between 25% and 75% silking for XL-45 and days between 15% and 50% silking

Figure 9. The yield as a function of population for the fertile and sterile counterparts of Hy_2 x C103 (lg_2) and Hy_2 x C103 (Lg_2) for Experiment 4a


UPRIGHT
STERILE
FERTILE
SILAGE YIELD (TONS/ACRE)
10.000
8.000
6.000
4.000
2.000
13
26
39
52
POPULATION (PLANTS PER ACRE X 10^3)


FLAT
SILAGE YIELD (TONS/ACRE)
10.000
8.000
6.000
4.000
2.000
13
26
39
52
POPULATION (PLANTS PER ACRE X 10^3)

for DL-11). The mean plant responses and the associated analyses of variance may be found in Appendix Tables 52 and 53, respectively.

For the two varieties, the number of plants desired per plot and the actual number of plants per plot were determined. For the variety XL-45 these two variables never varied more than six plants (when averaged across replications). Usually there was only a three to four plant discrepancy. For DL-11 there was more variability. In some instances there were as many as ten plants missing which represented about 16% of the desired number of plants missing. The probable explanation for this was that during mid and late July an infestation of corn borers and strong winds caused moderate damage to the DL-11 plots. The XL-45 plots were only mildly damaged, thus explaining why fewer plants were lost in the XL-45 plots than was the case for the DL-11 plots. For both varieties the controls tended to be the plots missing the most plants.

The next set of variables of interest were the silking dates (25%, 50%, and 75% for the XL-45 and 15%, 25%, and 50% for DL-11) and the silking intervals (25% to 75% for XL-45 and 15% to 50% for DL-11). It may be noted from Table 26 that the XL-45 plots with the four treatments reached 25% silking within 0.7 days of one another with the 1 week after anthesis treatment being the earliest and the control being the latest. Mid-silking (50%) dates were within 1.3 days of each other with the 0 weeks before anthesis treatment being the fastest and the control the slowest. The 75% silking dates were somewhat more variable with a difference of 2.5 days between the fastest (0 weeks before anthesis) and slowest (1 week before anthesis) treatments to silk. The treatment with the shortest silking interval was the treatment in which the leaves above the ear leaf were tied up at 0 weeks

Table 26. Silking dates and intervals of XL-45 at 40,000 plants per acre for the four treatments for Experiment 5

Hybrid	Treatment[a]	Silking %[b]			Silking interval[c]
		25	50	75	
XL-45	1 wk. before	73.2	74.7	78.3	5.1
	0 wk. before	73.3	74.2	75.8	2.5
	1 wk. after	72.8	75.0	78.2	5.4
	Control	73.5	75.5	78.2	4.7

[a]Time at which the leaves above the ear leaf were tied up in relation to anthesis.

[b]Silking percent in days from planting to respective silking percent.

[c]Silking interval in days between 25% and 75% silking.

before anthesis (2.5 days). This particular treatment was the only one that had a shorter silking interval than the control. The other treatments tended to increase the silking interval when compared to the control.

The silking dates and intervals for DL-11 should be viewed with caution (Table 27). The reason for this being that the silking date readings were being taken during the time that the damage from the corn borers and winds was occurring. The 15% silking dates were within 0.5 days of each other with the 1 week after anthesis treatment being the earliest and the control being the latest. The 25% silking dates were within 1.0 days of each other with the 1 week before anthesis treatment and the 0 weeks before anthesis treatment being the latest and earliest, respectively. Plots having their leaves above the ear leaf tied up 0 weeks before anthesis reached 50% silking the earliest and were 3.3 days faster than the slowest plots

Table 27. Silking dates and intervals of DL-11 at 40,000 plants per acre for the four treatments for Experiment 6

Hybrid	Treatment[a]	Silking %[b]			Silking interval[c]
		15	25	50	
DL-11	1 wk. before	74.2	75.5	79.8	5.6
	0 wk. before	74.2	74.5	76.5	2.3
	1 wk. after	74.0	75.0	77.7	3.7
	Control	74.5	75.0	77.0	2.5

[a]Time at which the leaves above the ear leaf were tied up in relation to anthesis.

[b]Silking percent in days from planting to respective silking percent.

[c]Silking interval in days between 15% and 50% silking.

(those treated at 1 week before anthesis). As was the case with the XL-45, the treatment with the shortest silking interval was those plots that had their leaves tied up at 0 weeks before anthesis. Also this was the only treatment that had a shorter silking interval than did the control.

A note may be made here concerning the silking dates of XL-45 and DL-11. For XL-45, a population-tolerant hybrid, the 25% silking dates had occurred by the time of 1 week after anthesis for most plots. But for DL-11, a population-intolerant hybrid, the 25% silking dates were somewhat delayed beyond 1 week after anthesis for many of the plots. Therefore, some care should be taken in interpreting the silking dates and intervals.

Tables 28 and 29 contain the variables of percent barrenness, grams of grain per plant (only for the nonbarren plants), grain yield, number of ears per plot, and number of nubbins per plot for XL-45 and DL-11, respectively.

Table 28. Yield characteristics of XL-45 planted at 40,000 plants per acre for the four treatments for Experiment 5

Hybrid	Treatment[a]	Barren %	Grams grain/ plant	Grain yield (bu/acre)	Number of ears/ plot	Number of nubbins /plot
XL-45	1 wk. before	22.2	12.6	123	47.7	1.67
	0 wk. before	23.0	13.1	123	45.7	2.00
	1 wk. after	17.1	13.5	133	47.7	1.00
	Control	19.7	13.8	125	44.3	1.00

[a]Time at which the leaves above the ear leaf were tied up in relation to anthesis.

Table 29. Yield characteristics of DL-11 planted at 40,000 plants per acre for the four treatments for Experiment 6

Hybrid	Treatment[a]	Barren %	Grams grain/ plant	Grain yield (bu/acre)	Number of ears/ plot[b]	Number of nubbins /plot
DL-11	1 wk. before	48.6	15.2	90	28.7ab	1.00
	0 wk. before	42.2	17.2	109	31.0ac	0.67
	1 wk. after	43.6	14.7	103	34.0c	1.00
	Control	49.2	17.2	92	26.0b	0.33

[a]Time at which the leaves above the ear leaf were tied up in relation to anthesis.

[b]Numbers followed by same letter were not significantly different at 0.05 level of probability.

Figure 10 depicts in bar graph form the effects on percent barrenness and grain yield of tying up the leaves above the ear leaf at 1 and 0 weeks before anthesis and 1 week after anthesis expressed as a percent of the control.

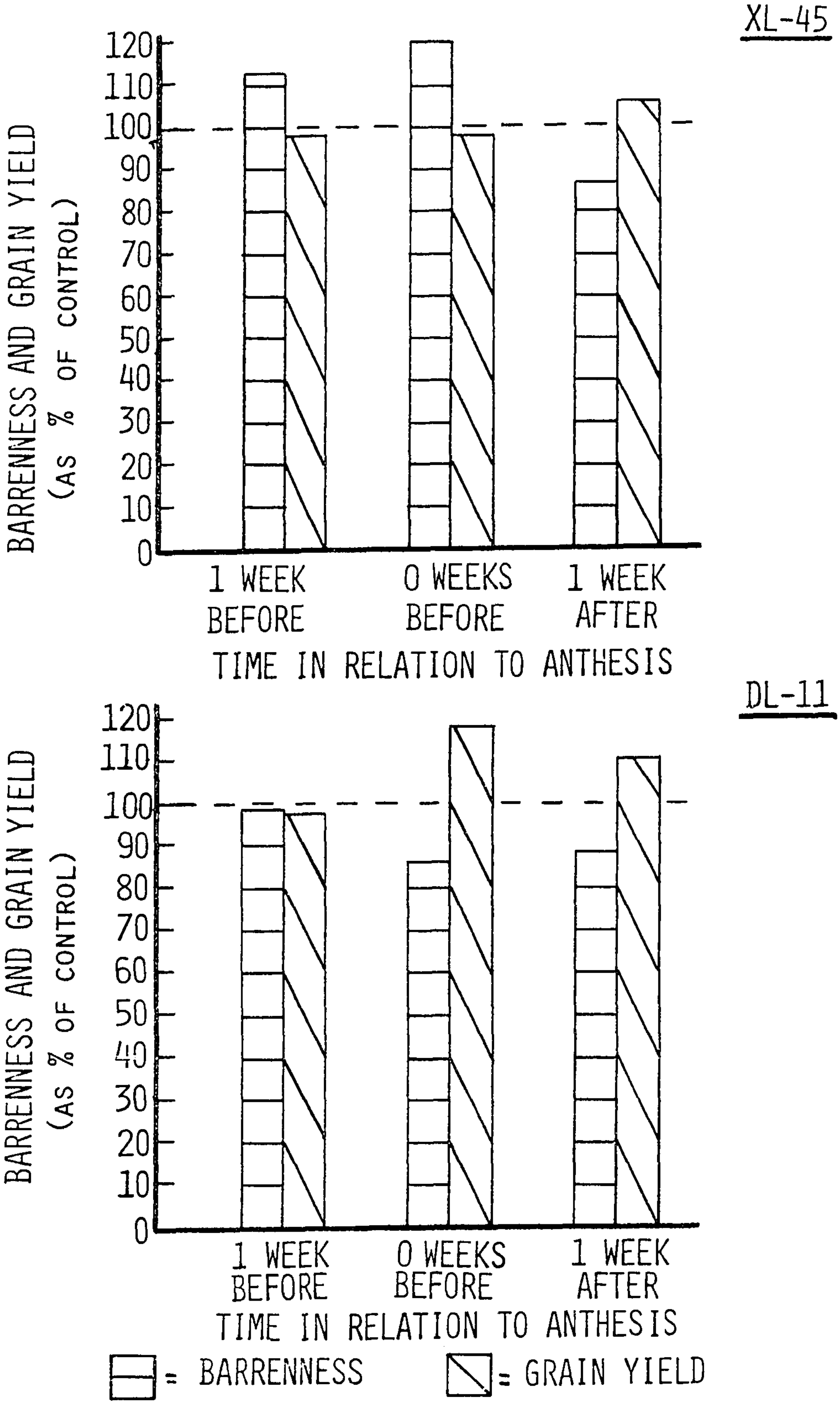
The percent barrenness, for XL-45, was only reduced below the control for the treatment in which the leaves above the ear leaf were tied up 1 week after anthesis. The other two treatments increased the barrenness in comparison with the control. All three treatments reduced the percent barrenness for DL-11 with the most reduction resulting from the 0 weeks before and 1 week after anthesis treatments.

In no case was the grams of grain per plant increased due to the tying up of the leaves at any time for either variety. In most instances the number of grams of grain per plant was relatively constant. It varied no more than 2.5 grams a plant within a variety.

The only treatment that increased the yield of the XL-45 was the tying up of the leaves above the ear leaf at 1 week after anthesis. This resulted in about an eight bushel per acre (6%) grain yield increase over the control. The other two treatments (1 and 0 weeks before anthesis) caused a two to three bushel per acre (2%) yield decrease when compared to the control. Two treatments (0 weeks before and 1 week after anthesis) caused a yield increase in DL-11. They caused a 17 and 11 bushel per acre (19% and 11%) increase, respectively. A slight yield reduction resulted from tying up the leaves above the ear leaf at 1 week before anthesis when compared to the control.

All treatments applied to the XL-45 caused an increase of from one to four ears per plot with the smallest increase resulting from the 0 weeks

Figure 10. Grain yield and barrenness of XL-45 and DL-11 expressed as a percent of the control when the leaves about the ear leaf were tied up at 1 and 0 weeks before and 1 week after anthesis for Experiments 5 and 6


XL-45
BARRENNESS AND GRAIN YIELD
(AS % OF CONTROL)
120
110
100
90
80
70
60
50
40
30
20
10
0
1 WEEK BEFORE
0 WEEKS BEFORE
1 WEEK AFTER
TIME IN RELATION TO ANTHESIS
DL-11
BARRENNESS AND GRAIN YIELD
(AS % OF CONTROL)
120
110
100
90
80
70
60
50
40
30
20
10
0
1 WEEK BEFORE
0 WEEKS BEFORE
1 WEEK AFTER
TIME IN RELATION TO ANTHESIS
= BARRENNESS
= GRAIN YIELD

before anthesis treatment and the largest increase as a result of the 1 week before and 1 week after anthesis treatments. All treatments caused a two to eight ear increase above the control for DL-11. This was significant at the 0.05 level of probability (Appendix Table 53). The sharpest increase in the number of ears resulted from the 1 week after anthesis tying up of the leaves above the ear leaf. Duncan's new multiple-range test was run on the data and the significantly different treatments are indicated in Table 29.

The number of nubbins per plot varied very little. In the variety XL-45 there was only a difference of one nubbin between the four treatments. This also was the case with DL-11. In both varieties the control plots had the fewest number of nubbins, but the variation was very small.

Experiments 7 and 8

Experiments 7 and 8 were identical experiments with the exception that XL-45 was the variety used for Experiment 7 and DL-11 for Experiment 8. A final population of 40,000 plants per acre was utilized. The four treatments utilized were glutamate at two rates (Gl-1 and Gl-2), sucrose (Suc), and a combination of the high rate of glutamate plus sucrose (Gl-2 + Suc). These treatments were applied to various leaves of the plants. They were the second leaf above the ear leaf (2A), the ear leaf (E), and the second leaf below the ear leaf (2B). A control (C) was included with each treatment.

Some of the plant characters measured were the grams of grain per plant (only for those plants having ears), the grain yield, the percent barrenness, the number of nubbins and ears per plot, the silking dates (15%, 25%, 50%, and 75% for XL-45 and 15%, 25%, and 50% for DL-11), and the silking intervals (25% to 75% for XL-45 and 15% to 50% for DL-11). These mean plant responses may be noted in Appendix Table 54 and the analyses of variance may be found in Appendix Table 55.

The 25% silking dates for Experiment 7 (XL-45) are shown in Table 30. It may be noted that regardless of chemical used or position of treatment that the plots reached 25% silking within 2.1 days of each other. The Gl-1 treatment applied at any of the treatment positions did not cause more than 1.0 days variation in the 25% silking dates. There was an indication that the Gl-2 treatment applied at the 2A, E, and 2B treatment positions may have slightly delayed the 25% silking dates when compared to the control. This same trend appeared to exist with the Suc and Gl-2 + Suc chemical treatments. When compared to the controls these chemicals applied at the 2A, E, and 2B treatment positions were associated with a slight delay in the 25% silking dates. It might be noted here that one-half of the total rate of each chemical treatment was applied about 1 week before anthesis with the remaining one-half being applied at the time of anthesis. It may be somewhat questionable if the treatments would have had enough time to exert their full influence by 25% silking.

The 50% silking dates also were not very diverse and no perceptable trends were evident (Table 30). By 75% silking the treatments could easily have had enough time to have had an effect. This may be best noted by referring to the silking intervals (see column showing silking interval as a percent of the control). The Gl-1 chemical treatment applied to the 2A and E leaves tended to hasten the silking rate, whereas, application of Gl-1 to the 2B leaf caused a slight increase in the silking interval. Gl-2 when

Table 30. Silking dates and intervals of XL-45 at one population as affected by the application of glutamate, sucrose, and a combination of the two compounds for Experiment 7

Hybrid	Chemical[a]	Position of treatment[b]	Silking %[c] 25	50	75	Silking interval[d]	Silking interval as % of control
XL-45	G1-1	2A	72.8	74.3	76.7	3.9	72
		E	73.5	75.3	78.3	4.8	91
		2B	72.5	75.0	78.2	5.7	106
		C	73.0	75.3	78.3	5.3	100
	G1-2	2A	73.0	75.3	78.5	5.5	100
		E	73.0	74.7	77.2	4.2	76
		2B	73.3	75.3	78.3	5.0	91
		C	71.8	74.0	77.3	5.5	100
	Suc	2A	73.2	76.2	79.5	6.3	86
		E	73.3	75.2	78.5	5.2	71
		2B	73.3	74.7	76.8	3.5	48
		C	72.7	75.7	80.0	7.3	100
	G1-2 + Suc	2A	73.2	75.7	79.2	6.0	129
		E	73.8	76.0	79.3	5.5	118
		2B	73.2	74.3	76.7	3.5	75
		C	71.7	73.5	76.3	4.6	100

[a]Chemicals used were glutamate (Gl) at two rates (1 and 2), sucrose (Suc), and a combination of glutamate 2 and sucrose (Gl-2 + Suc).

[b]Positions of treatment were the second leaf above the ear leaf (2A), the ear leaf (E), the second leaf below the ear leaf (2B) and a control (C).

[c]Days from planting to respective silking percent.

[d]Days between 25% and 75% silking.

applied at the 2A, E, or 2B treatment position was noted to have slightly faster silking rates than the control. Sucrose also was noted to be associated with shorter silking intervals when applied to the 2A, E, or 2B leaf. However, it should be noted here that the value for the control was somewhat higher than the other control values. The Gl-2 + Suc chemical treatment applied at the 2A or E leaf position tended to increase the silking intervals, whereas, the Gl-2 + Suc applied at the 2B treatment position caused a slight decrease in the silking interval in comparison with the control. These results also may be seen graphically in Figures 11 and 12.

The various factors associated with grain yield for XL-45 may be noted in Table 31.

The number of nubbins produced per plot did not generally exhibit much variation. However, for the Gl-2 chemical treatment applied to the 2B leaf, a slight increase in nubbin production was noted.

Variation in the number of ears per plot was somewhat more evident due to the treatments. The Gl-1 chemical treatment when applied to the 2A leaf was associated with an increase in the number of ears per plot produced when compared with the control. The E and 2B leaf treatment positions were not associated with such an increase. The Gl-2 chemical treatment at all treatment positions was associated generally with a slight decrease in this variable. The Suc chemical treatment appeared to show a slight increase in the ears produced per plot when applied to the E and 2B leaves, but not when applied to the 2A leaf. Gl-2 + Suc when applied at the E leaf position had a slightly higher number of ears per plot than the control or treatment of the 2A or 2B leaf.

