INTENSIVE MANAGEMENT STUDIES WITH CORN (*ZEA MAYS* L.) AND SOYBEANS (*GLYCINE MAX* L. MERRILL) AND RESULTING YIELD AND NUTRIENT COMPOSITION

By

Jonathan Glen Dahl

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ABSTRACT

EFFECT OF PLANT POPULATION ON YIELD AND NUTRIENT COMPOSITION OF CORN (*ZEA MAYS* L.) AND SOYBEANS (*GLYCINE MAX* L. MERRILL)

BY

JONATHAN GLEN DAHL

Various irrigated corn and soybean varieties were evaluated for yield and nutrient composition with higher plant populations. Additional subtreatments for the corn experiments included trickle versus sprinkler irrigation, plastic mulching, zinc and sulfur addition, and gel treatment. Nitrogen fertilization, foliar fertilization, and fungicide application were evaluated on soybeans.

Increasing plant density from 69,000 to 90,000 plants/ha increased corn grain yields by 11% in 1981. In 1982 only one of three experiments showed a yield response to higher plant populations. Corn nutrient composition was generally not affected by plant population. Plastic mulching, zinc plus sulfur, or gel had no effect on grain yield.

Soybean yield of one late-planted variety in 1981 was increased by 18% from the addition of 200 kg N/ha at either spring tillage or prebloom. In 1982 plant population, foliar fertilization, or fungicide application had no effect on yield. Foliar fertilization did not increase soybean seed N.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

CORN LITERATURE REVIEW

Corn Plant Population

The optimum plant population for maximum corn grain yield has been periodically reexamined. The development of new varieties and improved management practices have allowed higher plant populations to be used with little adverse effect. Lang et al. (1956) noted that hybrids do respond differentially to plant population pressure. In general, increasing corn plant population increases yield to a point, beyond which further increases occur. Holliday (1960) described this relationship according to two curves: (1) asymptotic; and (2) parabolic.

For the asymptotic curve each increase in plant population results in an increase in yield up to a maximum, where the curve levels off. Dry matter production often conforms to this type of curve. An explanation for this plateau response is presented from work on cotton and white clover (Ludwig et al.,1965; McCree and Troughton,1966). Respiration of the shaded leaves in the canopy is much lower than those exposed to intense illumination. This allows the overall crop growth rate to level off above optimum leaf area index (LAI) values. Williams et al. (1968) found that as the plants per hectare (ha) increased from 17,500 to 125,000, the dry weight increased by approximately 500 grams per square meter. The increase over this range was nearly linear. Similar increases in dry matter yield as a function of plant population are reported elsewhere (Stivers et al., 1971; Cummins and Dobson, 1973; Rutger and Crowder, 1967). A significant population by location interaction was found in one study (Rutger and Crowder, 1967). This indicates that the optimum population for maximum dry matter yield may depend on climatic or soil characteristics.

For the parabolic curve, yield increases with increasing plant population to a maximum. Each additional incremental increase in plant population results in decreases in yield from the maximum. Corn grain yield often conforms to this type of curve. Decreases in yield above the optimum plant population are due to a reduction in size or number of ears (Rutger and Crowder, 1967). The optimum plant population for maximum corn grain yield varies with hybrid and location (Lang et al., 1956; Rutger and Crowder, 1967). Williams et al. (1968) evaluated plant populations up to 125,000 plants/ha and obtained the maximum grain yield at 48,700 plants/ha. Yield dropped off sharply above this level even though the corn was irrigated. Poor seed-set at higher plant populations limited yields. Fery and Janick (1971) found the optimum plant population to be 38,000 plants/ha for nonirrigated corn with populations up to 109,000 plants/ha. Brown et al. (1970) compared irrigated and nonirrigated corn at various plant populations. Increasing population of irrigated corn, grown in 102 cm row spacing, from 27,000 to 62,000 plants/ha increased yields approximately 3,000 kg/ha. For the irrigated 51 cm row spacing, a population increase from 48,000 to 94,000 plants/ha increased yields approximately 2,000 kg/ha. They noted little response to increases in plant population for the nonirrigated treatments. They concluded that most of the competition between nonirrigated plants was for moisture. For irrigated plants, light was probably the main environmental factor governing competition. Other researchers have reported similar responses to plant population when moisture was adequate, and little response during dry years (Lutz et al., 1971; Hicks and Stucker, 1972; Giesbrecht, 1969).

Plant population also affects other characteristics of the plant. Increasing population from 40,000 to 80,000 plants/ha may significantly increase ear height and ear moisture (Rutger and Crowder, 1967). They also found decreased stalk diameter, ear weight, ear length, and ear diameter. Increasing population had no significant effect on plant height or percent barren stalks in their study. Other researchers found no effect of plant population on ear moisture at harvest (Lutz et al., 1971; Moll and Kamprath, 1977). Giesbrecht (1969) noted a tendency for higher lodging, and more barren stalks with high populations, particularly in a dry year.

Trickle versus Sprinkler Irrigation of Corn

Sprinkler irrigation has been used in the humid regions of the United States for many years to supplement rainfall during the growing season. Irrigation is especially important on sandy soils. Their low water-holding capacity makes timely water application necessary to insure maximum yield. Recently, trickle irrigation has become an alternative method for irrigating large fields.

Trickle irrigation involves the use of emitters, or small holes in plastic lines, laid by the base of the plant to deliver small quantities of water. Trickle irrigation is being adapted to almost all types of crop production (Boaz, 1973; Dan, 1974; Gornat et al., 1973; Goldberg et al., 1971; Halevy et al.,1973; Yagev and Choresh, 1974; Waterfield, 1973). It can also be used on a wide range of soil types and topographies. The U.S. acreage in trickle irrigation was only 250 hectares in 1970, but quickly expanded to 180,000 hectares by 1974 (Bresler, 1977). Bresler cites several advantages of trickle irrigation. These include improving the soil-water regime; reducing salinity hazards; partial wetting of the soil volume; maintaining dry foliage; improving nutrient availability; and surface-soil structure improvement.

Frequent, low-volume applications of water can improve the soil-water regime. There is evidence that yield of many crops is increased by maintaining high values of soil-water potential in the effective root zone (Rawitz, 1970; Hillel, 1972; Childs and Hanks, 1975).

The salinity hazard is reduced by trickle irrigation. Bernstein and Francois (1973) working with bell pepper (Capsicum frutescens) determined that while brackish water caused a 14% yield reduction for trickle irrigation, it caused a 94% reduction in yield for sprinkler irrigated plots. The sprinkler irrigation washed the salts down into the root zone causing osmotic shock, while the trickle irrigation kept the salts near the surface and at the periphery of the wetted zone.

Trickle irrigation results in only partial wetting of the soil volume. By reducing the area of the surface wetted, evaporation is reduced. Growth of weeds outside the wetted zone is also reduced.