Variations in barrenness also were quite evident. The Gl-1 chemical treatment applied to the 2A leaf was associated with a large (37%) decrease in barrenness when compared to the control (also see column depicting barrenness as a percent of the control). The Gl-2 chemical treatment applied at all treatment positions was associated with higher barrenness

Figure 11. Silking interval, barrenness, and grain yield expressed as a percent of the control when the second leaf above the ear leaf (2A), the ear leaf (E), or the second leaf below the ear leaf (2B) were treated with one of two rates of glutamate (1 or 2) for Experiment 7

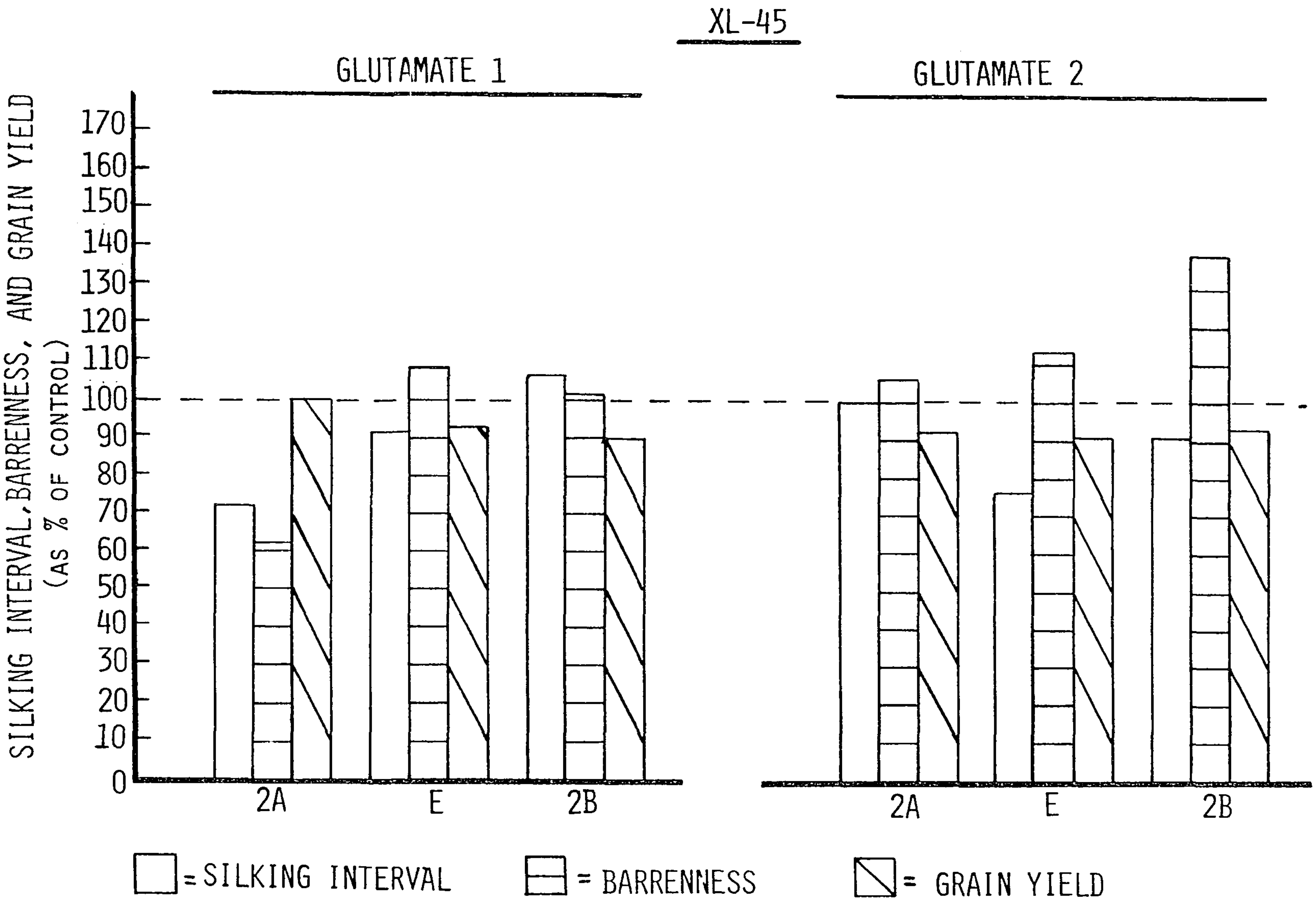

XL-45
GLUTAMATE 1
GLUTAMATE 2
SILKING INTERVAL, BARRENNESS, AND GRAIN YIELD
(AS % OF CONTROL)
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
2A
E
2B
2A
E
2B
= SILKING INTERVAL
= BARRENNESS
= GRAIN YIELD

Figure 12. Silking interval, barrenness, and grain yield expressed as a percent of the control when the second leaf above the ear leaf (2A), the ear leaf (E), or the second leaf below the ear leaf (2B) were treated with sucrose or glutamate plus sucrose for Experiment 7

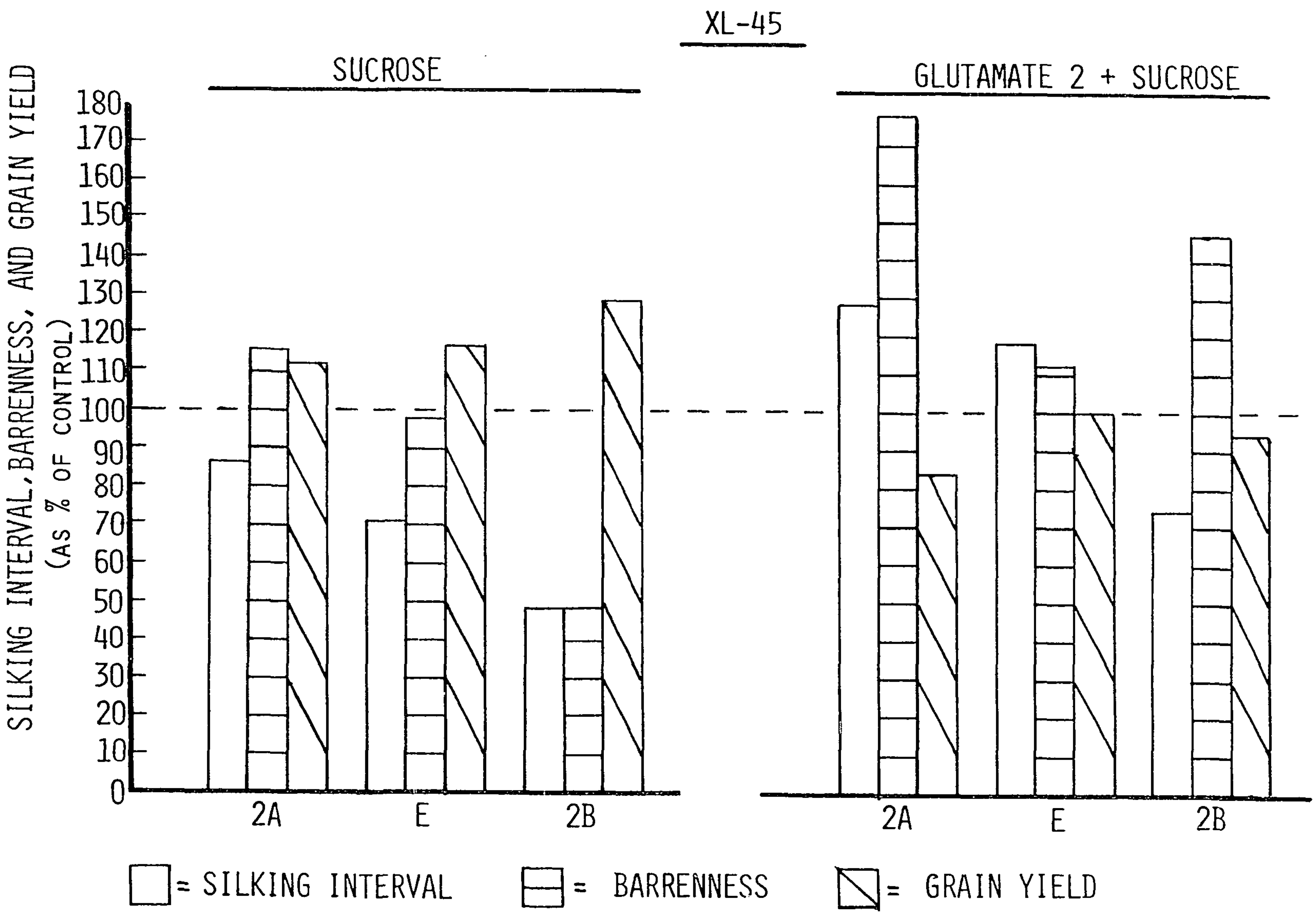

XL-45
SUCROSE
GLUTAMATE 2 + SUCROSE
SILKING INTERVAL, BARRENNESS, AND GRAIN YIELD
(AS % OF CONTROL)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
2A
E
2B
2A
E
2B
= SILKING INTERVAL
= BARRENNESS
= GRAIN YIELD

Table 31. Yield responses of XL-45 when planted at 40,000 plants per acre as affected by the application of glutamate, sucrose, and a combination of the two compounds for Experiment 7

Hybrid	Chemical[a]	Position of trtmnt.[b]	No. of nubbins/ plot	No. of ears /plot	Barren %	Barren as % of control	Grams grain/ plant	Grain yield (bu/ac.)	Grain yield as % cont.
XL-45	Gl-1	2A	0.67	29.0	11.3	63	13.2	140	101
		E	0.33	26.0	19.4	109	13.4	129	93
		2B	0.67	26.7	18.2	102	12.7	125	90
		C	0.33	27.7	17.9	100	13.5	138	100
	Gl-2	2A	0.33	24.3	21.7	106	13.3	121	92
		E	0.67	24.0	24.6	113	13.4	119	91
		2B	2.00	25.7	28.5	139	12.8	122	93
		C	1.67	25.7	20.5	100	13.8	131	100
	Suc	2A	0.33	24.7	26.6	116	14.1	129	112
		E	0.67	26.0	22.6	98	13.9	134	117
		2B	1.33	29.3	11.1	49	13.6	148	129
		C	0.67	25.0	22.9	100	12.4	115	100
	Gl-2 + Suc	2A	0.33	23.3	28.5	177	13.7	118	84
		E	0.67	28.3	18.1	113	13.5	141	100
		2B	0.00	25.0	23.7	147	14.3	132	94
		C	0.67	26.3	16.1	100	14.5	141	100

[a]Chemicals used were glutamate (Gl) at two rates (1 and 2), sucrose (Suc), and a combination of glutamate 2 and sucrose (Gl-2 + Suc).

[b]Positions of treatment were the second leaf above the ear leaf (2A), the ear leaf (E), the second leaf below the ear leaf (2B), and a control (C).

ratings when compared to the control. Suc applied to the 2B treatment position was associated with a large (51%) decrease in barrenness when compared with the control. The Gl-2 + Suc chemical treatment applied at all treatment positions was associated with higher barrenness ratings. This may be seen graphically in Figures 11 and 12.

Grams of grain per plant were not too variable. In comparison with their respective controls, a slight reduction in the number of grams of grain per plant was associated with the Gl-1 chemical treatment applied at the 2B treatment position and with the Gl-2 chemical treatment also applied at the 2B treatment position. Suc applied to the 2A, E, and 2B leaves tended to be associated with increases in this variable in comparison with the control, but the control was somewhat lower than the other control values. A slight reduction in this variable was noted in the Gl-2 + Suc chemical treatment when applied at the 2A, E, or 2B leaf treatment position. However, in this case the control appeared to have been slightly higher than the other controls.

The Gl-1 chemical treatment applied at the 2A treatment position was associated with a very slight grain yield increase. This also may be noted to be associated with a reduced barrenness rating. The Gl-2 chemical treatment applied at all leaf positions on the plant was associated with yield decreases and also was noted to have had higher barrenness ratings when compared with their respective control. Suc applications to the 2A, E, or 2B leaf treatment position showed higher grain yields than did the control and also generally had lower barrenness ratings than the control. Gl-2 + Suc was usually associated with yield decreases when applied at the 2A, E, or 2B leaf position. These reduced yields were noted to be associated with increased barrenness ratings. Figures 11 and 12 show this graphically.

Appendix Table 55 indicates that the different chemical treatments significantly affected the grain yield. Table 32 contains the various means for this variable. The indication was that the chemical treatment of Gl-2 significantly reduced the yield when compared with the other chemical treatments. It may also be noted that the error associated with chemicals in

Table 32. Grain yield of XL-45 as affected by treatments applied at various positions on the plant for Experiment 7

Chemical[a]	Position of Treatment[b]				Mean[c]
	2A	E	2B	C	
Gl-1	140[d]	129	125	138	133a
Gl-2	121	119	122	131	123b
Suc	129	134	148	115	131a
Gl-2 + Suc	118	141	132	141	133a
Mean	127	131	132	131	

[a]Chemicals used were glutamate (Gl) at two rates (1 and 2), sucrose (Suc), and a combination of glutamate 2 and sucrose (Gl-2 + Suc).

[b]Positions of treatment were the second leaf above the ear leaf (2A), the ear leaf (E), the second leaf below the ear leaf (2B), and a control (C).

[c]Means followed by same letter were not significantly different at the 0.05 level.

[d]Grain yield in bushels per acre.

Appendix Table 55 was unusually small. Therefore, this variable may not in fact have been significant.

Mean plant responses for the variables studied may be found in Appendix Table 54 and the analyses of variance for the variables are in Appendix Table 55 for Experiment 8 (DL-11).

Table 33 contains the silking dates (15%, 25%, and 50%) and the silking intervals (15% to 50%) for DL-11. The silking data of DL-11 here (Experiment 8) was somewhat more reliable than that of the DL-11 in Experiment 6. This was due to the slightly less exposure to the wind after the corn borer infestation for Experiment 8 versus Experiment 6. However, the

Table 33. Silking dates and intervals of DL-11 at one population (40,000 plants per acre) as affected by the application of glutamate, sucrose, and a combination of the two compounds for Experiment 8

Hybrid	Chemical[a]	Position of treatment[b]	Silking %[c] 15	Silking %[c] 25	Silking %[c] 50	Silking interval[d]	Silking interval as % of control
DL-11	Gl-1	2A	74.0	74.8	78.3	4.3	74
		E	74.0	74.8	77.7	3.7	63
		2B	74.5	75.3	79.7	5.2	89
		C	75.3	76.8	81.2	5.9	100
	Gl-2	2A	73.2	74.2	77.7	4.5	51
		E	74.5	75.8	79.8	5.3	60
		2B	74.0	74.7	76.7	2.7	30
		C	74.3	75.7	83.2	8.9	100
	Suc	2A	74.0	75.2	80.0	6.0	133
		E	73.3	74.7	79.3	6.0	133
		2B	73.8	74.7	78.3	4.5	100
		C	72.3	73.5	76.8	4.5	100
	Gl-2 + Suc	2A	73.3	73.8	76.3	3.0	29
		E	74.0	75.0	78.5	4.5	43
		2B	74.3	75.2	78.2	3.9	37
		C	74.0	76.2	84.5	10.5	100

[a]Chemicals used were glutamate (Gl) at two rates (1 and 2), sucrose (Suc), and a combination of glutamate 2 and sucrose (Gl-2 + Suc).

[b]Positions of treatment were the second leaf above the ear leaf (2A), the ear leaf (E), the second leaf below the ear leaf (2B), and a control (C).

[c]Days from planting to respective silking percent.

[d]Days between 15% and 50% silking.

results should be reviewed with some caution.

The use of all chemical treatments applied to all of the various positions of treatment appeared to have had little effect on the time from planting to 15% silking (Table 33). The 25% silking dates were a little more variable, but it was not until the 50% silking dates that a larger differential existed. The Gl-1 chemical treatment applied at the 2A, E, or 2B leaf position all tended to reduce the time to 50% silking when compared to the control. This was most notable for the E leaf treatment position. The Gl-2 chemical treatment applied at the 2A, E, or 2B leaf position tended to hasten the 50% silking date. For this rate, the 2B leaf position was at 50% silking in the shortest time from planting. At first it appears that the Suc chemical treatment applied to the 2A, E, or 2B leaf position caused a delay in 50% silking when compared to the control, but it may be noted that this control was exceptionally fast in reaching the 50% silking stage. If this control had been about equal to the other controls, a slight hastening of the 50% silking dates might have been noted due to the positions of treatment. The Gl-2 + Suc chemical treatment applied at the three leaf positions again tended to speed the 50% silking dates.

The silking intervals (also see silking interval as a percent of the control) show much the same results as was noted for the 50% silking dates. Gl-1 chemical treatment of the three leaf positions hastened the silking rates and especially when the chemical was applied to the E leaf. Gl-2 chemical treatment of the 2A, E, and 2B leaves reduced the silking interval. This was especially true for treatment of the 2B leaf. Suc chemical treatment applied at all treatment positions appeared to have lengthened the silking intervals, but had the control been in the realm of the other controls this probably would not have been the case. More reasonably, the Suc chemical treatment may have caused little change. The Gl-2 + Suc chemical treatment also reduced the silking intervals when applied to any of the treatment positions in comparison with the control. The difference probably was not as great as indicated in Table 33 due to the high value of the control. Figures 13 and 14 show the effects of the different chemicals and positions of treatment on the silking intervals.

Appendix Table 55 indicated that the 50% silking dates and the silking intervals were significantly affected by the various positions of treatment. Table 34 shows that chemical treatment of the 2A, E, or 2B leaf position reduced the time to 50% silking when compared to the control. The reduction ranged from 2.6 to 3.3 days when compared to the control. This same trend was evident in the silking intervals (Table 35). When compared to the controls, the chemical treatment of the 2A, E, or 2B leaf position reduced the silking intervals from 2.6 to 3.4 days.

The yield responses of DL-11 (Experiment 8) are shown in Table 36.

The different chemical treatments imposed at the different treatment positions on the plant did not cause much variation in the number of nubbins produced.

Number of ears per plot as affected by the different chemical treatments and positions of treatments did show some variation, however. Gl-1 when applied to the 2A leaf position gave an increase in ear production when compared with the control. This also was the case with XL-45 (Experiment 7). The other two positions of this treatment indicated a decrease in ear production from the application of Gl-1. Gl-2 applied at all positions of treatment indicated an increase in ear production over the control plot. Treatment at all leaf positions with sucrose tended to increase the number of ears produced within a plot. This was somewhat noticeable for the XL-45. Treatment using a combination of glutamate and sucrose (Gl-2 + Suc) applied at all of the leaf positions of treatment indicated an increase in ear

Figure 13. Silking interval, barrenness, and grain yield expressed as a percent of the control when the second leaf above the ear leaf (2A), the ear leaf (E), or the second leaf below the ear leaf (2B) were treated with either of two rates of glutamate for Experiment 8

DL-11

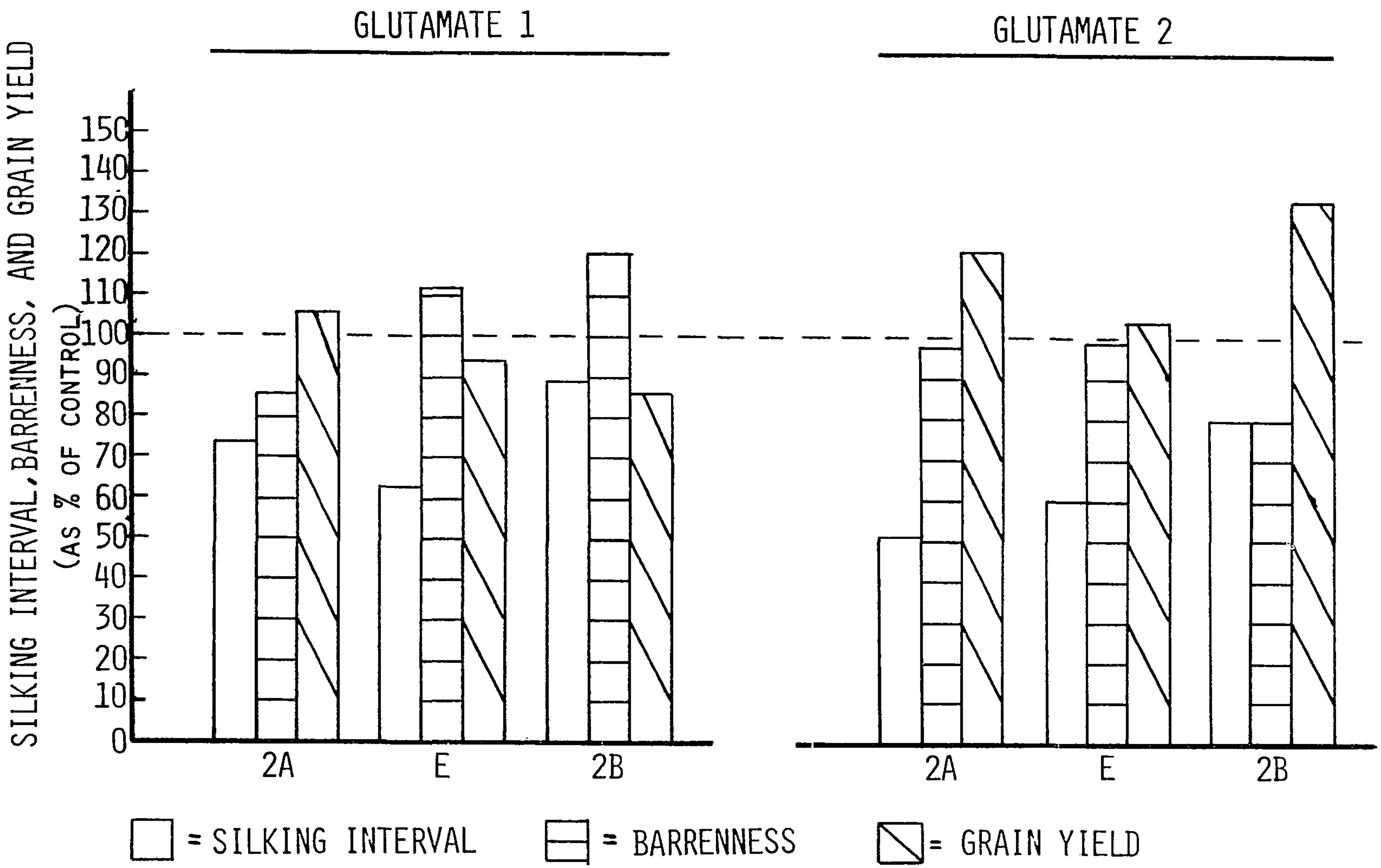

GLUTAMATE 1
GLUTAMATE 2
SILKING INTERVAL, BARRENNESS, AND GRAIN YIELD
(AS % OF CONTROL)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
2A
E
2B
2A
E
2B
= SILKING INTERVAL
= BARRENNESS
= GRAIN YIELD

Figure 14. Silking interval, barrenness, and grain yield expressed as a percent of the control when the second leaf above the ear leaf (2A), the ear leaf (E), or the second leaf below the ear leaf (2B) were treated with sucrose or glutamate plus sucrose for Experiment 8

DL-11

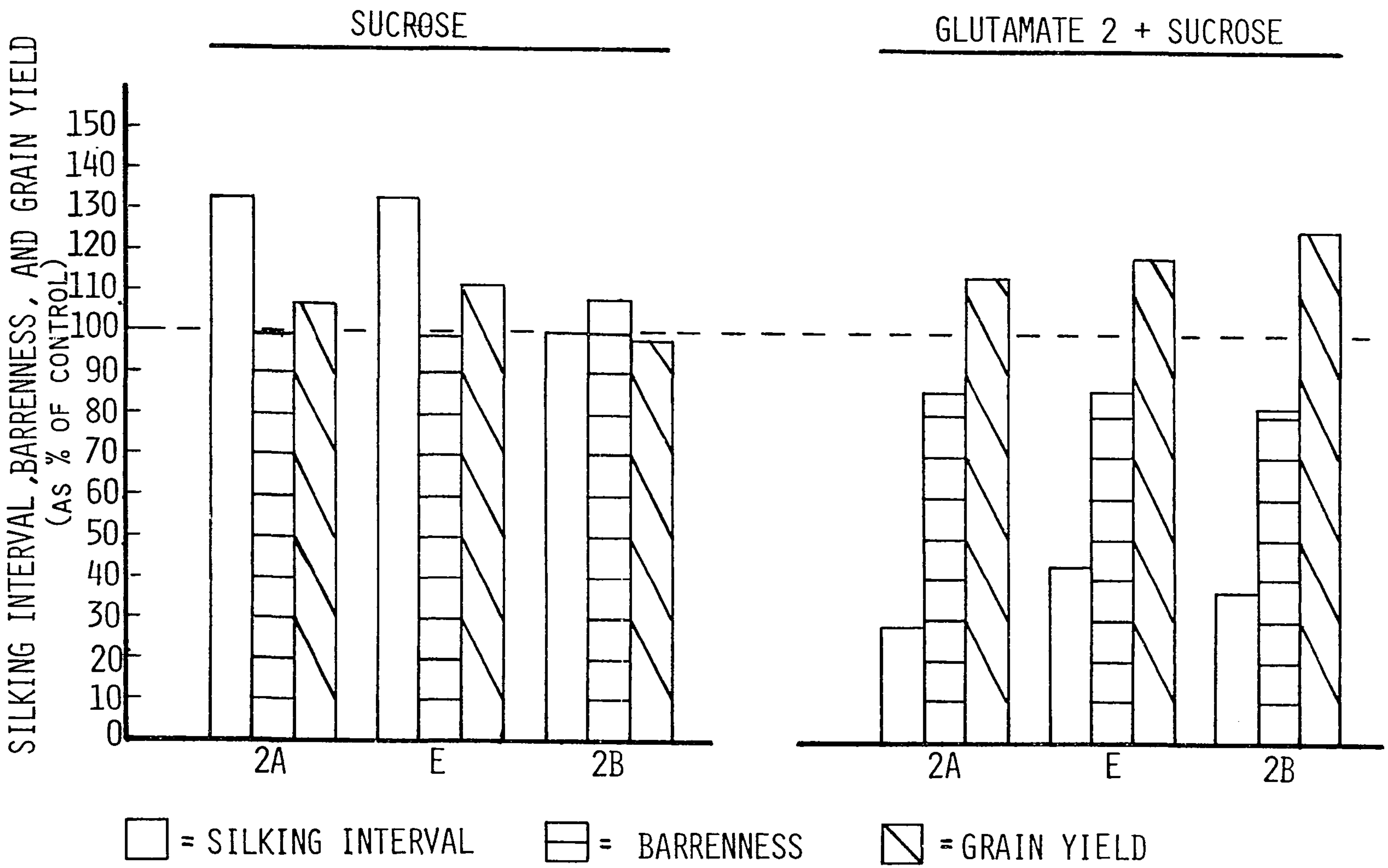

SUCROSE
GLUTAMATE 2 + SUCROSE
SILKING INTERVAL, BARRENNESS, AND GRAIN YIELD
(AS % OF CONTROL)
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
2A
E
2B
2A
E
2B
= SILKING INTERVAL
= BARRENNESS
= GRAIN YIELD

Table 34. The 50% silking dates of DL-11 as affected by treatments applied at various positions on the plant for Experiment 8

Chemical[a]	Position of Treatment[b]			
	2A	E	2B	C
Gl-1	78.3[c]	77.7	79.7	81.2
Gl-2	77.7	79.8	76.7	83.2
Suc	80.0	79.3	78.3	76.8
Gl-2 + Suc	76.3	78.5	78.2	84.5
Mean[d]	78.1a	78.8a	78.2a	81.4b

[a]Chemicals used were glutamate (Gl) at two rates (1 and 2), sucrose (Suc), and a combination of glutamate 2 and sucrose (Gl-2 + Suc).

[b]Positions of treatment were the second leaf above the ear leaf (2A), the ear leaf (E), the second leaf below the ear leaf (2B), and a control (C).

[c]Silking dates (50%) were reported in days after planting.

[d]Means followed by same letter were not significantly different at the 0.05 level.

production.

Noticeable differences in barrenness resulted from the various chemical treatments and positions of treatment (Table 36 and Figures 13 and 14).

As with XL-45, Gl-1 applied to the 2A leaf position reduced the percent barrenness while no reduction was evident for the other treatment positions when compared to the control. It may be noted that this control was slightly lower than the other controls. Gl-2 applied at all leaf positions reduced the percent barrenness (1% to 20%). Suc had little effect on barrenness except when applied at the 2B leaf position where an 8% increase in barrenness over the control was noted. The chemical treatment with

Table 35. Silking intervals (15% to 50% silking) of DL-11 as affected by treatments applied at various positions on the plant for Experiment 8

Chemical[a]	Position of Treatment[b]			
	2A	E	2B	C
Gl-1	4.3[c]	3.7	5.2	5.9
GL-2	4.5	5.3	2.7	8.9
Suc	6.0	6.0	4.5	4.5
Gl-2 + Suc	3.0	4.5	3.9	10.5
Mean[d]	4.5a	4.9a	4.1a	7.5b

[a]Chemicals used were glutamate (Gl) at two rates (1 and 2), sucrose (Suc), and a combination of glutamate 2 and sucrose (Gl-2 + Suc).

[b]Positions of treatment were the second leaf above the ear leaf (2A), the ear leaf (E), the second leaf below the ear leaf (2B), and a control (C).

[c]Days between 15% and 50% silking.

[d]Means followed by same letter were not significantly different at the 0.05 level.

Gl-2 + Suc may be noted to have decreased the barrenness when applied to any leaf position. However, the control was somewhat higher than the other controls. If this control had been of similar magnitude to the other controls, very little difference between the control and the three leaf treatment positions would have been evident.

Gl-1 applied at the E leaf position and Gl-2 applied at the 2B leaf position were associated with small increases in the grams of grain produced per plant. Suc sprayed onto the 2A and E leaf positions and Gl-2 + Suc applied to the E and 2B leaf positions also resulted in slight increases in

Table 36. Yield responses of DL-11 when planted at one population as affected by the application of glutamate, sucrose, and a combination of the two compounds for Experiment 8

Hybrid	Chemical[a]	Position of trtmnt.[b]	No. of nubbins/ plot	No. of ears /plot	Barren %	Barren as % of control	Grams grain/ plant	Grain yield (bu/ac.)	Grain yield as % contr.
DL-11	Gl-1	2A	0.33	16.3	43.2	86	15.1	92	106
		E	0.33	13.3	56.4	112	16.1	82	94
		2B	1.00	13.3	60.7	121	15.1	75	86
		C	0.33	15.3	50.3	100	15.0	87	100
	Gl-2	2A	0.33	15.0	55.6	98	15.3	84	121
		E	0.67	13.0	56.3	99	15.2	73	104
		2B	0.33	15.3	45.6	80	16.3	93	134
		C	0.33	12.3	56.9	100	15.0	70	100
	Suc	2A	0.67	13.7	54.3	100	16.3	81	107
		E	0.33	14.0	54.1	99	16.6	85	111
		2B	0.00	13.3	58.8	108	15.1	74	98
		C	1.00	13.3	54.5	100	15.3	76	100
	GL-2 + Suc	2A	0.33	14.0	53.7	86	15.2	78	114
		E	0.00	14.0	53.7	86	15.8	82	119
		2B	0.33	14.3	50.9	82	16.4	87	125
		C	0.67	12.0	62.3	100	15.5	69	100

[a]Chemicals used were glutamate (Gl) at two rates (1 and 2), sucrose (Suc), and a combination of glutamate 2 and sucrose (Gl-2 + Suc).

[b]Positions of treatment were the second leaf above the ear leaf (2A), the ear leaf (E), the second leaf below the ear leaf (2B), and a control (C).

the grams of grain produced per plant.

The grain yield per acre was boosted somewhat (five bushels per acre) with the addition of Gl-1 to the 2A leaf. This treatment chemical and position of treatment also caused the same effect for XL-45. The other two treatment positions of Gl-1 were not associated with yield increases in comparison with the control. Gl-2 applied at the three leaf positions were associated with yield increases of from 4% to 34% over the control. Slight yield increases (7% to 11%) were associated with the Suc treatment applied at the 2A and E leaf positions, respectively, but a 2% decrease was evident when the treatment was applied at the 2B leaf position. All treatment positions of the Gl-2 + Suc chemical treatment resulted in yield increases. These yield increases ranged from 14% to 25%. However, this control was slightly lower than the other controls; therefore, the increases were probably not this large (also note Figures 13 and 14).

Experiment 9

For Experiment 9 the commercial variety of XL-45 was used. The experiment was over-planted and thinned to 40,000 plants per acre. The treatments imposed upon the plots were leaf removal at 1 week before anthesis (LR 1), leaf removal at 0 weeks before anthesis (LR 0), leaf removal and the application of aluminum foil at 1 week before anthesis (LR + Al foil 1), leaf removal and the application of aluminum foil at 0 weeks before anthesis (LR + Al foil 0), application of aluminum foil at 1 week before anthesis (Al foil 1), and application of aluminum foil at 0 weeks before anthesis (Al foil 0). The above mentioned treatments were imposed at different leaf positions on the plant. When a leaf was removed it was the second leaf above the ear leaf (2A), the ear leaf (E), or the second leaf below the ear leaf (2B). When aluminum foil was applied to the plant it was wrapped around the stalk from the 2A, E, or 2B leaf to the tassel. A control (C) also was included in each treatment.

Various plant responses to the treatments were studied. These variables were the silking dates (25%, 50%, and 75%), the silking intervals

(25% to 75% silking), the number of ears and nubbins per plot, the percent barrenness, the grams of grain per plant (only for those plants having ears), and the yield per acre. These mean plant responses may be noted in Tables 37 and 38 and the analyses of variance are in Table 39.

The effects of leaf removal at 1 and 0 weeks before anthesis on the silking dates and intervals may be noted in Table 37. Regardless of whether the 2A, E, or 2B leaf was removed the plants all reached 25% silking within 0.4 days of each other for the LR 1 treatment and within 0.3 days of each other for the LR 0 treatment. By the time of 75% silking, a somewhat larger differential could be noted. Within the LR 1 and LR 0 treatments the position of treatment was responsible for a 2.1 and 2.6 day differential in the 75% silking dates, respectively. The rate of silking may be observed by noting the silking intervals (25% to 75% silking) in Table 37. For the LR 1 treatment it may be noted that the smallest silking interval was exhibited by the removal of the 2B leaf (4.2 days). This was the only treatment position having a shorter silking interval than the control (4.4 days). Removal of the 2A or E leaf tended to prolong the silking interval (also note column headed silking interval as a percent of control and Figure 15). The silking interval of the LR 0 treatment again showed that removal of the 2B leaf slightly hastened the silking process, whereas, removal of the 2A or E leaf prolonged the silking interval.

The treatments of LR + Al foil 1 and LR + Al foil 0 did not have much of a differential effect on the time to 25% silking. By the time of 75% silking a differential was more evident. For these two treatments, all positions of treatment caused a reduction in the silking rate (longer silking interval) except one. Treatment (LR + Al foil 1) of the E leaf caused

Table 37. Silking dates and intervals of XL-45 as affected by leaf removal, application of aluminum foil, and a combination of the two at two different dates for Experiment 9

Hybrid	Treatment[a]		Position of treatment[b]	Silking %[c] 25	50	75	Silking interval[d]	Silking interval as % of control
XL-45	1 wk. before anthesis	LR	2A	73.2	75.7	79.3	6.1	142
			E	72.8	75.5	79.2	6.4	146
			2B	73.0	74.7	77.2	4.2	96
			C	72.8	74.5	77.2	4.4	100
		LR + Al foil	2A	73.0	76.2	80.0	7.0	114
			E	73.2	75.3	78.7	5.5	89
			2B	73.8	77.8	82.5	8.7	141
			C	73.3	75.8	79.5	6.2	100
		Al foil	2A	72.7	75.2	78.7	6.0	144
			E	73.7	76.5	79.7	6.0	144
			2B	74.0	76.2	79.3	5.3	128
			C	73.0	74.7	77.2	4.2	100
	0 wk. before anthesis	LR	2A	73.3	77.0	81.3	8.0	146
			E	73.2	76.7	81.0	7.8	142
			2B	73.5	75.5	78.7	5.2	94
			C	73.2	75.3	78.7	5.5	100
		LR + Al foil	2A	72.5	75.5	79.5	7.0	156
			E	72.5	75.2	78.3	5.8	130
			2B	74.0	76.8	81.0	7.0	156
			C	73.5	75.2	78.0	4.5	100
		Al foil	2A	73.0	75.2	78.3	5.3	119
			E	73.0	74.8	77.7	4.7	104
			2B	73.0	75.5	79.0	6.0	133
			C	73.2	75.0	77.7	4.5	100

[a]Treatments included leaf removal at 1 and 0 weeks before anthesis (LR 1 and LR 0), leaf removal and application of aluminum foil at 1 and 0 weeks before anthesis (LR + Al foil 1 and LR + Al foil 0), and application of aluminum foil only at 1 and 0 weeks before anthesis (Al foil 1 and Al foil 0).

[b]Positions of treatment were the second leaf above ear leaf (2A), the ear leaf (E), the second leaf below ear leaf (2B), and a control (C).

[c]Days from planting to respective percent silking.

[d]Silking interval in days between 25% and 75% silking.

Table 38. Yield characteristics of XL-45 as affected by leaf removal, application of aluminum foil, and a combination of the two at two different dates for Experiment 9

Hybrid	Treatment[a]		Position of treatment[b]	No. of nubbins /plot	No. of ears /plot	Barren %	Barren as % of control	Grams of grain/ plant	Grain yield (bu/ac.)	Grain yield as % of control
XL-45	1 wk. before anthesis	LR	2A	0.67	25.0	25.2	115	11.9	111	85
			E	0.33	23.0	26.6	122	12.9	110	85
			2B	1.00	27.7	16.8	77	13.5	138	106
			C	1.00	25.0	21.9	100	14.0	130	100
		LR + Al foil	2A	3.00	23.7	31.8	170	11.7	103	76
			E	2.33	23.0	31.4	168	13.4	113	84
			2B	2.67	22.7	30.6	164	11.6	95	70
			C	0.67	27.7	18.7	100	13.2	135	100
		Al foil	2A	1.33	22.7	29.3	115	14.2	117	97
			E	3.00	23.3	31.1	122	12.7	109	90
			2B	1.33	25.3	24.1	95	12.5	118	98
			C	1.33	24.3	25.5	100	13.3	121	100
	0 wk. before anthesis	LR	2A	0.33	24.7	28.3	115	12.0	106	80
			E	1.33	26.7	25.0	137	12.7	125	94
			2B	0.67	23.7	24.5	134	12.6	111	84
			C	0.00	26.3	18.2	100	13.5	132	100
		LR + Al foil	2A	0.00	23.0	32.9	175	11.9	102	79
			E	0.33	23.7	25.7	136	12.5	107	82
			2B	1.33	22.3	31.7	168	14.6	120	92
			C	1.00	26.0	18.8	100	13.7	130	100
		Al foil	2A	1.33	25.3	29.3	134	12.7	119	92
			E	1.67	24.7	27.9	127	12.7	114	88
			2B	1.67	23.0	28.1	129	13.3	114	88
			C	1.67	26.3	21.9	100	13.2	129	100

[a]Treatments included leaf removal at 1 and 0 weeks before anthesis (LR 1 and LR 0), leaf removal and application of aluminum foil at 1 and 0 weeks before anthesis (LR + Al foil 1 and LR + Al foil 0), and application of aluminum foil only at 1 and 0 weeks before anthesis (Al foil 1 and Al foil 0).

[b]Positions of treatment were the second leaf above ear leaf (2A), the ear leaf (E), the second leaf below ear leaf (2B), and a control (C).

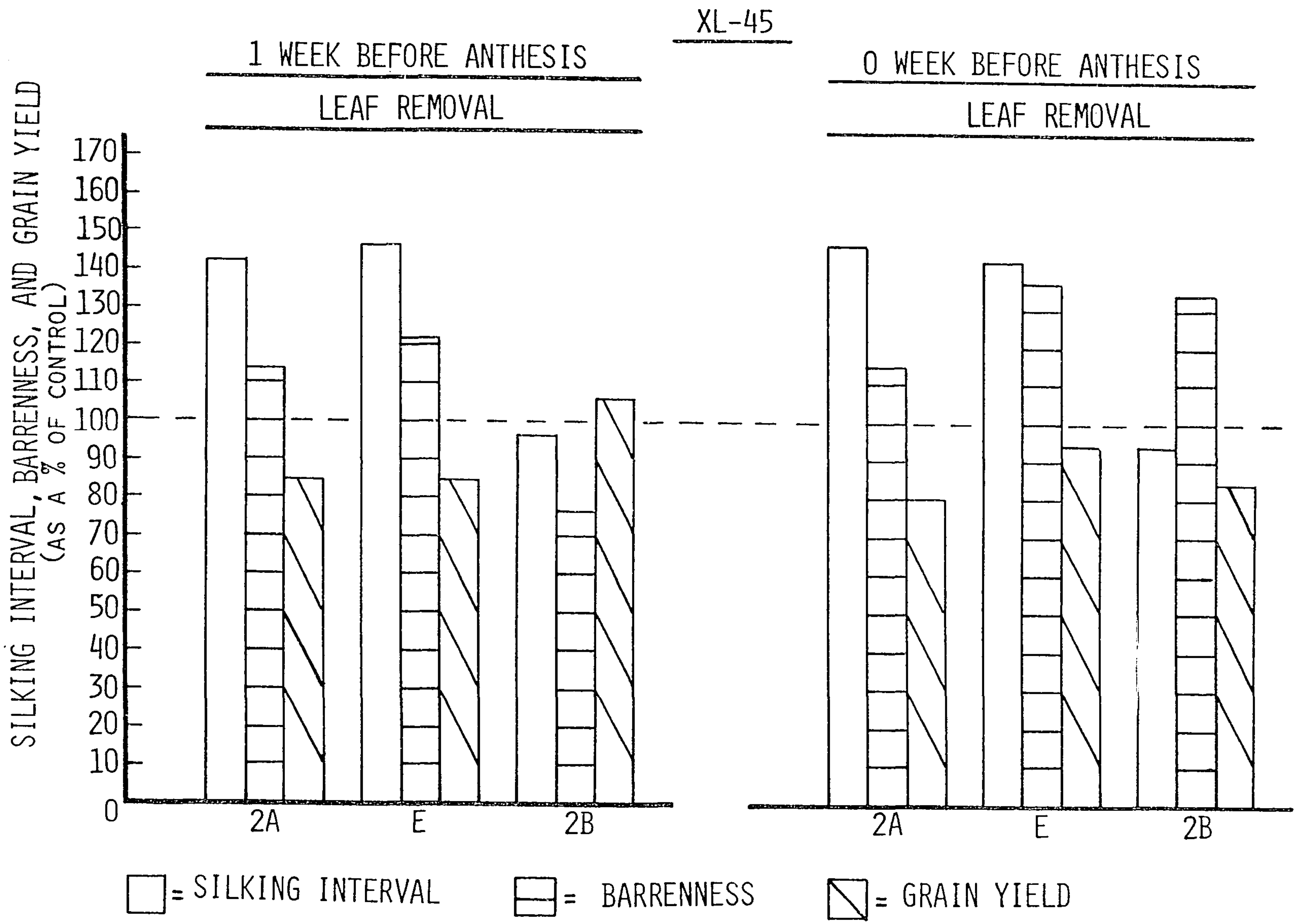
Table 39. Plant characteristics and their associated mean squares for XL-45 at 40,000 plants per acre due to leaf removal, aluminum foil application, and a combination of the two at two different dates for Experiment 9

Hybrid	Source	d.f.	Grams grain/ plant	Grain yield (bu/ac)	Barren %	No. of ears/ plot	No. of nubbins /plot	15% silking date	25% silking date	50% silking date	75% silking date	Silking interval
XL-45	Blocks	2	1.52	1054*	239	25.5	0.54	1.385	0.941	1.274	6.573	7.26
	Treatment (T)	5	0.90	166	58	5.3	5.37*	0.242	0.314	2.964	8.706	6.55
	Error (a)	10	1.79	202	120	6.9	1.31	0.915	1.308	2.833	5.948	2.38
	Position (P)	3	3.52*	1368**	255	15.8	1.28	1.621	1.273	3.153*	9.531*	9.51*
	T x P	15	1.76	259	33	7.0	1.30	0.429	0.418	1.558	3.945	2.95
	Error (b)	36	1.00	236	91	9.4	1.14	0.725	0.459	0.939	2.626	2.48

*Statistically significant at the 0.05 level of probability.