Maintaining dry foliage retards the development of leaf diseases. Frequent or continuous application of soluble fertilizers at low concentrations is possible and seems to be a good practice (Safran and

Parnas, 1975). Leaching of nutrients with low-volume water applications is not a problem. A final benefit is the improvement of surface-soil structure. Trickle irrigation reduces the energy of the water droplets and thus crust formation from the impact of droplets on the soil surface is prevented.

There are few studies comparing trickle and sprinkler irrigation. Bernstein and Francois (1973) using bell peppers cited a 50% yield advantage for trickle irrigation over sprinkler irrigation when equal amounts of water were applied. In the study the trickle irrigated plots had sufficient water for maximum yield, but the sprinkler irrigated plots did not. When sufficient water was applied to both treatments, yields were equal, but water use was 20% less for the trickle irrigated plots. Similar studies on field corn are not available, but the response of corn to irrigation is well documented.

The water requirement of corn is approximately 40 to 60 cm of evapotranspiration (ET) per season (Downey, 1971). Distribution of rainfall is often such that when corn has the greatest demand for water, little is available. Water deficits at anthesis are most damaging to grain yields followed by early ear and then the vegetative stages. A 53% reduction in grain yield was noted when water stress was imposed at anthesis, while a 30% reduction in grain yield resulted when water stress occurred during the three week period after silking (Classen and Shaw, 1970). Follett et al. (1978) set up irrigation treatments of 0, 0.5, 1.0, and 1.5 times the calculated crop ET according to the Jensen-Haise equation (0, 10, 23, and 37 cm of water applied, respectively). Forage yields in this study increased an average of 2.3, 5.2, and 6.5 metric tons per hectare for the 10, 23, and 37 cm of water applied, respectively. Similarly grain yields were increased 1,470, 3,360, and 4,290 kg/ha, respectively. They concluded that irrigation of sandy soils would result in large yield increases nearly every year in North Dakota.

Plastic Mulching of Corn

Soil temperatures in late April and early May in Michigan are usually too cold for rapid growth of corn. Slow growth during this period reduces the effective length of the growing season. Higher yielding long-season hybrids are rarely able to mature before the killing fall frost.

Beauchamp and Lathwell (1967) using root-zone temperatures of 12.5, 15, and 17.5 degrees celcius (C) studied the effect of temperature on corn growth. The temperature between the two-leaf and six-leaf stage had the greatest influence on growth. The period before the two-leaf stage was nearly as important. Root-zone temperatures of 15, 20, and 25 degrees C had virtually no influence on the length of the interval between the six-leaf and eight-leaf stage. Early soil warming appears to be an effective method of stimulating early corn growth.

Rykbost et al. (1975) used buried heating cables to raise soil temperatures by 1.0, 4.0, and 6.5 degrees C at 5, 25, and 45 cm depths, respectively. Emergence of field corn was 1 to 3 days earlier on heated plots, and early seedling growth rate was increased. Later in the season corn plants on heated plots were taller and had thicker stalks. A more practical method of heating the soil is with plastic mulches.

Plastic mulches warm the soil by trapping incoming radiation during the day. At night the loss of heat from the soil is reduced. Soil temperatures at depths of 5.0 to 7.6 cm were increased by 1.1 to 4.4 degrees C for clear plastic and 0.6 to 2.2 degrees C for black plastic (Adams, 1967; Lee et al., 1978; Iremiren and Milbourn, 1979). Black plastic is less efficient than clear plastic in retaining heat because of poor heat transfer from the plastic through the air layer to the soil (Lee et al., 1978).

Clear plastic mulch in England reduced the time from planting to emergence by 15 days, and to silking by 13 days for maize (Iremiren and Milbourn, 1979). They also reported a reduction in the spread of silking from 19 days without a plastic mulch, to 8 days with a plastic mulch. Similar studies found reductions in time to silking and to maturity by 2 to 9 days (Andrew et al., 1976; Lee et al., 1978). In addition to soil warming, plastic mulches have other benefits.

Conservation of moisture under plastic mulches is one such benefit. Where the plastic mulch fits snugly around the corn stalks, ET was reduced by 2/3 compared to corn grown without plastic mulching (Free and Bay, 1965). They also noted better aggregate stability of the surface layer under plastic mulch. This was attributed to reduced impact of raindrops hitting the soil surface.

Yield increases from soil warming are fairly common. Average dry matter yield increases of 11% and 22% are reported (Iremiren and Milbourn, 1979; Rykbost et al., 1975). Lee et al. (1978) found large differences in dry weight early in the season between a clear plastic mulch and either a black plastic mulch or no mulch. At maturity both the clear and black plastic mulches were significantly higher in dry weight than the control, but not each other. Others have concluded that there are other factors such as soil retention of nitrate (Black and Greb, 1962) and improved root environment (Sheldrake, 1967) under plastic mulches that have a greater influence on seasonal growth than temperature alone.

Soil warming increased field corn grain yields by an average of 20%, 39%, and 28% in studies by Free and Bay (1965), Iremiren and Milbourn (1979), and Rykbost et al. (1975), respectively. For sweet corn, ears per plant and weight per ear was higher for clear and black plastic mulches than for bare soil (Lee et al., 1978). However, in a year when air temperatures were above or near normal for May and June the benefit in early growth and yield was considerably less (Free and Bay, 1965).

SOYBEAN LITERATURE REVIEW

Nitrogen Fertilization of Soybeans

High soybean yields require large amounts of nitrogen (N). A 5000 kg/ha seed yield, with an average N content of five percent, requires 250 kg N/ha just for the seed. This places a tremendous demand on the plant. There are three sources from which the plant may fill this requirement: (1) biological nitrogen fixation; (2) mineralization of soil N; and (3) fertilizer N.

Biological nitrogen fixation is a natural process in which *Rhizobium* bacteria in the soil are able to fix nitrogen from the atmosphere and supply it to plants in exchange for carbohydrates. Under favorable moisture and temperature conditions nitrogen fixation begins about 14 days after soybean emergence (Hardy et al., 1971). Maximum fixation occurs during pod-filling (Harper and Hageman, 1972). It is estimated that nitrogen fixation can supply upwards of 160 kg N/ha, although 100 kg N/ha is average (Vest et al., 1973). This leaves a large portion of the soybean nitrogen supply that must come from the soil.

Mineralization of soil N is an important process for providing nitrogen to soybeans. The release of 45 kg N/ha during the growing season for each percent of soil organic matter is a good rule of thumb (Geist et al., 1970). Because N mineralization is dependent on soil temperature and moisture conditions it can be quite variable from year to year (Mengel and Kirkby, 1982). This variability contributes to the difficulty of predicting responses to nitrogen fertilization of soybeans.

Yield responses to N fertilization have been inconsistent and reported increases small. Ham et al. (1975) used various forms of N at 224 kg/ha before planting. He noted yield increases in 80% of the ammonium nitrate or urea treatments at two of the locations, but not at the third location. Sulfur-coated urea or urea plus sulfur did not increase yields. He also found that plant height and lodging either increased or remained constant with N fertilization. Nitrogen rates up to 224 kg/ha produced significant yield responses at 9 of 13 sites in Nebraska (Sorensen and Penas, 1978). The largest seed yield increase was 570 kg/ha in their study. In Arkansas, Bhangoo and Albritton (1976) observed yield increases of 21 to 26 percent when 224 kg/ha N as ammonium nitrate was applied before planting. They also noted that symbiotic N fixation decreased linearly to near zero as applied N went from 0 to 448 kg/ha. Total N uptake, however, was more than 30% higher in each of three years from application of 224 kg N/ha versus no N applied. There is a trade-off of fixed N for fertilizer N, but it is not an equal trade-off. Al-Ithawi et al. (1980) found similar results from increasing fertilizer N rate. Total N uptake increased an average of 20% and 10%, with average yield increases of 12% and 8%, for the two years of their study. While these studies have shown encouragement for the use of nitrogen fertilizers on soybeans, other studies have shown no response to nitrogen fertilization.

Beard and Hoover (1974) used rates of N up to 168 kg/ha in California and found no significant yield increases. Ammonium sulfate was the fertilizer source and treatments were applied preplant; or half preplant and half at flowering; or all at flowering. Fertilizer N applied before planting reduced nodule number, but up to 112 kg N/ha at flowering had no effect on nodule formation. In Illinois, soybean yield response to applied N was noted in only 3 of 133 trials (Welch et al., 1973). Rates up to 134 kg N/ha in Florida failed to produce a yield response (Hinson, 1975).

A number of soil factors related to yield response from N fertilization of soybeans have been studied. In Nebraska, Sorensen and Penas (1978) used regression analysis to eliminate variables of low agronomic relevance. Two models emerged from this procedure and the soil factors determined most important were soil pH, soil nitrate level, soil organic matter content, and yield level.

In the Nebraska study decreases in soil pH led to increases in soybean yield response to N fertilization. In Georgia, average yield increases of 1200 kg/ha from N + Mo application on acid soils (pH ranged from 4.5 to 5.6) are reported (Parker and Harris, 1977). Moderate to severe N deficiency symptoms were noted on plants not receiving N or Mo in each year. This likely resulted from the effect of low pH on the nitrogen-fixing bacteria (Ham et al., 1971). In other studies response to N fertilization does not appear linked to soil pH (Ham et al., 1975; Al-Ithawi et al., 1980; Bhangoo and Albritton, 1976).

Increasing the soil nitrate level led to a reduction in soybean yield response to N fertilization in Nebraska (Sorensen and Penas, 1978). Other studies report similar findings and conclude N fertilization of soybeans should be based on residual soil N levels (Bhangoo and Albritton, 1976; Al-Ithawi et al., 1980). Welch et al. (1973) in Illinois, however, found that 360 kg N/ha applied to the

preceding corn crop (with no more than 180 kg N/ha removed by the corn) had no effect on soybean yields the following year.

Soil organic matter content of 2.90% showed maximum yield response to N fertilization (Sorensen and Penas, 1978). They concluded that at low organic matter levels response was reduced due to structural effects, and at high organic matter levels due to extensive nitrification during the growing season.

The relationship between yield level and N application on soybeans is more complex. Yield level depends on environmental conditions (moisture, temperature, etc.) and on cultural factors (planting date, cultivar selection, soil conditions, etc.). This means a large number of variables can affect response to N fertilization. Sorensen and Penas (1978) noted increased response to N fertilization as yield level decreased. They concluded that low yield levels indicate environmental limitations on crop growth. These limitations are believed to reduce the effectiveness of Rhizobium sp. to fix nitrogen. Al-Ithawi et al. (1980) believe that responses to applied N are often noted at high yield levels. They concluded that nitrogen fixation would be unable to meet the needs of the plant at these levels and thus N fertilizers could be utilized.

The existence of two models to describe soybean yield response to N fertilization indicates it is a complex problem with no simple answers. Sorensen and Penas (1978) noted in some cases that one model worked better, and in other cases another model was superior. They suggest that there may be more than one way of combining the four factors (pH, soil nitrate level, soil organic matter, and yield level) to achieve maximum responses. They also indicate these factors may not influence N response directly, but may be related to other factors which do (such as soil temperature or moisture).

Soybean Planting Pattern

Soybean planting pattern has received considerable attention recently as researchers attempt to find the optimum plant geometry for maximum yield. Narrower rows and higher plant populations intercept a larger portion of the incoming solar radiation and theoretically produce higher yields. Conversely, increasing plant competition places more stress on the plants, and often leads to lodging. Narrow row soybeans require an effective herbicide program (cultivation is not possible), adequate moisture and nutrients, insect control, and proper variety selection (Beatty et al., 1982). Variety selection is also important when increasing plant populations. Various characteristics of soybeans have been studied using row width and plant population as variables.

Hicks et al. (1969) reported that pods per plant was unaffected by row width. Beatty et al. (1982) found that while the number of pods per plant decreased as row width decreased, the total number of pods was unaffected. This response may have been due to changes in plant population. Beatty increased plant population in the narrower rows, whereas Hicks kept the plant population constant. The effect of narrowing row spacing on lodging has been variable. Increases, decreases, and no effects on lodging have been reported (Hicks et al., 1969; Cooper, 1977; and Weber et al., 1966). Maturity date and plant height are little affected by row width (Weber et al., 1966).

Cooper (1977) noted seed yield increases as row width decreases.

There was a ten to twenty percent yield advantage for 17 cm rows over 50 and 75 cm rows. Irrigating early maturing cultivars in the 17 cm rows produced an even greater yield advantage of thirty to forty percent in his study. Taylor (1980) reported similar results in a year with adequate rainfall, but as the moisture level decreased the yield differences became less. He concluded row spacing had no effect on yield in a dry year. Soybean yield increases from narrower rows are reported elsewhere for the northern United States and Canada (Weber et al., 1966; Hicks et al., 1969; Beatty et al., 1982; and Johnston et al., 1969). These results are consistent with the hypothesis that canopy closure by initial pod-fill allows more photosynthesis to occur during pod-fill resulting in higher yields from narrow rows when there is adequate moisture.

Plant population changes have also been noted to affect other characteristics of soybeans. Dominguez and Hume (1978) reported that increased plant density decreased total flowers and and pods produced per plant. Higher plant populations caused an increase in flower abortion percent in their study. They concluded that the overall effect of higher plant populations was more total flowers and pods produced per unit area. The height of the lowest pod was increased with higher plant density in their study and also in a study by Lueschen and Hicks (1977).

Lodging has been noted to increase at higher plant populations (Hicks et al., 1969; Weber et al., 1966; Dominguez and Hume, 1978). Hicks et al. (1969) attributed the increase in lodging to a decrease in stem diameter. Dramatic increases in lodging score are not reported by most researchers from increasing plant populations. On a scale from one (erect) to five (prostrate) scores generally increase by one point or less when going from normal populations to populations up to 1.2 million plants/ha. Varietal differences in lodging susceptibility exist with the taller varieties being more likely to lodge (Cooper, 1971).