**Statistically significant at the 0.01 level of probability.

Figure 15. Silking interval, barrenness, and grain yield expressed as a percent of the control when the second leaf above the ear leaf (2A), the ear leaf (E), or the second leaf below the ear leaf (2B) was removed at 1 and 0 weeks before anthesis for Experiment 10


XL-45
1 WEEK BEFORE ANTHESIS
LEAF REMOVAL
0 WEEK BEFORE ANTHESIS
LEAF REMOVAL
SILKING INTERVAL, BARRENNESS, AND GRAIN YIELD
(AS A % OF CONTROL)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
2A
E
2B
2A
E
2B
= SILKING INTERVAL
= BARRENNESS
= GRAIN YIELD

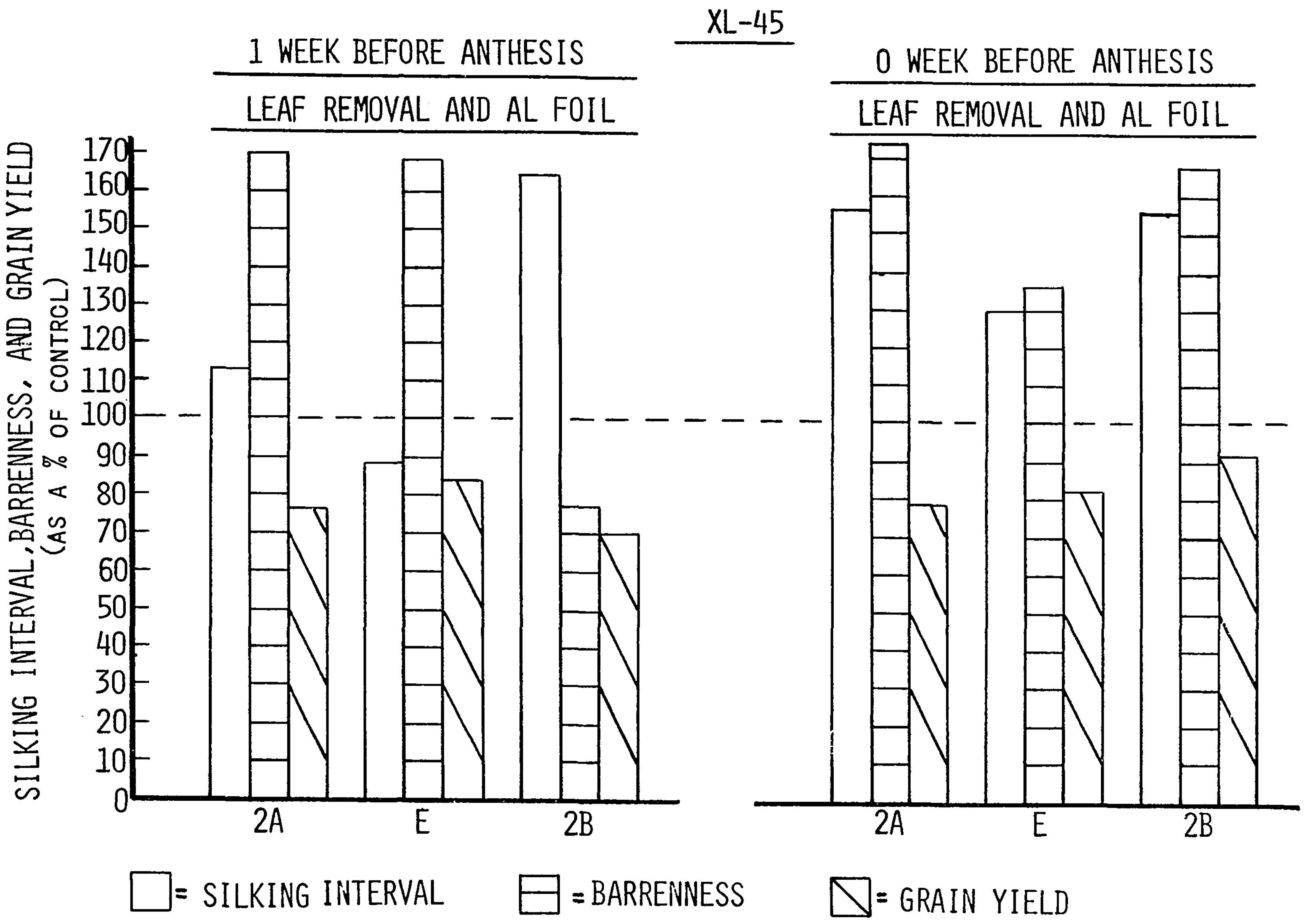
a faster silking rate in comparison with the control, but it may be noted that this control was somewhat higher than the other control plots. The LR + Al foil 0 treatment applied at all positions of treatment caused an increase in the silking intervals (Table 37 and Figure 16). This increase ranged from 1.3 to 2.5 days when compared to the control.

The Al foil 1 and Al foil 0 treatments at all positions of treatment yielded similar results to the LR + Al foil 1 and LR + Al foil 0 treatments. Within the Al foil 1 treatment a 1.3 day differential between the 25% silking dates was noted for the different positions of treatment. In the Al foil 0 treatment a 0.2 day differential was observed for the different positions of treatment. By the time the plots had reached 75% silking a 2.5 day and 1.3 day variation was noted within the Al foil 1 and Al foil 0 treatments, respectively, due to the different positions of treatment. The silking intervals indicated that these treatments (Al foil 1 and Al foil 0) applied at all positions of treatment caused a delay in the silking rate (Table 37 and Figure 17).

Table 39 contains the analyses of variance for the various variables. It may be noted that the 50% and 75% silking dates as well as the silking intervals were significant at the 0.05 level of probability for position of treatment (2A, E, 2B, or C). Table 40 shows the means of the various positions of treatment when averaged across all treatments. Mean 1 indicates the means of all the treatments that were imposed at 1 week before anthesis for each leaf position. Mean 0 is the mean for all treatments imposed at 0 weeks before anthesis and mean 1 + 0 is the mean of all treatments for each leaf position of treatment.

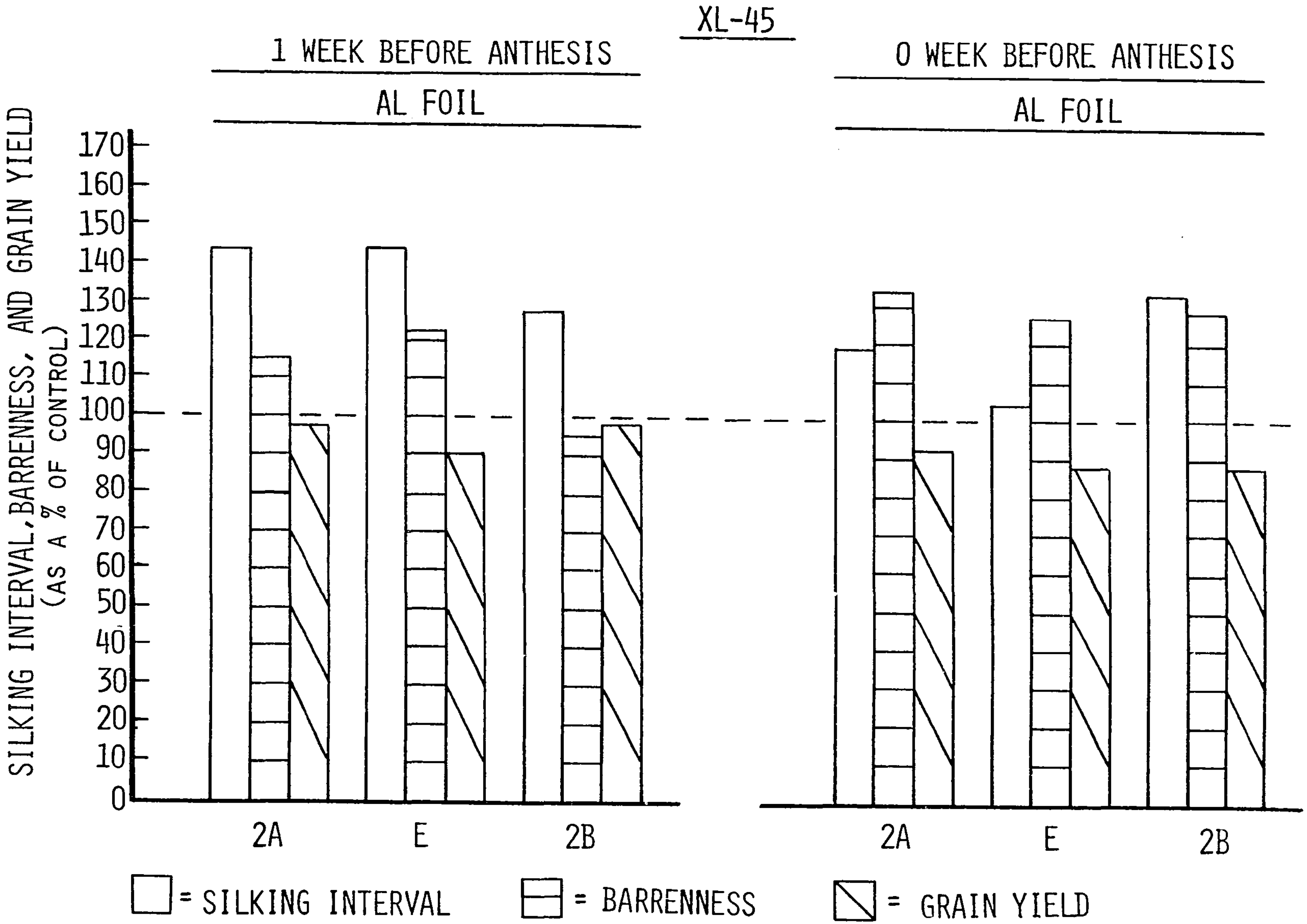
When averaged across all treatments (mean of 1 + 0), the control plots

Figure 16. Silking interval, barrenness, and grain yield expressed as a percent of the control when the second leaf above the ear leaf (2A), the ear leaf (E), or the second leaf below the ear leaf (2B) was removed and aluminum foil (Al foil) was applied to the stalk from the removed leaf to the tassel at 1 and 0 weeks before anthesis for Experiment 9



XL-45
1 WEEK BEFORE ANTHESIS
LEAF REMOVAL AND AL FOIL
0 WEEK BEFORE ANTHESIS
LEAF REMOVAL AND AL FOIL
SILKING INTERVAL, BARRENNESS, AND GRAIN YIELD
(AS A % OF CONTROL)
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
2A
E
2B
2A
E
2B
= SILKING INTERVAL
= BARRENNESS
= GRAIN YIELD

Figure 17. Silking interval, barrenness, and grain yield expressed as a percent of the control when aluminum foil (Al foil) was applied to the stalk from the second leaf above the ear leaf (2A), the ear leaf (E), or the second leaf below the ear leaf (2B) to the tassel at 1 and 0 weeks before anthesis for Experiment 9



XL-45
1 WEEK BEFORE ANTHESIS
AL FOIL
0 WEEK BEFORE ANTHESIS
AL FOIL
SILKING INTERVAL, BARRENNESS, AND GRAIN YIELD
(AS A % OF CONTROL)
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
2A
E
2B
2A
E
2B
= SILKING INTERVAL
= BARRENNESS
= GRAIN YIELD

Table 40. The 50% silking dates of XL-45 as affected by treatments applied at various positions on the plant for Experiment 9

Treatment[a]	Position of Treatment[b]			
	2A	E	2B	C
LR 1	75.7[c]	75.5	74.7	74.5
LR 0	77.0	76.7	75.5	75.3
LR + Al foil 1	76.2	75.3	77.8	75.8
LR + Al foil 0	75.5	75.2	76.8	75.2
Al foil 1	75.2	76.5	76.2	74.7
Al foil 0	75.2	74.8	75.5	75.0
Mean 1	75.7	75.8	76.2	75.0
Mean 0	75.9	75.5	75.9	75.2
Mean 1 + 0[d]	75.8a	75.7a	76.1a	75.1b

[a]Treatments were leaf removal at 1 and 0 weeks before anthesis (LR 1 and LR 0), leaf removal and the application of aluminum foil at 1 and 0 weeks before anthesis (LR + Al foil 1 and LR + Al foil 0), and application of aluminum foil at 1 and 0 weeks before anthesis (Al foil 1 and Al foil 0).

[b]Positions of treatment were the second leaf above the ear leaf (2A), the ear leaf (E), the second leaf below the ear leaf (2B), and a control (C).

[c]Days from planting to 50% silking.

[d]Means followed by same letter were not significantly different at the 0.05 level.

reached 50% silking the fastest and this was significant at the 0.05 level (Table 40). It may be noted that the imposition of any treatment to the 2A or E leaf caused somewhat of a delay in the 50% silking date when compared to the control, but not much of a difference was observed when compared to each other. Treatment of the 2B leaf caused the greatest delay (one day) in reaching 50% silking.

The same trend was evident at the 75% silking dates (Table 41) in which the control reached this silking level the earliest. Any treatment applied to the E, 2A, or 2B leaf caused a statistically significant delay in 75% silking and the increase was in this order of from least to most.

A somewhat different pattern was noted for the silking intervals due to variation in the 25% and 75% silking dates (Table 42). By noting the mean of 1 + 0 for each of the positions of treatment, it may be noted that the control plots had a statistically significant faster silking rate. Treatment of the E or 2B leaf caused a considerable delay (1.2 days) in the silking process when compared to the control, but these two positions of treatment were not different from each other. Treatment of the 2A leaf caused the greatest delay (1.7 days) in the silking rate.

It may be noted from Tables 40, 41, and 42 that generally the same trends existed for the treatments imposed at 1 and 0 weeks before anthesis as was the case for the combined 1 + 0 treatment times.

The yield data for XL-45 may be noted in Table 38. This included the number of nubbins and ears per plot, the percent barrenness, the grams of grain per plant, and the grain yield.

LR 1 and LR 0 did have a small effect on the number of nubbins produced per plot. The treatment, LR 1, when applied to the 2A or E leaf position caused a slight reduction in the number of nubbins per plot. There appeared to be an increase in the nubbins produced per plot due to the LR 0 treatment applied at all treatment positions when compared to the control, but the control produced no nubbins. This appears to be too low in comparison with the other controls. However, there was no more than 1.33 nubbins difference

Table 41. The 75% silking dates of XL-45 as affected by treatments applied at various positions on the plant for Experiment 9

Treatment[a]	Position of Treatment[b]			
	2A	E	2B	C
LR 1	79.3[c]	79.2	77.2	77.2
LR 0	81.3	81.0	78.7	78.7
LR + Al foil 1	80.0	78.7	82.5	79.5
LR + Al foil 0	79.5	78.3	81.0	78.0
Al foil 1	78.7	79.7	79.3	77.2
Al foil 0	78.3	77.7	79.0	77.7
Mean 1	79.3	79.2	79.7	78.0
Mean 0	79.7	79.0	79.6	78.1
Mean 1 + 0[d]	79.5a	79.1a	79.7a	78.1b

[a]Treatments were leaf removal at 1 and 0 weeks before anthesis (LR 1 and LR 0), leaf removal and the application of aluminum foil at 1 and 0 weeks before anthesis (LR + Al foil 1 and LR + Al foil 0), and application of aluminum foil at 1 and 0 weeks before anthesis (Al foil 1 and Al foil 0).

[b]Positions of treatment were the second leaf above the ear leaf (2A), the ear leaf (E), the second leaf below the ear leaf (2B), and a control (C).

[c]Days from planting to 75% silking.

[d]Means followed by same letter were not significantly different at the 0.05 level.

between the various positions of treatment for these two treatments. LR + Al foil 1 and LR + Al foil 0 treatments did cause more variation in the number of nubbins produced. This was especially true for the LR + Al foil 1 treatment. The LR + Al foil 1 treatment caused an increase in the number of nubbins produced. When compared to the control, the application of this

Table 42. The silking intervals of XL-45 as affected by treatments applied at various positions on the plant for Experiment 9

Treatment[a]	Position of Treatment[b]			
	2A	E	2B	C
LR 1	6.1[c]	6.4	4.2	4.4
LR 0	8.0	7.8	5.2	5.5
LR + Al foil 1	7.0	5.5	8.7	6.2
LR + Al foil 0	7.0	5.8	7.0	4.5
Al foil 1	6.0	6.0	5.3	4.2
Al foil 0	5.3	4.7	6.0	4.5
Mean 1	6.4	6.0	6.1	4.9
Mean 0	6.8	6.1	6.1	4.8
Mean 1 + 0[d]	6.6a	6.1a	6.1a	4.9b

[a]Treatments were leaf removal at 1 and 0 weeks before anthesis (LR 1 and LR 0), leaf removal and the application of aluminum foil at 1 and 0 weeks before anthesis (LR + Al foil 1 and LR + Al foil 0), and application of aluminum foil at 1 and 0 weeks before anthesis (Al foil 1 and Al foil 0).

[b]Positions of treatment were the second leaf above the ear leaf (2A), the ear leaf (E), the second leaf below the ear leaf (2B), and a control (C).

[c]Days between 25% and 75% silking.

[d]Means followed by same letter were not significantly different at the 0.05 level.

treatment to the 2A leaf position caused a 2.33 nubbin increase per plot while treatment of the E or 2B leaf position caused a 1.67 and 2.00 nubbin increase per plot, respectively. The LR + Al foil 0 treatment did not cause much of a change in the nubbin production. The Al foil 1 treatment also had some effect on the nubbin production. The application of the treatment to the E leaf position caused an increase of 1.67 nubbins per plot over the control, but the other positions of treatment had no effect. Little effect on nubbin production was noted due to the Al foil 0 treatment.

LR 1 did not cause much variation in the number of ears produced per plot except that maybe a slight increase might have been noted when the 2B leaf was removed. This was associated with an increase of 2.7 ears per plot over the control. The LR 0 treatment, at any treatment position, was not noted to have caused much of an increase in this variable. LR + Al foil 1 at all treatment positions caused a 4.0 to 5.0 ear per plot reduction when compared to the control and the LR + Al foil 0 treatment caused a 2.3 to 3.7 ear reduction. Al foil 1 at the various positions of treatment caused some variable results. In comparison with the control the Al foil 1 treatment applied at the 2B leaf caused a slight (one ear) increase in ear production, but the control seems to be somewhat lower than the other controls. The Al foil 0 treatment applied at all positions of treatment was noted to reduce slightly (1.1 to 3.3 ears) the number of ears produced per plot in comparison with the control.

Barrenness was the next variable studied. It may be noted from Table 38 the the LR 1 treatment when applied to the 2B leaf position caused a reduction (23%) in barrenness when compared to the control (also note column where barrenness was expressed as a percent of the control). The LR 0 treatment tended to increase barrenness at all positions of treatment (15 to 37%). These results may be seen graphically in Figure 15. The LR + Al foil 1 and LR + Al foil 0 treatments both caused an increase in barrenness at all positions of treatment and this increase ranged from 36% to 75% (Figure 16). The Al foil 1 and Al foil 0 treatments also increased the barrenness in all cases except one when compared with the control. The exception was the Al foil 1 treatment when applied to the 2B leaf position. Again, it may be noted here that this control was considerably higher than the other controls; therefore, such a trend probably did not exist (Figure 17).

It generally appears that the treatments causing the least increase in barrenness were the LR 1 and LR 0 treatments. The LR + Al foil 1 and LR + Al foil 0 treatments caused the most barrenness with the Al foil 1 and Al foil 0 treatments being intermediate.

Grams of grain per plant was reduced slightly from the control when the LR 1 and LR 0 treatments were imposed at any treatment position. The LR + Al foil 1, LR + Al foil 0, Al foil 1, and Al foil 0 treatments all showed little variation in the grams of grain per plant and no perceptable trends were obvious.

The last character studied was grain yield. The LR 1 and LR 0 treatments imposed at all treatment positions caused a reduction in the grain yield with the exception of one. LR 1 of the 2B leaf showed an eight bushel per acre (6%) yield increase over the control (Table 38 and Figure 15). All of the other treatment positions were noted to have lower yields than their respective controls. The greatest yield reductions were associated with the LR + Al foil 1 and LR + Al foil 0 treatments and the least yield reductions were in conjunction with the LR 1 and LR 0 treatments. Intermediate were the Al foil 1 and Al foil 0 treatments (Figures 16 and 17).

In Table 39 it may be noted that the position of the treatments was statistically significant for grams of grain per plant and highly significant for the grain yield. Blocks also were significant for the grain yield variable. Treatments significantly affected the number of nubbins per plot.

Table 43 contains data and means for the variable of grams of grain per plant as affected by position of treatment. When averaged across all treatments (mean 1 + 0), it may be noted that all positions of treatment reduced the number of grams of grain per plant when compared with the control by 0.5 to 1.1 grams. Treatments applied to the 2B leaf position reduced this variable the least. The grams of grain per plant was reduced the most by treatments applied to position the 2A leaf position with treatments to the E leaf position being intermediate. Treatments to the 2A leaf were the only ones that significantly reduced this variable. In most cases the actual differences were small.

The effect of position of treatment on grain yield also was interesting (Table 44). The highest yielding plots were the controls which yielded significantly more than the other positions of treatment. When the treatments were applied to the 2B leaf position the yields were reduced by 14 bushels per acre (11%). Treatments applied to the E or 2A leaf position caused a 17 (13%) and 20 (15%) bushel per acre yield loss, respectively, when compared to the control. These same general trends were evident when the treatments were applied at 1 or 0 weeks before anthesis.

The number of nubbins per plot was significantly affected by treatments. This data with the means may be noted in Table 45. The LR 0 treatment was associated with the highest number of nubbins per plot. The number of nubbins per plot ranged from a high of 2.17 (LR 0) to a low of 0.58 for the LR + Al foil 0 treatment.

For the characters that were significantly affected by either treatments or positions of treatments, the significance between such sources may be observed on the respective tables containing the means.

Table 43. Grams of grain per plant of XL-45 as affected by treatments applied at various positions on the plant for Experiment 9

Treatment[a]	Position of Treatment[b]			
	2A	E	2B	C
LR 1	11.9[c]	12.9	13.5	14.0
LR 0	12.0	12.7	12.6	13.5
LR + Al foil 1	11.7	13.4	11.6	13.2
LR + Al foil 0	11.9	12.5	14.6	13.7
Al foil 1	14.2	12.7	12.5	13.3
Al foil 0	12.7	12.7	13.3	13.2
Mean 1	12.6	13.0	12.5	13.5
Mean 0	12.2	12.6	13.5	13.5
Mean 1 + 0[d]	12.4a	12.8b	13.0b	13.5b

[a]Treatments were leaf removal at 1 and 0 weeks before anthesis (LR 1 and LR 0), leaf removal and the application of aluminum foil at 1 and 0 weeks before anthesis (LR + Al foil 1 and LR + Al foil 0), and application of aluminum foil at 1 and 0 weeks before anthesis (Al foil 1 and Al foil 0).

[b]Positions of treatment were the second leaf above the ear leaf (2A), the ear leaf (E) the second leaf below the ear leaf (2B), and a control (C).

[c]Grams of grain per plant for those plants having an ear.

[d]Means followed by same letter were not significantly different at the 0.05 level.

Table 44. The yield of XL-45 as affected by treatments applied at various positions on the plant for Experiment 9

Treatment[a]	Position of Treatment[b]			
	2A	E	2B	C
LR 1	111[c]	110	138	130
LR 0	106	125	111	132
LR + Al foil 1	103	113	95	135
LR + Al foil 0	102	107	120	130
Al foil 1	117	109	118	121
Al foil 0	119	114	114	129
Mean 1	110	111	117	129
Mean 0	109	115	115	130
Mean 1 + 0[d]	110a	113a	116a	130b

[a]Treatments were leaf removal at 1 and 0 weeks before anthesis (LR 1 and LR 0), leaf removal and the application of aluminum foil at 1 and 0 weeks before anthesis (LR + Al foil 1 and LR + Al foil 0), and application of aluminum foil at 1 and 0 weeks before anthesis (Al foil 1 and Al foil 0).

[b]Positions of treatment were the second leaf above the ear leaf (2A), the ear leaf (E), the second leaf below the ear leaf (2B), and a control (C).

[c]Grain yield in bushels per acre.

[d]Means followed by same letter were not significantly different at the 0.05 level.

Table 45. The number of nubbins per plot of XL-45 as affected by treatments applied at various positions on the plant for Experiment 9

Treatment[a]	Position of Treatment[b]				Mean[c]
	2A	E	2B	C	
LR 1	0.67[d]	0.33	1.00	1.00	0.75bc
LR 0	3.00	2.33	2.67	0.67	2.17a
LR + Al foil 1	1.33	3.00	1.33	1.33	1.75ab
LR + Al foil 0	0.33	1.33	0.67	0.00	0.58c
Al foil 1	0.00	0.33	1.33	1.00	0.67bc
Al foil 0	1.33	1.67	1.67	1.67	1.58abc
Mean 1	0.67	1.22	1.22	1.11	
Mean 0	1.55	1.78	1.67	0.78	
Mean 1 + 0	1.11	1.50	1.44	0.94	

[a]Treatments were leaf removal at 1 and 0 weeks before anthesis (LR 1 and LR 0) leaf removal and the application of aluminum foil at 1 and 0 weeks before anthesis (LR + Al foil 1 and LR + Al foil 0), and application of aluminum foil at 1 and 0 weeks before anthesis (Al foil 1 and Al foil 0).

[b]Positions of treatment were the second leaf above the ear leaf (2A), the ear leaf (E), the second leaf below the ear leaf (2B), and a control (C).

[c]Means followed by same letter were not significantly different at the 0.05 level.

[d]Number of nubbins per plot.

DISCUSSION

It has been shown by many studies that it is desirable to get light deeper into the canopy because with additional light the lower leaves of the canopy can make a positive contribution to yield. This has been well documented in the literature by various types of studies. Some of these studies have been accomplished by measuring the CO_2 uptake at different canopy levels (Moss and Peaslee, 1965), by removing a particular strata of leaves (Loomis, 1935; Hoyt and Bradfield, 1962; and Pendleton and Hammond, 1969), by shading various portions of the plant (Schmidt and Colville, 1967), by growing alternating tall and short varieties of corn (Pendleton and Seif, 1962), and by light reflection studies (Prine, 1961; and Pendleton et al., 1966). With this being the case, one method of increasing the contribution to photosynthesis of these lower leaves would be to use varieties with upright leaves to allow for better light penetration down into the canopy. Presently there are few varieties that have erect leaves (60^{o}+ from the horizontal). Therefore, not much actual field testing has been done with upright leaved varieties to check this method. About the only study that has been conducted with corn was a study by Pendleton et al. (1968) in which they utilized an isoline of C103 x Hy. One line had erect leaves and the other line had flat leaves. From this study they noted a yield advantage from the line with the erect leaves. They obtained similar results from positioning some of the leaves of 3306 into an upright position. Therefore, it was the purpose of this study to determine if a yield advantage might result from the use of varieties with upright leaves.

The criterion used to determine whether any differences existed between varieties with upright and flat leaves was the plant's ability to produce both dry matter and grain. Experiments 1, 2, and 4a approached the problem from the dry matter aspect and Experiments 3, 4, 5, and 6 approached it from the grain yield approach.

As mentioned previously, due to unequal LAIs between the upright and flat leaved varieties, the dry matter production and dry matter production rate were expressed on a unit LAI basis for Experiment 1. This did standardize the comparisons to a large extent, but some error was probably still existant due to the somewhat unequal LAIs. This problem was not existent for Experiment 2, and therefore, the dry matter production and dry matter production rate were expressed on a per acre basis.

Experiment 1 showed an advantage from using upright versus flat leaved varieties when averaged across all populations and harvest dates. The upright leaved varieties yielded about 75 pounds per LAI (8%) more dry matter than did the flat leaved varieties. However, there was no significant leaf angle by population by harvest date interaction which would have indicated a significant effect of leaf angle as the LAI was varied (due to changes in the population and harvest date). It was noted at the lowest population (14,000 plants per acre), that as the harvest date was advanced a greater advantage was noted to result from the upright leaved varieties. This type of trend would be expected at the later harvest dates when the LAIs would be higher and the chance of mutual shading greater. The LAI at this population (14,000 plants per acre) and harvest date 4 averaged about 2.1 for the upright and flat leaved varieties combined. Therefore, this seems to contrast somewhat with the conclusions of Duncan et al. (1968a) and Loomis et al. (1967). These authors have indicated that the advantage of upright leaved varieties will not be realized until an LAI of approximately 3.5 to 4.0 is attained.

At the higher populations, no consistent results were observed. On the average the upright leaved varieties may have yielded a little better than the flat leaved varieties, but no consistent results or trends were evident. This was somewhat unexpected in accordance with the theory of better light relations within an erect leaved canopy leading to higher yields. Two possible reasons for such unexpected results may be proposed. First, the mid-summer moisture conditions were somewhat unfavorable for corn production by being too dry. This problem would be expected to be accentuated at the higher population levels, thus, placing more of a stress on the plants as moisture became more limiting. It appears that this might have been the case because the results were more as would have been predicted at the lowest population (14,000 plants per acre). But as the population increased, the results became more inconsistent and this possibly was due to moisture instead of light becoming a limiting factor.

Secondly, the differences in leaf angle were not very much different. At comparable populations and harvest dates the leaf angles between the upright and flat leaved varieties only varied by about 3° to 6° which was very little. Also, the most erect leaf angle was only about 63° from the horizontal. According to Loomis et al. (1967), a real advantage of upright leaves will probably not be noted until the leaf angles exceed 65° to 70°.

The dry matter production rate per average unit LAI for Experiment 1 also was somewhat variable. However, the overall analysis of variance showed the upright leaved varieties to have a significantly higher dry matter production rate than did the flat leaved varieties (100 pounds per acre or 16%) when averaged across all populations and harvest date intervals. As was the case with the dry matter production there was no significant leaf angle by population by harvest date interval interaction.

It was noted that the dry matter production rate per average unit LAI at 14,000 plants per acre favored the upright leaved varieties over the flat leaved varieties at the last harvest date interval (3-4) by 45%. This was not the case at the earlier harvest date intervals at this population. At 19,000 plants per acre no yield advantage was noted at harvest date interval 1-2 and 3-4, but an advantage (30%) was noted at harvest date interval 2-3. At the higher populations (37,000 and 68,000 plants per acre) the upright leaved varieties usually yielded more than the flat leaved varieties, but the differential was less as the population was increased. This again possibly points to the fact that some other factor than that of light was becoming limiting at the higher population levels.

The results of Experiment 2 were exactly opposite to what would have been anticipated. First, the flat leaved varieties, when averaged across all populations and harvest dates, yielded more dry matter per acre than did the upright leaved varieties. They yielded an average of 505 pounds per acre (8%) more. It also was noted that at each population, very little difference between the upright and flat leaved varieties existed at the earliest harvest date, but as the harvest date advanced (consequently the LAI, also), an increasing divergence became evident and was in favor of the flat leaved varieties. In fact, a significant leaf angle by harvest date interaction was existant. With the harvest date advancing (also the LAI) from 1 to 4, the upright leaved varieties increased in production by 168% and the flat leaved varieties increased by 188%.

This same general trend was exhibited when the dry matter production rate per acre was studied. Again, there was a significant effect of leaf angle on the dry matter production rate when averaged across all populations and harvest date interval. The flat leaved varieties exhibited a 237 pound per acre (12%) advantage over the upright leaved varieties. It also might be noted that generally as the harvest date interval advanced at each population level, the flat leaved varieties yielded somewhat more. This "trend" was very inconsistent and nowhere approached the trend noted for the dry matter production per acre as these factor levels were changed.

The author is at somewhat of a loss to explain these results. However, from noting the results of Experiments 4 and 4a, some interesting observations may be noted. Experiment 4 consisted of three pairs of which all also were utilized in Experiment 2 for dry matter production. Experiment 4 was harvested for grain yield, whereas, Experiment 4a was a dry matter harvest experiment in which a dry matter sample of one pair from Experiment 4 was taken. The dry matter harvest for Experiment 4a was taken during late September. It might be noted here that the last dry matter harvest date for Experiment 2 was August 13.

For Experiment 4a, the upright leaved varieties yielded slightly more than the flat leaved varieties when averaged across all populations and the fertile:sterile component. The advantage for the upright leaved varieties was about 6% or 0.380 of a ton. When just averaged across the fertile variety only there was a 0.582 ton per acre (9%) advantage. However, it was generally noted for the fertile counterparts that as the population increased the upright leaved varieties yielded more. One notable exception to this was at 39,000 plants per acre where the flat leaved variety yielded slightly more (0.348 tons or 5%). This same trend was somewhat noticeable for the upright and flat leaved counterparts of the sterile and will be discussed in more detail later.

This same general trend of results also was noted for the fertile varieties used for grain yield in Experiment 4. Again, the sterile results will be discussed later. First, leaf angle was significant at the 5% level in favor of the flat leaved varieties when averaged across both the fertile and sterile components and across populations. A four bushel per acre (3%) advantage for such was noted. This was probably due to the highest absolute yield being exhibited by the flat leaved varieties at the lowest population of 13,000 plants per acre. If just the fertile counterparts are considered, the upright leaved varieties yielded five bushels per acre (5%) more than the flat leaved varieties when averaged across all populations. However, at the present time, the important comparison to make is between the upright and flat leaved varieties at comparable populations within the fertile. Here it is important to note that at 13,000 plants per acre the flat leaved varieties yielded about 16 bushels per acre (15%) more than the upright leaved varieties. At 26,000 plants per acre, there was little difference in the yield, but as the population was increased to 52,000 plants per acre, a yield advantage was evident for the upright leaved varieties. A 16 bushel per acre (20%) and a 19 bushel per acre (27%) yield advantage were noted for the upright leaved varieties at 39,000 and 52,000 plants per acre, respectively. Unfortunately, no LAI measurements were taken, but from looking at the LAI values for the corresponding varieties in Experiment 2 at approximately 26,000 plants per acre, the LAI would be estimated to be about 3.5 where the upright leaved varieties began to show an advantage.

This would be in better agreement with the data of Duncan et al. (1968a) and Loomis et al. (1967).

The interesting thing to note here is that very little, if any, yield advantage was noted for the upright leaved varieties when the plants were harvested for dry matter during the summer (prior to August 15). However, when a dry matter harvest was taken in the fall (late September) or when a grain yield harvest was taken, an advantage in yield for the upright leaved varieties was observed at the mid to higher population levels. This being the case, there may be some association between the value of upright leaves and the date of harvest (dry matter or grain yield) for corn. About the main difference between the dry matter harvests during the summer and the dry matter and grain harvests during the fall would be the presence of a strong carbohydrate sink (ear). Therefore, the real value of upright leaves over flat leaves of corn may be during the period of rapid ear filling. This may explain why the fall harvests (dry matter and grain) showed an advantage at the mid and higher population levels over the summer harvests (dry matter) for the upright leaved varieties, i.e., there existed a strong sink for the extra carbohydrates being produced by the upright leaved varieties. By the same reasoning, for the summer dry matter harvests the upright leaved varieties may have had the potential to produce more photosynthate, but due to no strong sink, a feedback type of inhibition may have occurred. This could explain why the upright leaved varieties did not show an advantage over the flat leaved varieties at the higher LAIs, but does not explain why the flat leaved varieties actually did better than the uprights. If this actually were the case, it would be expected that the upright leaved varieties would experience the feedback inhibition sooner.

Once this feedback inhibition occurred, the upright leaved varieties may have been inhibited more than the flat leaved varieties or have been slower in their release from such when a limited sink did become available.

This theory appears to contradict the results of Experiment 1 in which a slight advantage from upright leaved varieties was noted from summer harvests. But if a moisture stress did occur in July and August, perhaps moisture was limiting photosynthesis to such an extent that not enough carbohydrate was being produced by either the upright or flat leaved varieties to cause any type of feedback inhibition. The yield advantage that was generally noted from the upright leaved varieties in Experiment 1 may have resulted from their more efficient utilization of the limited water supply. It has been documented that erect leaves are usually somewhat cooler than flat leaves and therefore, can make more efficient utilization of a limited water supply (Shinn and Lemon, 1968; and Stevenson, 1969).

This theory is not presented as the answer to this question, but merely a suggestion of a possibility.

As mentioned earlier, the fertile and sterile aspect of corn varieties was not a major aspect of this study, but some interesting results were noted in Experiments 4 and 4a. The main effect of fertile:sterile was not significant for Experiment 4a but it was statistically highly significant for Experiment 4 (grain yield experiment). Although non-significant, the sterile did yield 0.247 tons per acre (4%) more dry matter than the fertile in Experiment 4a. For Experiment 4, the sterile yielded 16 bushels per acre (16%) more grain than did the fertile which was significant at the 0.05 level. Both of these were averaged across populations and the upright and flat leaved varieties. In Experiments 4 and 4a a population by fertile:

sterile interaction was significant. This interaction involved both the upright and flat leaved varieties. Experiment 4 showed a 6 (5%), 14 (13%), 24 (27%) and 22 (28%) bushel per acre yield increase as the population was increased from 13,000 to 26,000 to 39,000 to 52,000 plants per acre, respectively, due to the sterile component. The results of Experiment 4a were not so dramatic, but a sterile effect was noted at the three higher population levels. At 13,000 plants per acre the fertile outyielded the sterile by 0.763 tons per acre (12%). But at 26,000, 39,000, and 52,000 plants per acre, the sterile outyielded the fertile by 0.863 (13%), 0.709 (11%), and 0.145 (2%) tons per acre. Therefore, it may be noted that the sterile component has added some population tolerance to these varieties. This phenomenon has been noted and well documented by other researchers (e.g., Meyer, 1970) during recent years.

The highly significant interactions of leaf angle by fertile:sterile and leaf angle by population by fertile:sterile for Experiment 4 also were very interesting. It first may be noted that the sterile component was more advantageous for the flat leaved varieties than it was for the upright leaved varieties. Sterility imparted seven bushels per acre (7%) and 26 bushels per acre (27%) yield advantages to the steriles over the fertiles for the upright and flat leaved varieties, respectively. This suggests that the upright leaf character also imparts some population tolerance. The leaf angle by population by fertile:sterile interaction was interesting. For the fertile varieties, the flat leaved ones yielded about 16 bushels per acre (15%) more than did the upright leaved varieties at 13,000 plants per acre. They yielded about equally at 26,000 plants per acre and a yield advantage of 16 (20%) and 19 (27%) bushels per acre were noted for the upright leaved varieties at 39,000 and 52,000 plants per acre, respectively. The flat leaved steriles yielded consistently more than the upright leaved steriles at all population levels. This was somewhat unexpected. A possible explanation of why this happened for the isolines of Hy_2 x C103 may be postulated. As mentioned previously, no sterile cytoplasm was available for Hy_2 x C103. Therefore, to have a sterile, the fertile was detasselled for both the upright and flat leaved lines. When detasseling the upright leaved counterparts, more damage was done by having to remove one or two leaves with the tassel. This might explain the lower yields resulting from the upright leaved and sterile counterparts of Hy_2 x C103, but not for the whole experiment.