Plant population may also affect both plant height and maturity. An increase in plant height with increasing density was noted in two studies (Hicks et al., 1969; Weber et al., 1966). There is variability among cultivars as short determinate types increased more than other types. Other studies show no effect of density on plant height (Lueschen and Hicks, 1977; Costa et al., 1980; Dominguez and Hume, 1978). Weber et al. (1966) reported that maturity is delayed up to 3 days by increasing plant population from 258,000 to 516,000 plants/ha.

Increasing plant populations above normal rates does not always lead to increased yields (Hicks et al., 1969; Costa et al., 1980; Lueschen and Hicks, 1977). Weber et al. (1966) obtained the highest leaf area index (LAI) and dry weight with a population of 516,000 plants/ha, but not the highest yield. The highest yield was at 258,000 plants/ha, although there were no population levels between these two. Cooper (1974) determined 375,000 plants/ha to be optimum for 18 and 51 cm spaced rows in his study. Lueschen and Hicks (1977) observed a yield increase in one of three years from higher plant density. This yield increase was attributed to a more uniform plant stand in a year when a severe hail storm damaged many of the plants. Dominguez and Hume (1978) observed a linear yield increase when plant density was increased from 400,000 to 1.2 million plants/ha. Small yield increases of 340 and 360 kg/ha were reported for two years data. The ability of individual soybean plants to compensate for missing plants may account for the small response noted to increased plant density. Stivers and Swearingin

(1980) studied the effect of number of skips and length of skips in the row on final seed yield. Yield reductions were under 10% until 0.91 meter or longer skips occupied 50% of the total row length. Skips of 0.61 meters occupying 25% of the total row length reduced yields only 4.5%. The row spacing is this experiment was 76 cm. Skips in narrower rows would be expected to have even less effect on final seed yield.

Foliar Fertilization of Soybeans

Promises of increased yields are renewing interest in foliar fertilization of field crops. Much of the interest was sparked by the remarkable soybean yield increases in Iowa (Garcia and Hanway, 1976). Foliar fertilizer research has focused on fertilizer materials, penetration and uptake of fertilizer solutions, assimilation of foliar applied nutrients, and the resulting plant nutrient concentrations and grain yield.

A wide variety of materials have been used to foliar fertilize field crops. Neumann et al. (1981) tested several fertilizer solutions containing N, P, K, and S on corn leaves. They found that minor differences in chemical structure of the fertilizers made a big difference in the concentrations causing leaf damage. For example, K_2HPO_4 was damaging at concentrations of 0.05 M, whereas KH_2PO_4 was damaging only at much higher concentrations (0.50 M). Neumann concluded that while all osmotically-active fertilizer compounds can induce tissue damage, those with high solution pH values (greater than approximately 6.5) cause damage at lower concentrations (0.04 to 0.10 M) than those with low solution pH values. Urea phosphate is an exception.

Dr. John Hanway (personal communication) recommends using urea, potassium polyphosphate, and potassium sulfate for foliar fertilization. These materials have proven most effective in his studies at Iowa State University. The nitrogen component is most important, because it is required in large quantities by the plant. Urea is the most effective and least toxic nitrogen form (Hanway, 1980). The phosphate materials do not cause leaf burn (tissue injury) at the levels normally applied (Barel and Black, 1979).

Hanway (1980) worked on determining the proper ratio between the elements (N-P-K-S), and on the rate of application for soybeans. Increasing the amount of any of the nutrients above the 10:1:3:0.5 ratio of N:P:K:S did not result in additional yield increase. Interestingly, this is the ratio found in soybean seeds. The maximum rate of urea Hanway found he could safely apply without causing serious leaf burn was 22 kg N/ha at each application, or 88 kg N/ha for the entire season. Leaf burn can be a serious problem and, if significant, usually leads to yield reductions. Little is known about the mechanism that induces leaf burn. It is known that cyanate, biuret, and cyanamide (decomposition products of urea) are responsible for causing the burn from urea application (Hanway, unpublished source). Spraying in the hot sun contributes significantly to leaf burn (Hanway, 1980; Vasilas et al., 1980). Vasilas also reported that morning applications resulted in faster drying of labeled N^{15} on leaf surfaces, more N lost to volatilization, and a lower percentage of the N taken up than for evening applications.

Uptake of foliar fertilizers by plants has been widely studied. The most important barrier to leaf entry is the cuticle. Because the cuticle must serve as a first line of defense it is only natural that it should be thick and relatively impermeable. Most penetration of the cuticle is accomplished through the stomatal pores, hairs, and fine cracks. The stomates are believed to be the major absorption sites for the leaves. Wittwer et al. (1967) noted that the cuticle is much thinner inside the stomates, and the absorbing area is much greater. Work with pears has determined that for significant quantities of a fertilizer solution to penetrate the stomates, the surface tension of the penetrating solution must be relatively low (Greene and Bukovac, 1974). This indicates the importance of including a surfactant in the spray solution. Neumann and Giskin (1979) found that in a greenhouse study Phaseolus vulgaris had a higher yield response to foliar fertilizers when an organosilicone surfactant (L77) was added rather than a carbohydrate based surfactant (Tween 80). They concluded that L77 allowed the spray solution to spread over the leaf as thin films, whereas Tween 80 formed droplets, which concentrated the salts and caused more leaf burn. This supports earlier studies by Neumann and Prinz (1974). The stomates must be open for penetration, although the degree of opening does not appear important (Shonherr and Bukovac, 1972).

There are various factors that control the thickness of the cuticle and thus would affect absorption of foliar fertilizers. Hull et al. (1975) listed certain plant and soil factors that determine cuticle thickness. These included plant size or maturity, soil texture, and terrain. He listed the most important environmental factors as light intensity, temperature, and moisture conditions. The pattern of cuticle lipid constituents appears to be constant under different environmental conditions, but the total amount of cuticle is proportional to the light intensity (Tribe et al., 1968). It is generally concluded that light promotes cuticle development (Hull et al., 1975). Temperature affects wax formation more than the cuticle. Work with Nicotiana glauca showed maximum cuticle development at median temperatures, but a greater percentage of wax at higher temperatures (Skoss, 1955). Moisture stress inhibits absorption of foliar applied solutes (Currier and Dybing, 1959; Van Overbeek, 1956). Foliar absorption of labeled P^{32} was lower at -3 atmospheres than at -1/3 atmosphere (Pallas and Williams, 1962).

Because there may be differences in cuticle thickness at different locations, the efficiency of foliar fertilizers may also vary. Site by site uptake studies using radioactive labeled fertilizer sources may be necessary. In one such study using ^{15}N-labeled urea on soybeans, four sprays (88 kg N/ha total) resulted in 44% (in 1976) and 67% (in 1977) of the N being taken up by the plant (Vasilas et al., 1980). Of this, approximately 94% eventually ended up in the seed. The plants were sprayed in the morning in 1976 and in the evening in 1977. They concluded that morning sprays resulted in faster drying of the spray on the leaf surfaces and thus less uptake. The 67% efficiency in 1977 compares favorably with soil applied nitrogen.