The purpose of Experiment 3 was to note how a short erect leaved variety would perform under high population levels. For this particular inbred, it was noted that generally the grain yield increased from the lowest (30,000 plants per acre) to the highest population (120,000 plants per acre). It may be observed that the absolute yields were not very high, (30 to 44 bushels per acre), but it was important to note that a possible advantage may exist by having high populations of short and erect leaved tolerant varieties in which all plants produce an ear.

Experiments 5 and 6 were conducted to study the effects of additional light upon the ear leaf of a tolerant variety (XL-45) and an intolerant variety (DL-11). This was done by positioning the leaves about the ear leaf into an erect position by using rubber bands to hold them up. The leaves were positioned upright at 1 and 0 weeks before anthesis and at 1 week after anthesis.

The treatments (tying up of the leaves at 1 and 0 weeks before anthesis, 1 week after anthesis, and a control) had some interesting effects on the silking rate. For both varieties, the silking intervals were reduced by tying up the leaves above the ear leaf at 0 weeks before anthesis. It appeared that tying up the leaves at 1 week before and 1 week after anthesis slowed the silking rate.

All of the treatments in which the leaves above the ear leaf were tied up appeared to have reduced the barrenness (0.6% to 7.0%) for DL-11 but only the treatment where the leaves above the ear leaf were tied up at 1 week after anthesis reduced the barrenness for XL-45. In all cases but one, the treatments reduced the number of grams of grain produced per plant (figured only on those plants producing an ear) for both the XL-45 and DL-11. Also, all treatments where the leaves above the ear leaf were tied up caused an increase in the number of ears produced per plot. There was an average increase of 2.7 and 5.2 additional ears per plot produced due to tying up the leaves of XL-45 and DL-11, respectively. It may be noted that the only treatment that increased the yield of XL-45 was the tying up of the leaves above the ear leaf at 1 week after anthesis, however, tying up of the leaves above the ear leaf at 1 and 0 weeks before anthesis caused only a two bushel per acre decrease when compared to the control. Therefore, since barrenness was generally increased but yet the grain yield was not decreased much and in one case even increased, an increase in the ear size may have occurred. For DL-11, positioning of the leaves above the ear leaf into an erect position caused yield increases when done at 0 weeks before anthesis and 1 week after anthesis. This increase ranged from 11 to 17 bushels per acre. Tying up these leaves at 1 week before anthesis only resulted in a two bushel per acre decrease. Therefore, the barrenness for DL-11 was reduced due to positioning the leaves above the ear leaf into an erect configuration and this was reflected mostly in the increased number of ears produced per plot.

It may be noted here that the author was not very satisfied with the use of rubber bands for positioning leaves into an upright position. First, some damage was done to the leaves with the repeated repositioning of the rubber bands. Secondly, it was felt that a considerable amount of leaf area was rendered non-useable due to the tight clustering of the leaves with the tightly positioned rubber bands around them. However, despite these disadvantages, some yield increases were noted which may point to the fact that light on the ear leaf is highly important.

Experiments 7 and 8 were conducted to note any effects on the above mentioned variables (see Experiments 5 and 6) from spraying various chemicals onto the plant at various leaf positions. The actual spraying was done shortly before anthesis and the varieties used were a population-tolerant hybrid (XL-45) and a population-intolerant hybrid (DL-11). The chemicals used were two rates of glutamate, one rate of sucrose, and one rate of the combination glutamate and sucrose.

Several researchers (Hageman et al., 1961; Hageman and Flesher, 1960; and Knipmeyer et al., 1962) believe that part of the reason that light is important down into the canopy is because of being needed to reduce nitrate to ammonia. They have suggested that light hitting the middle and lower leaves of the plant aid in nitrogen reduction such that it may combine with the various carbon skeletons to form the amino acids. These researchers have postulated that perhaps reduced nitrogen is the limiting factor resulting from decreased light down into the canopy instead of photosynthates.

This experiment was designed to test this theory.

First it was noted that some of the treatments had an effect on the silking rate. A moderate amount of variability was noted to exist among the controls and this was especially true for DL-11. If the controls within XL-45 and within DL-11 were averaged and the treatments compared to this mean, it was noted that most treatments tended to reduce the silking interval (speed the silking rate). Two exceptions to this were noted and they were the Suc and Gl-2 + Suc treatments applied to the 2A leaf for XL-45.

However, if the results of each treatment were compared with their respective controls, somewhat different results occurred. The treatments of Gl-1 and Gl-2 at all leaf positions tended to speed the silking rate for both XL-45 and DL-11. One exception to this was Gl-1 at the 2B leaf position for XL-45 where an 0.4 day delay was noted. Suc tended to speed the silking rate for XL-45 and delay such for the DL-11. However, these results should be viewed with caution because the respective controls of these treatments represented the extremes noted for these two varieties. The combination of Gl-2 and Suc tended to delay the silking rate for XL-45 and speed such for DL-11. It is desirable to note again that these silking results were quite variable and should be viewed with extreme caution.

Regarding the position of treatment, it was noted that whenever the treatments were applied to the 2A, E, or 2B leaf positions that a hastening of the 50% silking date and shortening of the silking interval for DL-11 occurred which was statistically significant at the 0.05 level.

The number of nubbins per plot was not very variable due to the imposed treatments for either XL-45 or DL-11, but some interesting trends were noted on the number of ears produced per plot. Gl-1 appeared to have increased the number of ears produced per plot when applied to the 2A leaf only for both XL-45 and DL-11. This treatment again at only the 2A position was associated with a decrease in barrenness and an increase in yield for both of the varieties utilized here. Gl-2 at any leaf position tended to decrease the number of ears produced per plot, increase the percent barrenness, and decrease the yield when applied to XL-45. Just the opposite results were noted for DL-11. Gl-2 at all leaf positions increased the number of ears produced per plot, slightly decreased the percent barrenness, and increased the grain yield. Suc applied to the E or 2B leaf of XL-45 caused an increase in the number of ears produced per plot as well as a decrease in barrenness and an increase in yield. Suc applied to the 2A leaf of XL-45 decreased the ears produced per plot, increased the barrenness, and increased the yield somewhat. This yield increase may have been nonexistant due to comparison with an exceptionally low yielding control. For DL-11, Suc had very little influence on these three variables (number of ears produced per plot, percent barrenness, and grain yield). Gl-2 + Suc tended to reduce the number of ears per plot, increase the percent barrenness, and slightly decrease the grain yield for XL-45. The opposite results were noted for this treatment on DL-11 where an increase in ear production, a decreased barrenness rating, and a yield increase were noted.

If grain yield is to be considered the overall indication of the worth of a treatment, it would appear that none of the treatments really proved to be superior in increasing the yields of XL-45 or DL-11. Some of the higher yields did result from Gl-1, Suc, and Gl-2 + Suc applied at the 2A, 2B, and E leaf positions, respectively, for XL-45. The Gl-1 at the 2A leaf and Gl-2 at the 2B leaf also were higher yielding treatments for the DL-11.

About the most important aspects to be noted from these Experiments (7 and 8) were that the Gl-1, Gl-2, and Suc treatments at all leaf positions tended to hasten the silking rate for XL-45 while this same trend was noted for DL-11 due to the Gl-1, Gl-2, and Gl-2 + Suc treatments. The above mentioned higher yielding treatments for XL-45 and DL-11 also were associated with these shorter silking intervals, generally.

Experiment 9 was conducted to note any effects on the various variables measured resulting from leaf removal, application of aluminum foil, and a combination of the two when imposed at 1 and 0 weeks before anthesis. These treatments also were applied to the 2A, E, and 2B leaves.

The treatments applied at any position had little noticeable effect on the number of days from planting to 25% silking. It also was noted that this would have been expected due to the short time interval between the imposition of the treatments and the 25% silking dates. However, by 50% and 75% silking, some variation between the different treatments were evident. Of all of the treatments imposed at the various positions, only three resulted in a shorter silking interval (25% to 75% silking). These three were LR 1 and LR 0 treatments applied at the 2B leaves and the LR + Al foil 1 applied at the E leaf. However, the last treatment's effect (LR + Al foil 1 at the E leaf) may not really have been existant due to comparison with a large control value. The results of these treatments appear to be associated with the following yield data.

It also was noted that position of treatment had some statistically significant effects on the 50% and 75% silking dates and also the silking intervals. Any treatment applied to the 2A, E, or 2B leaf tended to delay the 50% and 75% silking dates when compared to the control. Very little variation was evident between the treatments at the 2A, E, or 2B leaf positions of treatment. This was then reflected in the silking interval where all treatments applied to the 2A, E, or 2B leaf caused a slowing of the silking rate. Again, little difference was noted between treatments applied at the 2A, E, or 2B leaf position.

LR 1 and LR 0 at all leaf positions caused little variation in the number of nubbins produced per plot. However, LR 1 applied at the 2B leaf caused a slight increase (2.7) in the number of ears produced per plot. This was associated with a 23% reduction in barrenness and an eight bushel per acre (6%) yield increase. All of the other LR 1 and LR 0 treatments imposed at the remaining leaf positions were generally associated with decreases in the number of ears produced per plot, increases in the percent barrenness, and decreases in the grain yield per acre.

Initially, it may appear somewhat unexpected as to why LR 1 of the 2B leaf would increase ear production per plot, decrease barrenness, and cause a slight increase in the yield per acre. This might be explained by the fact that with the 2B leaf removed, the potential ear located within this leaf axil would not be competing as much for available photosynthate. It has generally been indicated that the leaf subtending the ear is very important in supplying it with photosynthate (Tanner and Daynard, 1967). With the 2B leaf removed the ear associated with this leaf would probably be reduced as a carbohydrate sink, thereby, providing less competition with the main ear for available carbohydrates. The removal of the 2B leaf would not be expected to cause any loss of carbohydrate supply to the main ear because Palmer and Musgrave (1966) have indicated that very little $C^{14}O_2$ fed to leaves below the main ear leaf was ever recovered by the main ear. If this is the case, the additional carbohydrate "pulled" by this ear from the leaves positioned above it might therefore be diverted to the main ear and result in a slight yield increase.

Another interesting aspect of these two treatments was that the LR 0 of the 2B leaf did not result in a yield increase as was the case for the LR 1 treatment of the 2B leaf. The aspect to note here might be the difference in time at which the treatments were imposed. In this regard, Collins (1963) has noted that the period of three weeks before anthesis "brackets the critical period when the fate of second ears is generally decided." He also noted that abortion of the second ears was initiated when the second ears did not adequately compete with the top ear during a three day period before silking. Therefore, these results would indicate that this secondary sink would have to be terminated before silking occurs in order to insure that it will abort. This was probably what was occurring with the LR 1 treatment of the 2B leaf but was too late for the LR 0 treatment of the 2B leaf.

The LR + Al foil 1 and LR + Al foil 0 treatments at all positions of treatment caused decreases in the number of ears per plot, increases in the percent barrenness, and yield decreases. This might possibly have been the result of two factors being operative here. First, with the addition of the aluminum foil a moderate amount of photosynthetic tissue in the form of leaf sheaths was not exposed to sunlight. Therefore, a reduced amount of photosynthesis could have resulted. Secondly, with the application of the aluminum foil, a reduced amount of light was reaching the stalk of the plant. This being the case, there could possibly have been higher amounts of IAA in the stalk to inhibit lateral growth (e.g., ears). Therefore, these two factors of less photosynthate and increased apical dominance may have been responsible for the increased barrenness and decreased yield. It also was noted that the LR + Al foil 1 treatments were more detrimental than the LR + Al foil 0 treatments when averaged across all positions of treatment for the yield variables.

The Al foil 1 and Al foil 0 treatments at all positions of treatment generally caused decreases in ear production per plot, increases in barrenness percent, and yield decreases. The same reasons as were put forth for the LR + Al foil 1 and LR + Al foil 0 treatments appeared to have applied here. In addition, the Al foil 1 treatments appeared to have been more detrimental than the Al foil 0 treatments.

The observation also was made that the LR + Al foil 1 and LR + Al foil 0 treatments on the average were more instrumental in reducing the yields than were the Al foil 1 and Al foil 0 treatments. This was probably due to the additional factor of leaf removal which removed even more photosynthetic tissue from the process of photosynthesis. Also, on the average, there was not much difference in yield resulting from the LR 1 and LR 0 treatments versus the Al foil 1 and Al foil 0 treatments.

It is believed that as higher yields are sought by the farmers that higher plant populations will be utilized. This being the case, more efficient utilization of the incoming solar radiation will become a prime factor. Such can partially be accomplished by utilizing varieties adapted to narrow rows and possessing upright or erect leaves.

SUMMARY

Field experiments were conducted during the summers of 1967, 1968, and 1969 to determine the effects on certain plant responses of three different types of treatment regimes.

The first type of treatment regime involved a comparison of upright and flat leaved varieties of corn in which their relative abilities to produce both dry matter and grain were studied. In these studies pairs of varieties were formed in which the individual varieties of a pair were matched as closely as possible for all characters except leaf angle.

In 1967, the dry matter production and dry matter production rate (dry matter produced between the different harvest dates) were expressed on a unit leaf area basis due to somewhat unequal LAIs within a pair. It appeared that at a population of 14,000 plants per acre, as the harvest date was advanced (consequently the LAI also increased) from harvest date 1 (June 27) to harvest date 4 (August 3 and 4), the upright leaved varieties demonstrated an increasing ability to produce more dry matter per unit of leaf area. This was not the trend observed at the higher population levels of 19,000, 37,000, and 68,000 plants per acre, although the upright leaved varieties yielded slightly more. It was believed that a moisture stress during July and August might have been responsible for the little differential noted between the upright and flat leaved varieties at the higher population levels. Also, the slight yield advantage observed for the upright leaved varieties may have resulted from more efficient utilization of the limited water supply instead of more efficient use of the sunlight.

Two dry matter harvest experiments were performed during 1968. The

first experiment consisted of four dry matter harvest dates and they were taken between the dates of July 9 and August 13. It was noted in this experiment that the upright leaved varieties did not result in yield advantages over the flat leaved varieties at the higher LAIs. Conversely, it was observed that a slight advantage at the higher LAIs was associated with the flat leaved varieties. The second dry matter harvest experiment was performed during the latter part of September. It was noted in this experiment that at the lower population level (13,000 plants per acre), the flat leaved varieties produced more dry matter per acre. As the population increased to 52,000 plants per acre, an advantage became more evident in favor of the upright leaved varieties.

During 1968, a grain yield study was conducted in which the varieties used also were utilized in the 1968 summer dry matter harvest experiment. The results of this grain yield experiment showed the same trends observed for the fall dry matter harvest experiment in which at the lower population levels the flat leaved varieties yielded best, but at the higher populations the upright leaved varieties were superior in yield. It appeared that the yield advantage began to be in favor of the upright leaved varieties at an LAI of about 3.5.

It was postulated that perhaps the reason that no yield (dry matter production) advantage was noted for the upright leaved varieties at the higher LAIs during the summer harvests was that no strong carbohydrate sink (ear) was present. This might explain why a yield advantage was noted from the fall dry matter harvest and grain yield harvest.

One experiment was partially devoted to the study of the fertile:sterile component of corn production. It was generally found that the sterile varieties outyielded the fertile varieties, when averaged across populations, when harvested for both grain yield and dry matter. The grain yield experiment demonstrated a steady increase in yield from the sterile over the fertile of from 5% to 28% as the population increased from 13,000 to 52,000 plants per acre. For the dry matter harvest experiment, the fertile outyielded the sterile by 12% at 13,000 plants per acre, but at the higher populations the sterile outyielded the fertile by 2% to 13%.

It also was noted that the sterile nature imparted more of a grain yield advantage to the flat leaved varieties than it did for the upright leaved varieties. This suggested that both the upright leaved character and the sterile nature tended to impart population tolerance to corn varieties.

The effect of additional light upon the ear leaf was studied by tying up the leaves above the ear leaf at 1 and 0 weeks before anthesis and at 1 week after anthesis for XL-45 and DL-11. It was noted for both varieties that tying these leaves up at 0 weeks before anthesis hastened the silking rate when compared to the control. All of the treatments at all dates in which the leaves above the ear leaf were tied up reduced the barrenness for DL-11, but only when such leaves were tied up at 1 week after anthesis was a barrenness reduction noted for XL-45. Tying these leaves up tended to cause an increased number of ears produced per plot for both XL-45 and DL-11, but yield increases only occurred when the leaves were positioned upright at 1 week after anthesis for XL-45 and at 0 weeks before and 1 week after anthesis for DL-11.

The second type of treatment regime studied was the application of glutamate, sucrose, and a combination of these two chemicals to various leaves (the second leaf above the ear leaf, the ear leaf, and the second leaf below the ear leaf) of the plant. Such variables as the silking rate, percent barrenness, and grain yield were studied.

It was noted that both of the glutamate rates applied at all of the leaf treatment positions generally tended to speed the silking rate for both XL-45 and DL-11. The application of sucrose at all leaf treatment positions generally speeded the silking rate for XL-45, but slowed such for the DL-11. The combination of glutamate and sucrose generally delayed the silking rate for XL-45 and resulted in a speeding of such for the DL-11.

No consistent results in barrenness and grain yield were noted. However, some high yielding treatments were observed. The low rate of glutamate applied to the second leaf above the ear leaf, sucrose applied to the second leaf below the ear leaf, and glutamate plus sucrose applied to the ear leaf were high yielding treatments for XL-45. High yielding treatments for DL-11 were the low and high rates of glutamate when applied to the second leaf above the ear leaf and the second leaf below the ear leaf, respectively. There tended to be some relationship between the treatments with the higher yields and the faster silking rates, but this was not always evident.

The third treatment regime involved treatments where various leaves were removed, where aluminum foil was wrapped around the stalks of the plants, and where a combination of the above two treatments were performed. When a leaf was removed it was the second leaf above the ear leaf, the ear leaf, or the second leaf below the ear leaf. When aluminum foil was applied to the stalk it was from one of the above mentioned leaves to the tassel of the plant and the combination of the two treatments were both of these treatments applied simultaneously. In addition, these treatments were applied at 1 and 0 weeks before anthesis.

It was observed that generally all treatments, regardless of time or position of treatment, slowed the silking rate in comparison with the control. Little variation was noted to exist between the different treatments.

However, the observation was made that removing the second leaf below the ear leaf at 1 week before anthesis resulted in an increased number of ears produced per plot, a reduction in barrenness, and a slight increase in yield. It was postulated that such occurred because the competition between this potential second ear and the main ear for available carbohydrate was reduced.

The treatments involving the leaf removal plus the application of aluminum foil all generally reduced the number of ears produced per plot, increased the percent barrenness, and decreased the yield. It was suggested that this resulted from a decrease in the functioning photosynthetic tissue available and from an increase in apical dominance. It appeared that the combination of leaf removal and application of aluminum foil treatments were the most severe while the leaf removal treatments were the least detrimental. The aluminum foil only treatments appeared to be intermediate.

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ACKNOWLEDGMENTS

I wish to express my deepest gratitude to my very able and sincere major professor, Dr. Irvin C. Anderson. His sincerity, guidance, and encouragement was certainly an inspiration to me and will always be remembered and appreciated.

My gratitude also is extended to the other members of my graduate committee, Drs. Clifford E. LaMotte, Wilbert A. Russell, Robert H. Shaw, and Donald G. Woolley for their patience and guidance. Special appreciation is extended to Dr. C. E. LaMotte for his direction in the minor area of work and to Dr. W. A. Russell for the supplying of much of the seed used in the field research.

To my wife, Marge, a very special heartfelt thanks for her encouragement and assistance in the research and preparation of this manuscript.

I also am indebted to my parents, R. N. and Anna Maude Hopper, and my parents-in-law, Perry and Charlene Eubank, who have never hestitated to help me in any way.

Encouragement from Ronnie and Melinda Hopper, Kelly and Beverly Eubank, Jodie and Janiece Brown, Keith and JoAnn Eubank, and Leslie Eubank also was deeply appreciated.