Foliar fertilizers are supposed to extend the seed-filling period by supplying leaf nutrients and thus delaying leaf senescence. This is generally not the case. Gross photosynthesis in the upper leaves does increase slightly following the initial spray (Boote et al., 1977; Sesay and Shibles, 1980). Photosynthetic rate, soluble protein, and chlorophyll in both control and foliar fertilized treatments started to decline at the same time and rate (Sesay and Shibles, 1980). This indicates foliar fertilizers do little to extend the life of the soybean plant. Boote et al. (1977) concluded that gross photosynthesis was extended one day at most. Leaf N increased initially, then declined parallel to photosynthesis (Boote et al., 1977; Parker and Boswell, 1980; Sesay and Shibles, 1980). Increases of 9.2% and 6.1% were reported for upper and lower leaves, respectively. Similar trends were reported for P and K (Boote et al., 1977; Parker and Boswell, 1980; Sesay and Shibles, 1980). Sesay and Shibles also reported that the decline in nutrient levels began before the first spray application at initial pod-fill. The spray only delayed the decline in their study. Increases in grain N are also reported (Parker and Boswell, 1980; Syverud et al., 1980).

Yield results obtained from foliar fertilization are mixed. Large soybean yield increases are reported, as are decreases. Garcia and Hanway (1976) used two fertilizer sprays applied between the R4 and R7 growth stages (during pod-fill) to produce yield increases up to 540 kg/ha. The largest increases in their study were obtained when the sprays contained all four nutrients (N-P-K-S). The study was repeated the following year with four to five spray applications of N,P,K, and S. The largest yield increase of 1040 kg/ha was reported from applying the nutrients at a rate of 88 + 8.8 + 26.4 + 8.8 kg/ha of N + P + K + S. Increasing N from 88 to 176 kg/ha resulted in decreases in yield from the maximum. Irrigation along with the foliar fertilizers increased yields the most in their study (1550 kg/ha).

Vasilas et al. (1980) used many of the same principles as Hanway, but received no soybean yield response the first year. They attributed this to an unsatisfactory irrigation system. Severe leaf burn and water stress were observed. The next year using trickle irrigation they obtained a significant yield increase of 1040 kg/ha from foliar fertilization. Syverud et al. (1980) used higher rates of N than Hanway to increase yields in a dry year. Yields increased as N was increased from 44 to 132 kg/ha in their study. No yield response was noted in a normal rainfall year. They concluded that in a dry year the roots would be unable to take up sufficient N to satisfy the needs of the plant. Boote et al. (1977) reported slight yield decreases from using higher rates of foliar fertilizer than those reported by Hanway. Parker and Boswell (1980) reported yield decreases up to 500 kg/ha from foliar fertilization. Considerable leaf burn was noted in their study.

CHAPTER 2

EFFECT OF PLANT POPULATION ON GROWTH AND YIELD OF CORN

INTRODUCTION

Considerable research on the optimum plant population for maximum corn grain yield was conducted in the late 1960's. Since then new hybrids have been developed that are better able to withstand the pressures of higher plant populations. The objective of this study was to evaluate three corn hybrids at three plant population levels to determine the optimum plant population for maximum yield in the 1980's. A second objective was to gather information on differences in growth stage development and nutrient uptake between hybrids and plant populations.

MATERIALS AND METHODS

Management Practices and Experimental Design

The corn studies were conducted on the Michigan State University Soil Research Farm in 1981 and 1982. The soil type for the studies was a Metea loamy sand. Metea is a loamy, mixed, mesic Arenic Hapludalfs and is typically well drained.

The 1981 study was designed to evaluate three corn hybrids (Pioneer 3780, Michigan 5922, and Pioneer 3572) at three plant populations (69,000, 84,000, and 100,000 plants/ha). The experimental design was a three by three factorial with one extra treatment. The row width for the lower two populations was 76 cm. In order to plant the highest plant population level it was necessary to use a 63-13 cm double-row spacing. These treatments were planted by first planting 76 cm rows, and then offsetting the planter drawbar 13 cm and planting the second row. To check the effect of row spacing, an extra treatment, Michigan 5922 at 84,000 plants/ha in the 63-13 cm double-row, was planted. The plot size was 305 cm by 2438 cm with four replications.

The corn is rotated each year with the soybeans to prevent insect buildup in the soil. The study was deep chiseled to a depth of 50 cm in the fall of 1980. Spring tillage consisted of disking, and twice over with a field cultivator.

Weed control was accomplished with a preplant application of Lasso (2.8 kg active ingredient (a.i.)/ha) plus Atrazine (0.56 kg a.i./ha) plus Bladex (1.12 kg a.i./ha). Furadan insecticide (1.12 kg a.i./ha) was applied over the row at planting. Furadan was also applied in the whorls of the plants on June 24 for control of corn borer.

Fertilizer was applied in split applications. Before planting 560 kg/ha of 46-0-0 and 336 kg/ha of 0-0-60 were applied and incorporated. A starter fertilizer of 224 kg/ha 13-52-0 was applied at planting. An additional 438 kg/ha of 46-0-0 was dissolved and applied through the irrigation system in early July. Total N + P_2O_5 + K_2O was 489 + 116 + 202 kg/ha.

Planting was on April 27 using a John Deere Max-Emerge planter. The seed depth was 3.8 cm. Starter fertilizer was banded 5.1 cm to the side and 5.1 cm below the seed.

Irrigation was scheduled with the aid of tensiometers placed at two depths, 31 and 46 cm. Water was applied when the tensiometers averaged 50 centibars suction. A total of 23.0 cm of water was applied between June 30 and August 24 with an overhead sprinkler irrigation system.

The plots were harvested on October 12 for grain, and on October 20 the stover was removed. The grain was hand harvested from both center rows and run through a picker-sheller. The stover was hand harvested, ground in a silage chopper, weighed, and moisture tested for dry matter calculation. The grain harvest area was 152 cm by 2438 cm, and the silage harvest area was 76 cm by 910 cm.

In 1982 the plant population study was incorporated into two separate studies. The first study consisted of two hybrids (Pioneer 3780 and DeKalb 55A) at two plant population levels (69,000 and 84,000 plants/ha) in which the plots were either sprinkler or trickle irrigated. The corn hybrids were the whole plot treatments and plant populations were the subplot treatments. The second experiment was a plant population study with DeKalb 55A at two plant population levels (69,000 and 84,000 plants/ha). There were various other subplot treatments which will be detailed in Chapter 4. Row width was 76 cm and the plot size was 305 cm by 1219 cm with four replications in each study.

The studies were deep chiseled to a depth of 50 cm in the fall of 1981. The area was moldboard plowed to a depth of 20 cm in the spring, and then disked and field cultivated before planting.