APPENDIX

Table 46. Plant characteristics and responses exhibited by ten varieties at four harvest dates and four populations for Experiment 1

Variety	Population $(X10^3)$[a]	Harvest date[b]	LAI	$\bar{X}$LAI[c]	Leaf Angle[d]	DM/ LAI[e]	Rate/ $\bar{X}$LAI[f]
Pa884P[g]	14	1	0.38	0.57		499	841
		2	0.76	0.90		890	745
		3	1.03	1.12	56.5	1288	958
		4	1.21			1999	
	19	1	0.40	0.60		843	569
		2	0.79	1.62		860	1350
		3	2.43	2.29	57.6	1130	349
		4	2.13			1703	
	37	1	0.92	1.37		467	857
		2	1.83	2.55		877	757
		3	3.26	3.58	62.8	1084	595
		4	3.90			1517	
	68	1	1.54	2.31		453	542
		2	3.08	4.04		633	405
		3	4.99	5.38	62.4	718	315
		4	5.77			903	
B57[h]	14	1	0.28	0.42		927	550
		2	0.55	0.86		882	684
		3	1.17	1.57	48.8	926	1211
		4	1.97			1499	

[a]Population in plants per acre.

[b]Harvest dates were for dry matter.

[c]Average LAI was the LAI between the two harvest dates.

[d]Leaf angle was only measured at one harvest date and expressed as degrees from the horizontal.

[e]Dry matter accumulated on a unit leaf area basis.

[f]Rate of dry matter accumulated on an average LAI basis between the two harvest dates.

[g]The upright leaved member of the pair.

[h]The flat leaved member of the pair.

Table 46. (Continued)

Variety	Population $(X10^3)$[a]	Harvest date[b]	LAI	$\overline{X}$LAI[c]	Leaf angle[d]	DM/LAI[e]	Rate/$\overline{X}$LAI[f]
	19	1	0.55	0.83		480	560
		2	1.10	1.47		662	609
		3	1.84	1.97	58.5	903	808
		4	2.09			1789	
	37	1	0.93	1.39		551	762
		2	1.85	2.74		848	514
		3	3.62	3.42	57.7	780	247
		4	3.23			1150	
	68	1	1.46	2.19		538	510
		2	2.92	3.57		652	517
		3	4.21	4.92	59.7	882	276
		4	5.63			891	
H60[g]	14	1	0.33	0.49		683	769
		2	0.65	0.90		922	1152
		3	1.14	1.04	56.4	1424	439
		4	0.93			2243	
	19	1	0.37	0.56		932	520
		2	0.74	1.07		861	1036
		3	1.40	1.46	50.1	1185	773
		4	1.52			1984	
	37	1	0.92	1.38		713	530
		2	1.84	2.03		755	432
		3	2.22	2.64	60.7	929	644
		4	3.06			1220	
	68	1	1.76	2.64		354	510
		2	3.52	4.06		560	272
		3	4.60	4.26	61.1	679	195
		4	3.91			677	
HD2286[h]	14	1	0.33	0.49		570	813
		2	0.65	1.14		903	924
		3	1.63	1.71	48.0	1033	617
		4	1.79			1482	
	19	1	0.59	0.89		436	790
		2	1.18	1.44		768	550
		3	1.69	1.98	51.1	992	790
		4	2.26			2023	

Table 46. (Continued)

Variety	Population $(X10^3)$[a]	Harvest date[b]	LAI	$\overline{X}$LAI[c]	Leaf Angle[d]	DM/LAI[e]	Rate/$\overline{X}$LAI[f]
	37	1	1.02	1.52		457	516
		2	2.03	2.78		616	472
		3	3.54	3.79	56.2	764	630
		4	4.04			1243	
	68	1	1.43	2.15		431	537
		2	2.86	3.66		619	357
		3	4.45	4.53	53.5	684	239
		4	4.60			863	
Hy[g]	14	1	0.50	0.75		389	831
		2	1.00	1.31		821	722
		3	1.61	1.80	55.3	1112	1070
		4	1.98			1961	
	19	1	0.47	0.70		466	765
		2	0.93	1.46		812	779
		3	1.98	2.31	57.6	955	1143
		4	2.62			1769	
	37	1	1.03	1.54		362	923
		2	2.05	3.30		875	527
		3	4.56	4.21	60.2	765	462
		4	3.86			1437	
	68	1	1.33	2.00		520	609
		2	2.66	4.51		718	452
		3	6.37	6.34	65.8	620	349
		4	6.30			986	
B14[h]	14	1	0.43	0.64		670	561
		2	0.85	1.45		762	1219
		3	2.05	2.07	49.2	1225	704
		4	2.09			1842	
	19	1	0.53	0.79		606	709
		2	1.05	1.60		838	1161
		3	2.14	2.23	52.3	1260	512
		4	2.30			1610	
	37	1	1.19	1.78		434	833
		2	2.37	3.32		844	481
		3	4.26	4.10	56.0	828	434
		4	3.94			1410	

Table 46. (Continued)

Variety	Population (X10^3)[a]	Harvest date[b]	LAI	$\overline{X}$LAI[c]	Leaf angle[d]	DM/ LAI[e]	Rate/ $\overline{X}$LAI[f]
	68	1	1.87	2.80		424	473
		2	3.73	4.75		567	356
		3	5.75	5.86	60.3	686	149
		4	5.97			830	
B54[g]	14	1	0.18	0.28		1036	523
		2	0.37	0.61		913	1205
		3	0.86	1.19	47.7	1308	1925
		4	1.51			2621	
	19	1	0.29	0.44		818	633
		2	0.59	0.91		891	1009
		3	1.23	1.36	56.4	1169	841
		4	1.49			1674	
	37	1	0.54	0.82		652	673
		2	1.08	1.74		833	858
		3	2.39	2.23	54.1	968	325
		4	2.07			1491	
	68	1	0.99	1.49		374	578
		2	1.97	3.05		623	402
		3	4.12	4.41	57.8	600	254
		4	4.70			816	
WF9[h]	14	1	0.37	0.56		925	616
		2	0.74	1.30		934	964
		3	1.85	2.13	51.4	1018	913
		4	2.40			1763	
	19	1	0.73	1.09		572	599
		2	1.45	1.83		738	821
		3	2.21	2.32	53.0	1220	1036
		4	2.44			2665	
	37	1	1.19	1.79		498	625
		2	2.38	4.01		712	469
		3	5.63	4.45	51.6	625	487
		4	3.27			1915	
	68	1	1.81	2.72		415	515
		2	3.62	4.61		594	398
		3	5.59	5.38	58.9	755	331
		4	5.16			1244	

Table 46. (Continued)

Variety	Population $(X10^3)$[a]	Harvest date[b]	LAI	$\overline{X}$LAI[c]	Leaf angle[d]	DM/ LAI[e]	Rate/ $\overline{X}$LAI[f]
SX 29[g]	14	1	0.77	1.16		1029	802
		2	1.54	2.12		1121	657
		3	2.70	3.06	57.7	1171	1810
		4	3.40			2540	
	19	1	1.11	1.67		788	800
		2	2.22	2.44		997	640
		3	2.66	3.02	58.9	1426	1113
		4	3.38			2109	
	37	1	2.36	3.54		543	751
		2	4.72	5.34		835	428
		3	5.96	6.28	59.7	1043	581
		4	6.59			1504	
	68	1	2.17	3.26		791	711
		2	4.34	5.92		929	527
		3	7.50	6.88	65.6	955	243
		4	6.26			1438	
B14 x 577[h]	14	1	1.02	1.53		570	779
		2	2.04	2.75		873	806
		3	3.45	3.58	46.2	1170	839
		4	3.71			2193	
	19	1	1.13	1.69		937	602
		2	2.25	2.73		923	548
		3	3.20	3.27	52.2	1115	660
		4	3.32			1769	
	37	1	1.86	2.79		809	767
		2	3.72	5.80		981	409
		3	7.87	6.33	50.0	748	341
		4	4.78			1656	
	68	1	3.24	4.86		696	471
		2	6.47	8.86		702	274
		3	11.24	9.38	54.1	619	157
		4	7.52			1096	

Table 47. Plant characteristics and the associated mean squares for ten varieties at four harvest dates and four populations for Experiment 1

Source	d.f.	LAI	Leaf angle	DM/ LAI	d.f.[a]	$\overline{X}$LAI	Rate/ $\overline{X}$LAI
Blocks	2	0.03	1.51	152844	2	0.01	56655
Pairs (P)	4	61.80**	278.91	755288	4	54.00**	105633
Error (a)	8	1.25	149.36	241072	8	1.06	62182
Leaf Angle (LA)	1	18.00**	2734.18**	678850**	1	17.21**	892277**
P x LA	4	4.48*	283.71	133277	4	4.43**	91627
Error (b)	10	0.77	82.17	49332	10	0.61	33053
Population (Po)	3	213.32**	1433.65**	6009060**	3	179.37**	4193556**
P x Po	12	2.48*	87.40	68747	12	2.56**	56585
LA x Po	3	0.57	63.33	188902	3	0.63	35626
P x LA x Po	12	1.96	56.44	127834	12	1.70*	54435
Error (c)	60	1.08	96.17	131290	60	0.87	65500
Harvest Date (D)	3	177.62**	0.00	21291055**	2	120.78**	23880
P x D	12	3.17**	0.00	136567	8	1.69**	174426
LA x D	3	1.63*	0.00	30810	2	0.66	66090
P x LA x D	12	1.23*	0.00	101455	8	0.43	216511
Po x D	9	10.47**	0.00	964123**	6	6.50**	773659**
P x Po x D	36	0.84	0.00	44864	24	0.25	158014
LA x Po x D	9	0.77	0.00	196513	6	0.23	125857
P x LA x Po x D	36	0.30	0.00	78533	24	0.11	141808
Error (d)	240	0.60	0.00	128287	160	0.25	126328

[a]The degrees of freedom for the average LAI and the rate per average LAI were different due to having only three rate intervals (time between harvest dates 1-2, 2-3, and 3-4).

* Statistically significant at the 0.05 level of probability.

**Statistically significant at the 0.01 level of probability.

Table 48. Plant characteristics and responses exhibited by 18 varieties (nine pairs) at four populations and four harvest dates for Experiment 2

Variety	Population ($X10^3$)[a]	Harvest date[b]	LAI	$\bar{X}$LAI[c]	Leaf angle[d]	DM/ acre[e]	Rate/ acre[f]
B14 x 577[g]	10	1	1.55	0.78	35.5	1570	1570
		2	1.73	1.64	37.5	3195	1626
		3	1.34	1.54	27.5	4188	993
		4	1.93	1.64	36.5	6327	2139
	20	1	3.13	1.57	39.0	3371	3371
		2	3.45	3.29	43.5	6103	2732
		3	3.11	3.28	38.5	8079	1976
		4	3.41	3.26	41.0	10026	1947
	40	1	4.67	2.34	38.5	5383	5383
		2	6.46	5.57	40.5	8074	2691
		3	4.63	5.55	40.5	9209	1135
		4	4.25	4.44	42.5	9868	659
	80	1	7.35	3.68	42.5	6102	6102
		2	7.76	7.56	43.0	8811	2709
		3	6.53	7.15	40.0	11083	2273
		4	5.65	6.10	41.0	11575	492
SX 29[h]	10	1	1.55	0.78	34.5	1561	1561
		2	1.67	1.61	38.0	3451	1890
		3	1.59	1.63	36.0	4501	1050
		4	1.80	1.70	34.0	6583	2082

[a]Population in plants per acre.

[b]Harvest dates were for dry matter.

[c]Average LAI was the LAI between the two harvest dates except for the first one and it was the LAI between 0 and harvest date 1.

[d]Leaf angle was measured at each harvest date and expressed as degrees from the horizontal.

[e]DM/acre was the amount of dry matter harvested at each harvest date.

[f]Rate/acre was the amount of dry matter produced between the harvest dates.

[g]The upright leaved member of the pair.

[h]The flat leaved member of the pair.

Table 48. (Continued)

Variety	Population ($X10^3$)[a]	Harvest date[b]	LAI	$\overline{X}LAI$[c]	Leaf angle[d]	DM/ acre[e]	Rate/ acre[f]
	20	1	2.78	1.39	37.5	2710	2710
		2	3.31	3.04	36.5	6213	3503
		3	2.84	3.08	26.5	8176	1963
		4	2.93	2.89	38.0	10351	2175
	40	1	4.70	2.35	38.0	4497	4497
		2	5.50	5.10	41.0	8156	3659
		3	4.34	4.92	33.0	10006	1850
		4	4.41	4.38	45.5	12388	2382
	80	1	8.68	4.34	46.5	6026	6026
		2	8.77	8.73	39.5	9704	3678
		3	7.97	8.37	39.5	10526	822
		4	5.86	7.16	42.0	12425	1899
695 x 334[g]	10	1	1.85	0.93	38.5	2041	2041
		2	1.94	1.90	36.5	3960	1919
		3	1.98	1.99	45.0	6351	2391
		4	1.90	1.94	42.0	7456	1106
	20	1	2.91	1.45	47.0	3452	3452
		2	3.19	3.05	39.0	6766	3314
		3	3.66	3.43	40.5	8221	1456
		4	3.12	2.48	40.0	8937	716
	40	1	5.40	2.70	51.0	5306	5306
		2	6.27	5.84	43.5	8904	3598
		3	5.83	6.05	45.0	9908	1005
		4	5.37	5.60	42.5	11001	1093
	80	1	8.90	4.45	53.5	5542	5542
		2	9.17	9.04	49.5	9449	3907
		3	7.51	8.34	47.0	11307	1858
		4	6.52	7.02	41.0	12275	968
3306[h]	10	1	1.48	0.74	43.0	1976	1976
		2	1.78	1.63	30.0	4220	2244
		3	1.76	1.77	35.0	5563	1343
		4	2.10	1.93	34.5	7656	2093
	20	1	2.89	1.45	43.0	3338	3338
		2	3.17	3.03	31.5	6891	3554
		3	3.58	3.38	37.5	8611	1720
		4	3.14	3.34	34.0	11141	2530

Table 48. (Continued)

Variety	Population $(X10^3)$[a]	Harvest date[b]	LAI	$\overline{X}$LAI[c]	Leaf angle[d]	DM/ acre[e]	Rate/ acre[f]
	40	1	5.14	2.57	45.0	5322	5322
		2	6.26	5.70	39.0	8656	3334
		3	5.53	5.90	40.5	9258	602
		4	4.98	5.26	41.0	12620	3362
	80	1	8.59	4.29	47.0	6721	6721
		2	9.48	9.04	40.5	10896	4175
		3	8.98	9.23	43.5	11823	927
		4	7.44	8.21	33.5	13274	1451
Hy_2 x C103 (lg_2)[g]	10	1	1.18	0.59	41.0	1793	1793
		2	1.64	1.41	46.0	3297	1505
		3	1.58	1.61	48.0	4704	1407
		4	1.27	1.43	40.5	5611	907
	20	1	2.39	1.19	45.5	3363	3363
		2	3.20	2.79	37.0	6932	3610
		3	1.44	2.32	45.5	7339	408
		4	2.40	1.92	45.0	10169	2830
	40	1	4.33	2.17	52.5	4911	4911
		2	5.60	4.97	51.0	9038	4127
		3	5.22	5.41	47.0	10148	1110
		4	3.90	4.56	51.5	12225	2077
	80	1	7.83	3.92	54.0	5737	5737
		2	7.64	7.74	61.0	8989	3253
		3	8.02	7.83	47.0	12282	3293
		4	5.51	6.77	60.0	13286	1004
Hy_2 x C103 (Lg_2)[h]	10	1	1.63	0.82	37.0	2358	2358
		2	1.84	1.74	24.5	3951	2134
		3	1.65	1.75	24.0	4940	989
		4	1.37	1.51	28.5	5830	891
	20	1	2.65	1.33	34.0	2984	2984
		2	3.33	2.99	31.0	6387	3403
		3	3.32	3.33	26.0	8314	1928
		4	3.00	3.17	32.0	10010	1696
	40	1	4.63	2.32	37.0	4744	4744
		2	5.63	5.13	32.5	8928	4184
		3	4.79	5.21	41.0	10184	1256
		4	3.65	4.22	30.5	12148	1964

Table 48. (Continued)

Variety	Population $(X10^3)^a$	Harvest date[b]	LAI	$\overline{X}LAI^c$	Leaf Angle[d]	DM/ acre[e]	Rate/ acre[f]
	80	1	7.12	3.56	44.0	5822	5822
		2	9.79	8.46	37.5	9969	4147
		3	7.37	8.58	31.5	11636	1667
		4	7.06	7.22	38.0	13568	1932
B73[g]	10	1	0.93	0.46	37.0	1073	1073
		2	1.17	1.05	43.5	3081	2008
		3	1.33	1.25	35.5	4045	964
		4	1.18	1.26	36.5	4692	647
	20	1	1.85	0.93	49.0	2175	2175
		2	2.14	2.00	37.5	4712	2537
		3	2.14	2.14	44.5	5733	1021
		4	2.10	2.12	37.0	7392	1659
	40	1	2.94	1.47	43.5	2923	2923
		2	3.90	3.43	36.5	6444	3521
		3	3.96	3.93	37.0	7856	1412
		4	3.67	3.82	37.5	9745	1890
	80	1	4.91	2.45	45.5	4525	4525
		2	7.40	6.15	43.0	8131	3606
		3	6.62	7.01	43.0	10339	2208
		4	5.58	6.10	43.5	11790	1452
W22[h]	10	1	0.99	0.49	37.0	1236	1236
		2	1.38	1.19	32.5	2875	1639
		3	1.30	1.34	35.5	3338	464
		4	1.24	1.27	30.5	4871	1533
	20	1	1.95	0.98	35.5	1943	1943
		2	3.41	2.69	36.0	4078	2135
		3	2.27	2.84	31.0	5461	1383
		4	1.91	2.09	27.0	6823	1362
	40	1	2.94	1.47	41.0	3155	3155
		2	4.39	3.67	39.5	5489	2334
		3	2.24	3.29	39.0	7863	2375
		4	3.32	2.78	35.5	9139	1276
	80	1	6.46	3.23	43.0	3843	3843
		2	6.58	6.52	40.0	6940	3098
		3	6.00	6.29	42.0	9230	2290
		4	5.13	5.57	40.5	10347	1118

Table 48. (Continued)

Variety	Population ($X10^3$)[a]	Harvest date[b]	LAI	$\overline{X}LAI$[c]	Leaf angle[d]	DM/ acre[e]	Rate/ acre[f]
B14[g]	10	1	1.09	0.55	38.0	1163	1163
		2	1.55	1.32	36.5	2681	2018
		3	1.39	1.47	35.5	3493	813
		4	1.11	1.25	36.0	3843	350
	20	1	1.87	0.94	39.5	1773	1773
		2	2.43	2.15	38.0	4156	2383
		3	2.66	2.55	39.0	5322	1167
		4	2.17	2.42	33.5	6664	1342
	40	1	3.18	1.59	47.5	2883	2883
		2	4.80	3.99	41.5	6075	3192
		3	4.60	4.70	39.0	7811	1736
		4	2.26	3.48	40.0	9095	1285
	80	1	5.76	2.88	45.0	3724	3724
		2	6.74	6.25	45.0	7216	3492
		3	6.61	6.68	48.5	8619	1403
		4	5.55	6.08	44.5	10477	1858
Hy[h]	10	1	0.91	0.46	38.0	1139	1139
		2	1.18	1.05	32.5	2249	1110
		3	1.30	1.24	30.0	3200	952
		4	0.69	1.00	30.5	3861	661
	20	1	1.77	0.89	35.5	2005	2005
		2	2.36	2.07	25.0	4574	2569
		3	2.14	2.26	31.5	5152	578
		4	1.76	1.95	39.0	7190	2039
	40	1	3.37	1.69	34.5	3171	3171
		2	4.06	3.72	36.0	6033	2862
		3	3.95	4.01	30.5	7883	1850
		4	3.14	3.55	28.0	9514	1631
	80	1	5.84	2.92	38.5	4172	4172
		2	6.22	6.04	34.5	8181	4010
		3	5.92	6.07	31.5	9042	861
		4	5.32	5.62	35.5	10985	1943
Oh43[g]	10	1	0.79	0.40	46.5	1142	1142
		2	0.94	0.87	49.0	2147	1005
		3	0.89	0.92	44.5	2899	752
		4	0.83	0.86	52.5	3557	659

Table 48. (Continued)