Weed control was accomplished with a preplant application of Lasso (2.8 kg a.i./ha) plus Atrazine (0.56 kg a.i./ha) plus Bladex (1.12 kg a.i./ha). Lorsban insecticide (1.5 kg a.i./ha) was applied over the machine planted rows.

Fertilizer was applied to the studies in split applications. Before planting 303 kg/ha of 5-20-20 and 504 kg/ha of 46-0-0 were applied and incorporated. A starter fertilizer of 168 kg/ha of 8-32-14 with 4% sulfur and 2% zinc was applied to the machine planted treatments. No starter fertilizer was applied to the hand planted treatments. An additional 246 kg/ha 46-0-0 was supplied to all plots through the irrigation system in early July. The total N + P_2O_5 + K_2O for machine planted plots was 374 + 114 + 84 kg/ha, respectively; and for hand planted plots it was 361 + 60 + 60 kg/ha, respectively.

Planting was on April 23 for the trickle versus sprinkler irrigation study and on April 24 for the plant population study. A John Deere Max-Emerge planter was used on the machine planted treatments. The seed depth was 3.8 cm and starter fertilizer was banded 5.1 cm to the side and 5.1 cm below the seed.

Tensiometers were used at the same depths as in 1981 to schedule irritation. Irrigation was initiated when tensiometers averaged 50 centibars suction. A total of 14.0 cm of water was applied between July 1 and September 3.

Grain harvest was begun on September 30 when one center row was hand picked and run through a picker-sheller. On October 1 the stover from the hand harvested row was fed through a silage chopper, weighed, and moisture tested for dry matter calculation. The other center row was machine picked and shelled on October 15. Harvest area for the grain was 152 cm by 1219cm, and for the stover it was 76 cm by 1219cm.

Growth and Yield

Date of emergence and observations on growth were recorded throughout the growing season in 1981 and 1982. The growth stages up to pollination were recorded for each hybrid in 1981. The growth stage descriptions are given in Table 2-1. Percent lodging was recorded in 1981. Also, the effectiveness of Furadan treatment for corn borer control was checked in treated versus nontreated rows of Pioneer 3780 in 1981. Final plant populations and barren stalks were counted at harvest. Grain yields were calculated from the center two rows of the plots and adjusted to 15.5% moisture. In 1981 the entire row was harvested for grain, but in 1982 a two to three foot border on the ends of the plots was not harvested.

Soil Sampling and Analysis

Composite soil samples were taken each year in April to a depth of 20 cm. Samples were air dried at room temperature and sent to the Michigan State University Soil Testing Laboratory for analysis. The

Table 2-1. [1]Growth stages of the corn plant.

Growth type	Diagnostic character	Growth stage (Numerical Designation)
Pre-emergence	Seed planted	0
Emergence	Coleoptile above soil	0.1
Two-leaved	2 leaves fully open	0.5
Early whorl	4 to 6 leaves fully emerged	1
Mid-whorl	8 to 10 leaves fully emerged	2
Late whorl	12 to 14 leaves fully emerged	3
Tassel	16 leaves fully emerged	4
Silk	Silks emerging, pollen shedding	5.0
	Plant pollinated; silks green to brown	5.5
Maturity	Brown silk, cob full sized, blister stage	6
	Kernals in "soft dough"	7
	Few kernals with dents, embryos developing	8
	All kernals with dents	9
	Grain mature and drying	10

[1]From Hanway, J. J., 1971. Special Report 48, Iowa State University.

samples were ground to pass an 18 mesh screen.

Soil pH was determined using a 1:1 soil water mixture. In 1981 soil pH was 6.2, and in 1982 it was 6.6.

Extractable P was measured spectrophotometrically. The samples were extracted with 0.025N HCL in 0.03N NH_4F as according to Bray P-1 method described by Knudsen (1980). The reducing agent was stanus chloride. Bray P was 120 ppm in 1981, and 100 ppm in 1982.

Exchangeable K, Ca, and Mg were extracted with 1.0N NH_4OAc. A Technicon Autoanalyzer was used determine the K, Ca, and Mg levels in the samples. In 1981 the exchangeable K, Ca, and Mg were 184, 480, and 70 ppm, respectively. In 1982 the exchangeable K, Ca, and Mg were 116, 677, and 156 ppm, respectively.

Organic matter as determined by a Leco carbon analyzer was 2.0% in each year.

Plant Sampling and Analysis

In 1981 all plots were ear leaf sampled at early silking to determine the nutrient status of the actively growing plants. Grain and stover samples were collected at harvest. All samples were taken from harvest rows.

Samples were dried in forced air ovens for 7 days at 60 degrees C. Plant samples were then ground to pass a 40 mesh screen, while grain samples were ground to pass a 20 mesh screen.

In 1981 all samples were analyzed at the Michigan State University plant analysis laboratory. Samples were digested and analyzed for N by a modified version of the Kjeldal procedure described by Bremner (1965). Determination of P, K, Ca, Mg, Zn, Mn, Cu, was made with an SMI IIIA directly-coupled plasma emission spectrophotometer.

Statistical Analyses

Statistical analyses were performed using a Cyber 750 computer at the Michigan State University Computer Laboratory. Statistical procedures used are those given by Steel and Torrie (1980).

RESULTS AND DISCUSSION

Growing Conditions in 1981 and 1982

Growing conditions in 1981 were near normal with 2443 Growing Degree Days recorded from April 27 to September 30. Precipitation for the growing season was above normal, however much of the rainfall came in September when the demand for water by the plants was low (Table 2-2). Rainfall from June 22 to August 25 was only 5.8 cm. Open pan evaporation during this period was 34.7 cm.

Growing conditions in the spring of 1982 were nearly ideal. Late April and May were very warm and dry, promoting rapid soil warming and rapid plant growth. In June the weather was very cloudy and cool. This appeared to slow the progress of the plants greatly. The remainder of the season was favorable for plant development. Growing Degree Days were calculated to be 2484 from planting to harvest. Precipitation was more evenly distributed throughout the growing season than in 1981 (Table 2-3).

Effect of Plant Population and Corn Hybrid on Growth Stage

Plant population had little effect on growth stage development from emergence (on May 13) to pollination. Figures 2-1, 2-2, and 2-3 show that increasing plant population from 69,000 to 100,000 plants/ha delayed the length of time from emergence to pollination by at most 2 days. All three population levels of Michigan 5922 reached stage 5.5 on August 3. Since the growth stage observations are subjective ratings

Table 2-2. Water balance at Soils Research Farm, East Lansing, MI, for 1981 (for the corn studies).

Month	Precipitation (cm)	Irrigation (cm)	Open Pan Evaporation (cm)	Balance (cm)
April	14.5	----	Not Recorded	----
May	9.3	----	9.7	-0.4
June	9.0	----	17.5	-8.5
July	3.8	15.7	16.7	+2.8
August	6.7	7.3	14.4	-0.4
September	23.6	----	9.3	+14.3
Total	66.9	23.0	67.6	----

Table 2-3. Water balance at Soils Research Farm, East Lansing, MI, for 1982 (for the corn studies).