Variety	Population (X10^3)[a]	Harvest date[b]	LAI	$\overline{X}$LAI[c]	Leaf angle[d]	DM/ acre[e]	Rate/ acre[f]
	20	1	1.54	0.77	54.0	2042	2042
		2	1.97	1.76	49.0	4041	2000
		3	1.92	1.95	46.5	5436	1395
		4	4.55	3.24	48.5	6278	842
	40	1	3.18	1.59	61.0	3118	3118
		2	3.61	3.40	51.5	6729	3611
		3	3.65	3.63	46.0	7871	1143
		4	3.52	3.59	46.5	9676	1805
	80	1	5.88	2.94	55.0	4684	4684
		2	7.01	6.45	55.0	7753	3069
		3	5.44	6.23	51.0	9356	1603
		4	4.20	4.82	53.0	11278	1923
B66[h]	10	1	0.97	0.48	42.5	1354	1354
		2	1.05	1.01	40.5	2578	1224
		3	2.18	1.62	51.0	3639	1061
		4	2.18	2.18	40.5	4684	1045
	20	1	1.76	0.88	41.0	2240	2240
		2	1.90	1.83	39.0	4648	2408
		3	1.69	1.79	47.5	5774	1126
		4	1.57	1.63	45.5	6977	1203
	40	1	3.08	1.54	43.0	3139	3139
		2	3.98	3.53	42.0	6900	3761
		3	3.05	3.52	47.0	8299	1399
		4	2.41	2.73	48.0	9884	1585
	80	1	5.59	2.80	46.5	4997	4997
		2	6.52	6.06	47.5	8668	3671
		3	4.94	5.73	54.0	9469	801
		4	3.60	4.27	49.5	12018	2549
M14 x C103 1517-243-129[g]	10	1	0.72	0.36	40.5	1086	1086
		2	0.87	0.79	38.5	2569	1484
		3	0.78	0.82	37.5	2785	216
		4	0.75	0.77	40.0	3464	679
	20	1	1.46	0.73	39.5	2188	2188
		2	1.76	1.61	45.0	3913	1725
		3	1.63	1.70	42.0	4884	971
		4	1.63	1.63	49.5	6217	1333

Table 48. (Continued)

Variety	Population (X10^3)[a]	Harvest date[b]	LAI	$\overline{X}$LAI[c]	Leaf angle[d]	DM/ acre[e]	Rate/ acre[f]
	40	1	2.88	1.44	46.0	3269	3269
		2	2.79	2.84	52.5	6367	3098
		3	3.09	2.94	52.5	7310	943
		4	3.00	3.05	46.0	9421	2111
	80	1	4.99	2.50	53.0	4200	4200
		2	5.01	5.00	57.0	7302	3103
		3	5.12	5.07	60.0	8205	903
		4	4.56	4.84	60.0	10482	2277
A632[h]	10	1	1.00	0.50	37.0	1334	1334
		2	1.23	1.12	31.0	2801	1468
		3	0.97	1.10	36.0	3200	399
		4	1.08	1.03	30.0	5411	2212
	20	1	1.82	0.91	34.0	2184	2184
		2	2.01	1.92	27.5	4180	1996
		3	1.75	1.88	35.0	5253	1074
		4	1.79	1.82	34.5	7311	2058
	40	1	3.40	1.70	36.0	2867	2867
		2	3.48	3.44	32.5	6367	3500
		3	3.70	3.59	32.0	8213	1846
		4	3.78	3.74	26.0	10400	2187
	80	1	5.32	2.66	41.0	3940	3940
		2	6.13	5.73	42.0	7769	3829
		3	5.24	5.68	39.5	8949	1180
		4	5.54	5.39	40.0	11917	2968
B25[g]	10	1	0.77	0.39	35.0	688	688
		2	0.90	0.84	47.5	1481	793
		3	0.85	0.88	51.5	2098	617
		4	0.72	0.79	48.5	2537	440
	20	1	1.47	0.74	38.5	1309	1309
		2	1.79	1.63	43.0	2822	1513
		3	1.92	1.86	56.0	3887	1065
		4	1.54	1.74	50.5	4594	1094
	40	1	3.19	1.60	41.5	2887	2887
		2	5.29	4.24	43.5	4834	1947
		3	3.10	4.20	58.5	5924	1090
		4	2.90	3.00	43.0	6570	647

Table 48. (Continued)

Variety	Population ($X10^3$)[a]	Harvest date[b]	LAI	$\bar{X}LAI$[c]	Leaf angle[d]	DM/ acre[e]	Rate/ acre[f]
	80	1	5.18	2.59	44.5	4274	4274
		2	5.86	5.52	47.0	6972	2699
		3	4.50	5.18	58.5	7965	993
		4	4.49	4.50	50.5	8912	948
R181B[h]	10	1	1.00	0.50	48.5	914	914
		2	1.01	1.01	36.5	2618	1705
		3	0.88	0.94	41.0	3265	647
		4	0.88	0.88	34.5	4127	862
	20	1	1.93	0.97	40.0	2139	2139
		2	1.98	1.95	38.5	4114	1976
		3	1.71	1.80	37.0	5688	1574
		4	1.43	1.57	34.0	6217	529
	40	1	3.65	1.83	46.5	3525	3525
		2	4.18	3.92	37.5	7058	3533
		3	3.56	3.87	47.0	8761	1704
		4	3.15	3.36	36.5	11169	2408
	80	1	6.06	3.03	55.5	4156	4156
		2	6.98	6.52	46.5	8115	3960
		3	5.01	6.00	48.5	10185	2070
		4	4.02	4.52	43.0	11091	906
B72[g]	10	1	1.05	0.52	41.5	1354	1354
		2	1.41	1.23	38.0	2423	1069
		3	1.63	1.52	41.0	3854	1432
		4	1.35	1.50	36.5	4070	216
	20	1	1.99	1.00	44.5	2236	2236
		2	2.91	2.45	36.0	3769	1533
		3	2.70	2.81	46.0	5737	1968
		4	2.31	2.51	41.0	6489	752
	40	1	3.57	1.79	43.5	3546	3546
		2	4.46	4.02	45.5	5737	2191
		3	4.57	4.52	41.5	7611	1875
		4	4.04	4.31	46.0	8843	1232
	80	1	5.43	2.72	49.0	3448	3448
		2	7.19	6.31	48.5	7038	3590
		3	7.93	7.56	45.5	9042	2004
		4	5.77	6.85	51.5	10497	1456

Table 48. (Continued)

Variety	Population (X10^3)[a]	Harvest date[b]	LAI	$\overline{X}$LAI[c]	Leaf angle[d]	DM/acre[e]	Rate/acre[f]
B70[h]	10	1	1.02	0.51	39.0	1647	1647
		2	1.78	1.40	28.0	2855	1208
		3	1.33	1.55	34.0	4204	1350
		4	0.93	1.13	35.0	4928	724
	20	1	1.52	0.76	45.0	2204	2204
		2	2.15	1.84	39.5	4989	2785
		3	2.22	2.19	39.5	7695	2707
		4	1.78	2.00	27.5	8082	387
	40	1	3.65	1.83	39.5	3949	3949
		2	4.01	3.83	38.0	7822	3874
		3	3.46	3.74	43.0	10200	2378
		4	3.13	3.30	35.0	12096	1896
	80	1	5.56	2.78	49.5	5099	5099
		2	6.13	5.85	41.0	8753	3655
		3	5.83	5.98	42.0	11351	2598
		4	4.20	5.02	36.0	12742	1391

Table 49. Plant characteristics and the associated mean squares for nine pairs (18 varieties) at four harvest dates and four populations for Experiment 2

Source	d.f.	LAI	$\bar{X}$LAI	Leaf angle	DM/ acre	Rate/ acre
Blocks	1	0.22	0.29	6.67	261728	283687
Pairs (Pa)	8	30.26**	23.79**	726.84*	66468416**	6550228**
Error (a)	8	0.54	0.34	126.45	789806	147121
Population (Po)	3	700.00**	471.51**	1671.50**	811418112**	75827856**
Pa x Po	24	2.27**	1.94**	29.89	1169884	266976*
Error (b)	27	0.34	0.22	23.03	780059	135411
Leaf Angle (LA)	1	0.01	0.10	6792.51**	36694608**	8052115**
Pa x LA	8	1.69**	1.20**	308.50**	6680576**	877662**
Po x LA	3	0.70	0.55	40.91	751269	247728
Pa x Po x LA	24	0.65	0.48	39.60	771155	168177
Error (c)	36	0.46	0.38	24.27	638266	113832
Harvest Date (D)	3	18.12**	137.07**	238.60**	807092734**	111416480**
Pa x D	24	0.69*	0.69**	66.20**	1434044**	2168340**
Po x D	9	4.77**	12.76**	12.20	14551040**	13377683**
Pa x Po x D	72	0.41	0.16	20.63	507736**	675827
LA x D	3	0.54	0.23	146.41**	4312809**	1243753
Pa x LA x D	24	0.35	0.22	68.60**	673519**	644208
Po x LA x D	9	0.32	0.11	36.38	515894	605418
Pa x Po x LA x D	72	0.38	0.14	22.74	205121	368469
Error (d)	216	0.45	0.16	25.87	324032	635583

* Statistically significant at the 0.05 level of probability.

**Statistically significant at the 0.01 level of probability.

Table 50. Yield of six varieties (three pairs) at four population levels and with the fertile and sterile counterparts of each for Experiment 4

Variety	Population ($X10^3$)[a]	Fertile: Sterile[b]	Yield (Bu/acre)	Mean
695 x 334[c]	13	F	112	115
		S	119	
	26	F	119	121
		S	123	
	39	F	113	118
		S	123	
	52	F	97	99
		S	101	
3306[d]	13	F	136	138
		S	139	
	26	F	138	150
		S	162	
	39	F	108	128
		S	148	
	52	F	84	104
		S	124	
B14 x 577[c]	13	F	120	121
		S	122	

[a]Population in plants per acre.

[b]Fertile:sterile types were the fertile (F) and sterile (S).

[c]The upright leaved member of the pair.

[d]The flat leaved member of the pair.

Table 50. (Continued)

Variety	Population ($X10^3$)[a]	Fertile: Sterile[b]	Yield (Bu/acre)	Mean
	26	F	115	117
		S	119	
	39	F	101	107
		S	113	
	52	F	104	109
		S	115	
SX 29[d]	13	F	127	131
		S	135	
	26	F	123	127
		S	132	
	39	F	79	94
		S	109	
	52	F	78	91
		S	104	
Hy_2 x C103 (lg_2)[c]	13	F	88	91
		S	94	
	26	F	101	101
		S	101	
	39	F	74	81
		S	89	
	52	F	65	71
		S	77	

Table 50. (Continued)

Variety	Population $(X10^3)$[a]	Fertile: Sterile[b]	Yield (Bu/acre)	Mean
Hy_2 x C103 (Lg_2)[d]	13	F	107	111
		S	115	
	26	F	70	92
		S	114	
	39	F	53	73
		S	92	
	52	F	47	67
		S	87	

Table 51. The yield response mean squares for the various design components for Experiment 4

Source	d.f.	Yield
Blocks	3	395
Pairs (Pa)	2	21818**
Error (a)	6	257
Leaf Angle (LA)	1	927*
Pa x LA	2	1758**
Error (b)	9	124
Population (Po)	3	9100**
Pa x Po	6	517**
LA x Po	3	1492**
Pa x LA x Po	6	325*
Error (c)	54	121
Fert:Ster. (F:S)	1	13342**
Pa x F:S	2	268*
LA x F:S	1	4165**
Pa x LA x F:S	2	187*
Po x F:S	3	869**
Pa x Po x F:S	6	31
LA x Po x F:S	3	409**
Pa x LA x Po x F:S	6	121
Error (d)	72	

* Statistically significant at the 0.05 level of probability.

**Statistically significant at the 0.01 level of probability.

Table 52. Plant characteristics and responses of XL-45 and DL-11 at 40,000 plants per acre for Experiments 5 and 6

Hybrid	Treatment[a]	Plants desire /plot	Har. plants /plot	Grams grain/ plant	Grain yield (bu/ac.)	Bar- ren (%)	No. of ears /plot	No. of nubbins /plot	15% silk. date	25% silk. date	50% silk. date	75% silk. date[b]	Silk. inter- val[c]
XL-45	1 wk. before	61	61.3	12.6	123	22.2	47.7	1.67	72.5	73.2	74.7	78.3	5.1
	0 wk. before	61	59.3	13.1	123	23.0	45.7	2.00	72.8	73.3	74.2	75.8	2.5
	1 wk. after	61	57.7	13.5	133	17.1	47.7	1.00	72.0	72.3	75.0	78.2	5.4
	Control	61	55.3	13.8	125	19.7	44.3	1.00	73.0	73.5	75.5	78.2	4.7
DL-11	1 wk. before	61	56.0	15.2	90	48.6	28.7	1.00	74.2	75.5	79.8	--	5.6
	0 wk. before	61	53.7	17.2	109	42.2	31.0	0.67	74.2	74.5	76.5	--	2.3
	1 wk. after	61	60.3	14.7	103	43.6	34.0	1.00	74.0	75.0	77.7	--	3.7
	Control	61	51.3	17.2	92	49.2	26.0	0.33	74.5	75.0	77.0	--	2.5

[a]Time at which the leaves above the ear leaf were tied up in relation to anthesis.

[b]DL-11 plots rarely ever reached 75% silking.

[c]Silking interval for XL-45 was the time between 25% and 75% silking and for DL-11 it was the time between 15% and 50% silking.

Table 53. Plant characteristics and the associated mean squares of XL-45 and DL-11 at 40,000 plants per acre for Experiments 5 and 6

Hybrid	Source	d.f.	Har. plants /plot	Grams grain/ plant	Grain yield (bu/ac.)	Bar-ren (%)	Number of ears /plot	No. of nubbins /plot	15% silk. date	25% silk. date	50% silk. date	75% silk. date	Silk. inter-val
XL-45	Blocks	2	35.58	0.19	205.3	11.1	12.33	1.58	0.646	0.021	0.521	2.312	2.77
	Treat.	3	19.42	0.89	63.7	21.3	8.00	0.75	0.583	0.243	0.944	4.299	5.14
	Error	6	20.25	0.31	55.4	18.4	12.67	2.58	0.313	0.243	0.965	5.674	4.66
DL-11	Blocks	2	0.33	1.46	160.5	23.3	6.08	0.75	0.146	1.188	8.062	--	6.27
	Treat.	3	44.22	5.23	249.1	36.9	34.75*	0.31	0.132	0.500	6.472	--	7.08
	Error	6	9.56	1.37	109.8	16.2	3.75	0.31	0.174	0.687	3.535	--	2.83

*Statistically significant at the 0.05 level of probability.

Table 54. Plant characteristics and responses of XL-45 and DL-11 at 40,000 plants per acre due to the application of glutamate, sucrose, and a combination of the two compounds for Experiments 7 and 8

Hybrid	Chemical[a]	Position of trmt.[b]	Grams grain/ plant	Grain yield (bu/ac.)	Barren (%)	No. of ears /plot	No. of nubbins /plot	15% Silk. date[c]	25% Silk. date[c]	50% Silk. date[c]	75% Silk. date[c,d]	Silk. interval[e]
XL-45	Gl-1	2A	13.2	140	11.3	29.0	0.67	72.3	72.8	74.3	76.7	3.9
		E	13.4	129	19.4	26.0	0.33	72.7	73.5	75.3	78.3	4.8
		2B	12.7	125	18.2	26.7	0.67	71.5	72.5	75.0	78.2	5.7
		C	13.5	138	17.9	27.7	0.33	72.2	73.0	75.3	78.3	5.3
	Gl-2	2A	13.3	121	21.7	24.3	0.33	72.0	73.0	75.3	78.5	5.5
		E	13.4	119	24.6	24.0	0.67	72.7	73.0	74.7	77.2	4.2
		2B	12.8	122	28.5	25.7	2.00	72.7	73.3	75.3	78.3	5.0
		C	13.8	131	20.5	25.7	1.67	71.2	71.8	74.0	77.3	5.5
	Suc	2A	14.1	129	26.6	24.7	0.33	72.3	73.2	76.2	79.5	6.3
		E	13.9	134	22.6	26.0	0.67	72.5	73.3	75.2	78.5	5.2
		2B	13.6	148	11.1	29.3	1.33	72.7	73.3	74.7	76.8	3.5
		C	12.4	115	22.9	25.0	0.67	71.5	72.7	75.7	80.0	7.3
	Gl-2 + Suc	2A	13.7	118	28.5	23.3	0.33	72.5	73.2	75.7	79.2	6.0
		E	13.5	141	18.1	28.3	0.67	72.8	73.8	76.0	79.3	5.5
		2B	14.3	132	23.7	25.0	0.00	72.7	73.2	74.3	76.7	3.5
		C	14.5	141	16.1	26.3	0.67	71.2	71.7	73.5	76.3	4.6
DL-11	Gl-1	2A	15.1	92	43.2	16.3	0.33	74.0	74.8	78.3	--	4.3
		E	16.1	82	56.4	13.3	0.33	74.0	74.8	77.7	--	3.7
		2B	15.1	75	60.7	13.3	1.00	74.5	75.3	79.2	--	5.2
		C	15.0	87	50.3	15.3	0.33	75.3	76.8	81.2	--	5.9
	Gl-2	2A	15.3	84	55.6	15.0	0.33	73.2	74.2	77.7	--	4.5
		E	15.2	73	56.3	13.0	0.67	74.5	75.8	79.8	--	5.3
		2B	16.3	93	45.6	15.3	0.33	74.0	74.7	76.7	--	2.7
		C	15.0	70	56.9	12.3	0.33	74.3	75.7	83.2	--	8.9

Suc	2A	16.3	81	54.3	13.7	0.67	74.0	75.2	80.0	--	6.0
	E	16.6	85	54.1	14.0	0.33	73.3	74.7	79.3	--	6.0
	2B	15.1	74	58.8	13.3	0.00	73.8	74.7	78.3	--	4.5
	C	15.3	76	54.5	13.3	1.00	72.3	73.5	76.8	--	4.5
Gl-2	2A	15.2	78	53.7	14.0	0.33	73.3	73.8	76.3	--	3.0
+	E	15.8	82	53.7	14.0	0.00	74.0	75.0	78.5	--	4.5
Suc	2B	16.4	87	50.9	14.3	0.33	74.3	75.2	78.2	--	3.9
	C	15.5	69	62.3	12.0	0.67	74.0	76.2	84.5	--	10.5

[a]Chemicals used were glutamate (Gl) at two rates (1 and 2), sucrose (Suc), and a combination of glutamate 2 and sucrose (Gl-2 + Suc).

[b]Positions of treatment were the second leaf above the ear leaf (2A), the ear leaf (E), the second leaf below the ear leaf (2B), and a control (C).

[c]Days from planting to respective silking percent.

[d]DL-11 rarely ever reached 75% silking so it was not reported here.

[e]Silking interval was days between 25% and 75% silking for XL-45 and 15% and 50% silking for DL-11.

Table 55. Plant characteristics with their associated mean squares for XL-45 and DL-11 at 40,000 plants per acre due to the application of glutamate, sucrose and a combination of the two compounds for Experiments 7 and 8

Hybrid	Source	d.f.	Grams grain/ plant	Grain yield (bu/ac.)	Bar-ren (%)	No. of ears /plot	No. of nub-bins/pl.	15% Silk. date	25% Silk. date	50% Silk. date	75% Silk. date	Silking interval
XL-45	Blocks	2	1.01	26	24	0.8	1.02	0.880	0.786	2.250	7.130	7.91
	Chemical (C)	3	1.37	263*	106	12.2	1.36	0.069	0.222	0.852	2.158	1.21
	Error (a)	6	0.86	48	43	3.8	0.97	1.054	1.029	2.910	9.387	6.91
	Position (P)	3	0.11	63	16	3.6	0.81	2.986	2.708	1.561	2.200	3.88
	C x P	9	1.08	371	97	10.3	0.68	0.602	0.644	1.885	4.880	3.65
	Error (b)	24	1.06	241	75	6.9	0.65	1.532	0.983	0.981	2.996	3.86
DL-11	Blocks	2	0.17	310	52	7.1	0.75	1.1405	0.943	16.630	--	15.82
	Chemical (C)	3	0.55	67	20	2.7	0.08	2.368	1.868	1.450	--	1.16
	Error (a)	6	2.37	719	162	17.9	0.22	0.571	0.977	5.283	--	3.43
	Position (P)	3	1.20	162	41	5.1	0.13	0.618	2.201	29.046*	--	27.64*
	C x P	9	1.00	197	103	4.0	0.35	1.280	2.215	15.468	--	10.79
	Error (b)	24	2.11	370	84	9.5	0.30	1.026	1.087	7.280	--	6.51

*Statistically significant at the 0.05 level of probability.