Month	Precipitation (cm)	Irrigation (cm)	Open Pan Evaporation (cm)	Balance (cm)
April	1.2	----	Not Recorded	----
May	8.9	----	13.1	-4.2
June	6.0	----	15.0	-9.0
July	9.1	6.3	17.8	-2.4
August	3.6	7.7	15.8	-4.5
September	10.4	----	10.0	+0.4
Total	39.2	14.0	71.7	----

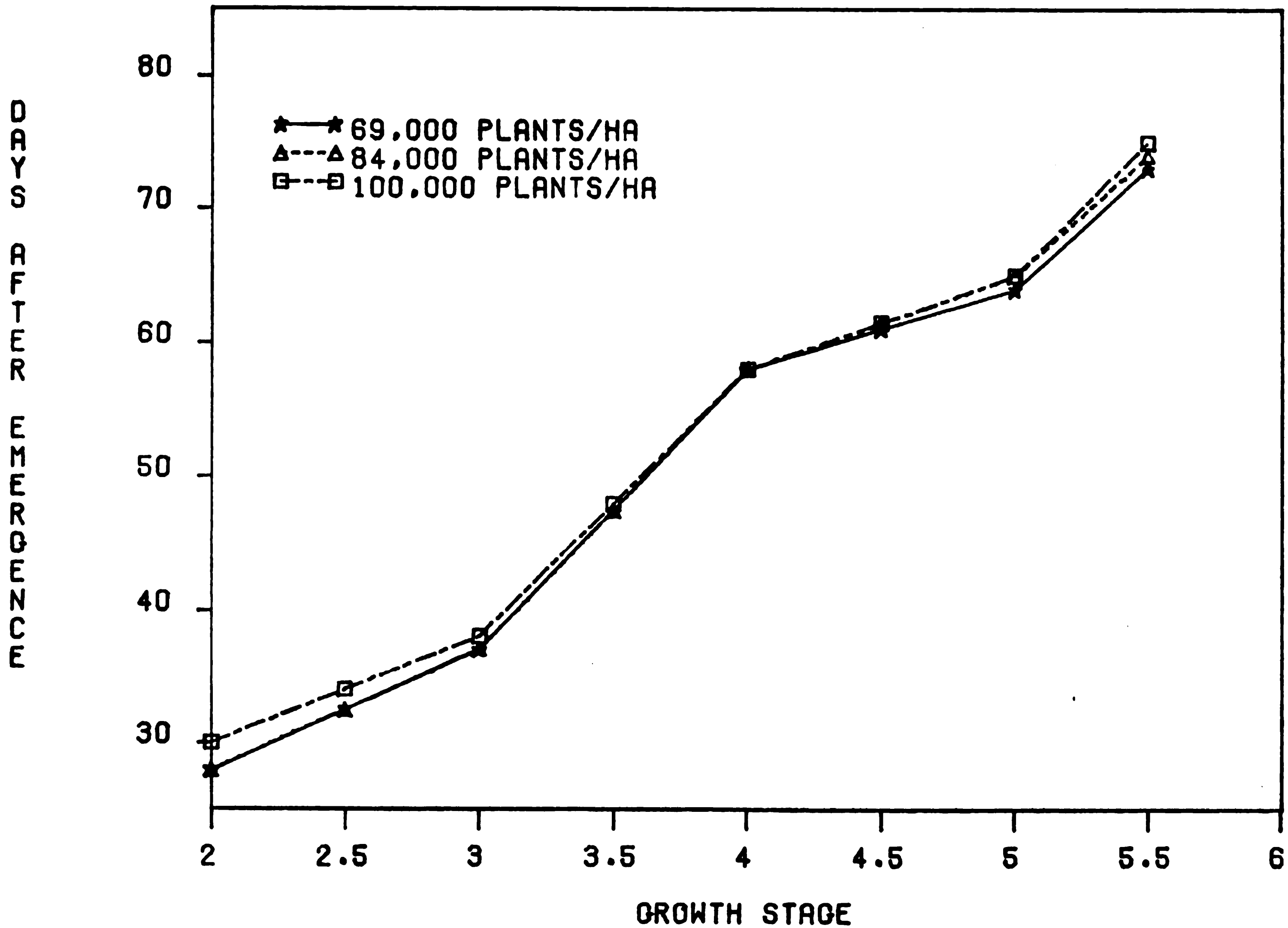

Figure 2-1. Effect of plant population on growth stage development of Pioneer 3780 in 1981.

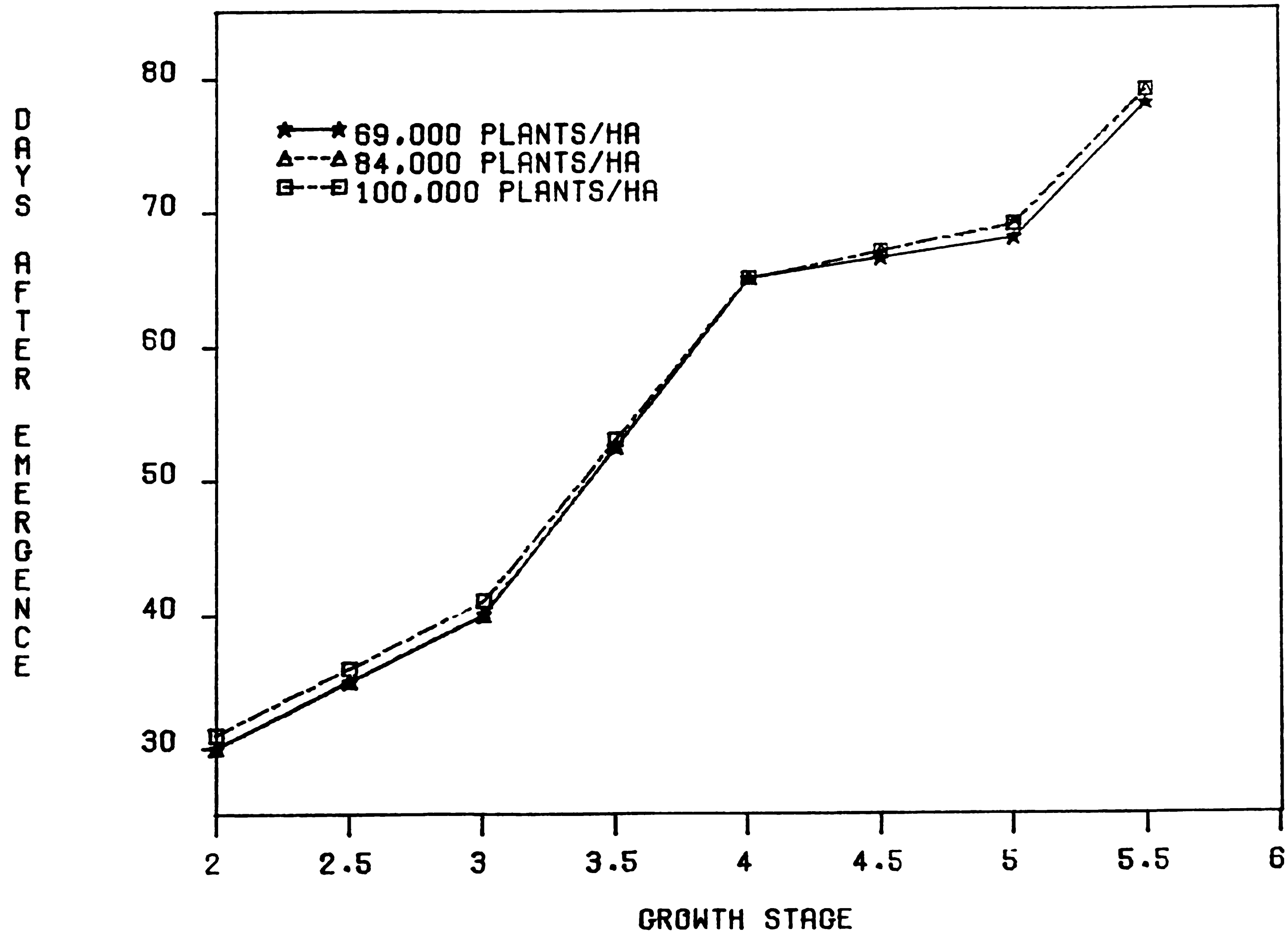

Figure 2-2. Effect of plant population on growth stage development of Pioneer 3572 in 1981.

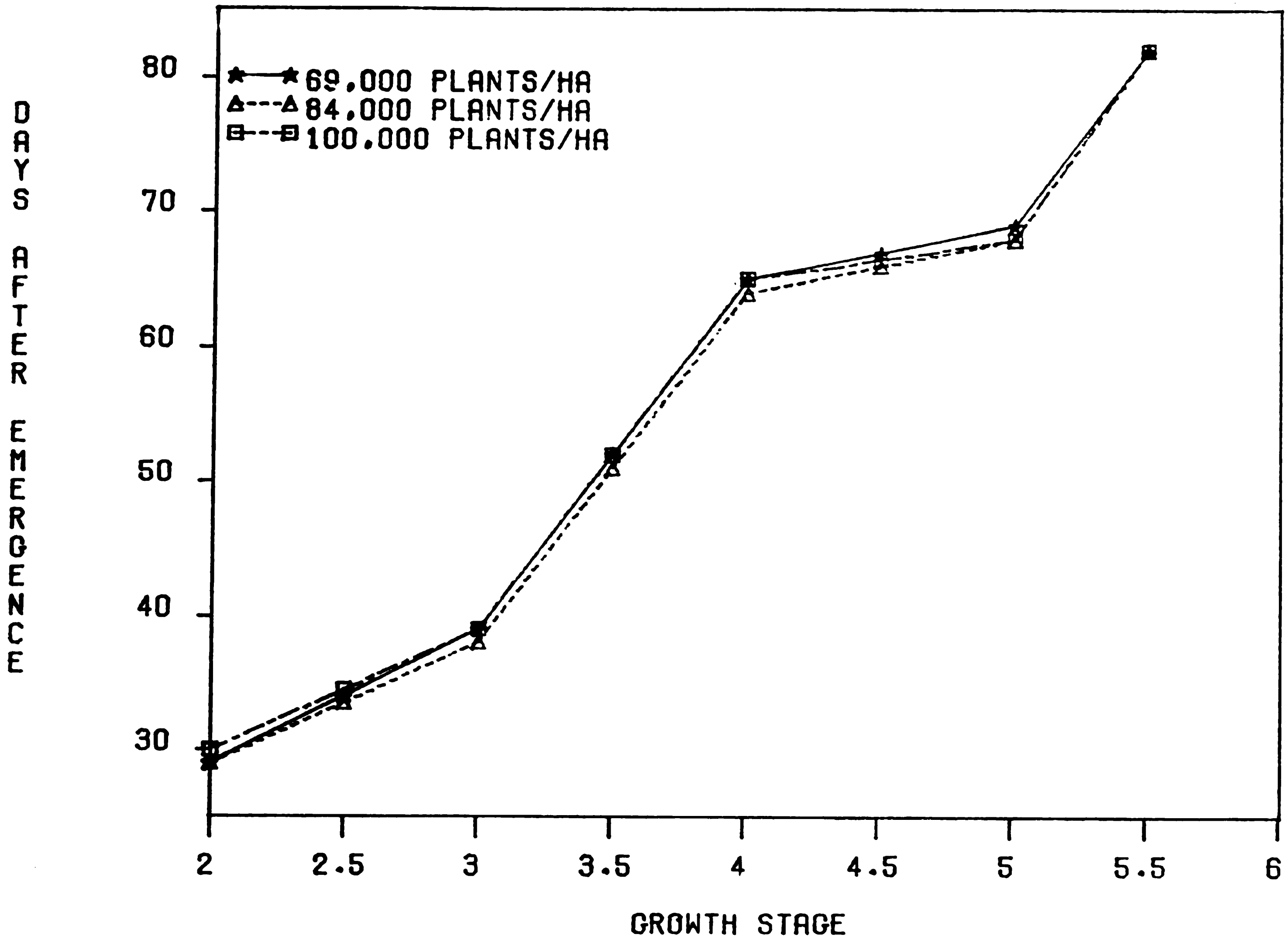

Figure 2-3. Effect of plant population on growth stage development of Michigan 5922 in 1981.

and involve averaging plants within the plots, differences of one to two days are probably not significant. Further evidence that plant population has little effect on growth stage development is the grain moisture at harvest (Table 2-6). None of the three corn hybrids had significantly higher grain moisture at 100,000 plants/ha than at 69,000 plants/ha. Other researchers have also reported that ear moisture at harvest is unaffected by plant population (Lutz et al., 1971; Moll and Kamprath, 1977).

Growth stage development did vary among the three corn hybrids (Figure 2-4). This was expected because the three hybrids have different relative maturity ratings. Michigan 5922 is rated approximately 10 days later maturing than Pioneer 3780, with Pioneer 3572 midway between the two. Pioneer 3780 reached each growth stage before the other two hybrids. The Michigan 5922 hybrid grew faster than the Pioneer 3572 hybrid initially, but completed pollination three days later than Pioneer 3572. Grain moisture at harvest showed the same trend in relative maturity of the hybrids (Table 2-6). Pioneer 3780 averaged 28.1% grain moisture versus 29.1% for Pioneer 3572 and 31.4% for Michigan 5922.

Effect of Plant Population on Performance and Yield of Corn

Grain yields for 1981 are presented in Table 2-4. Each of the three corn hybrids in this study showed significant grain yield responses when planted population was increased form 69,000 to 100,000 plants/ha. All three hybrids responded similarly to increasing plant density, and total yield increases were nearly the same (Figure 2-5). This is somewhat surprising since the maturity classifications are

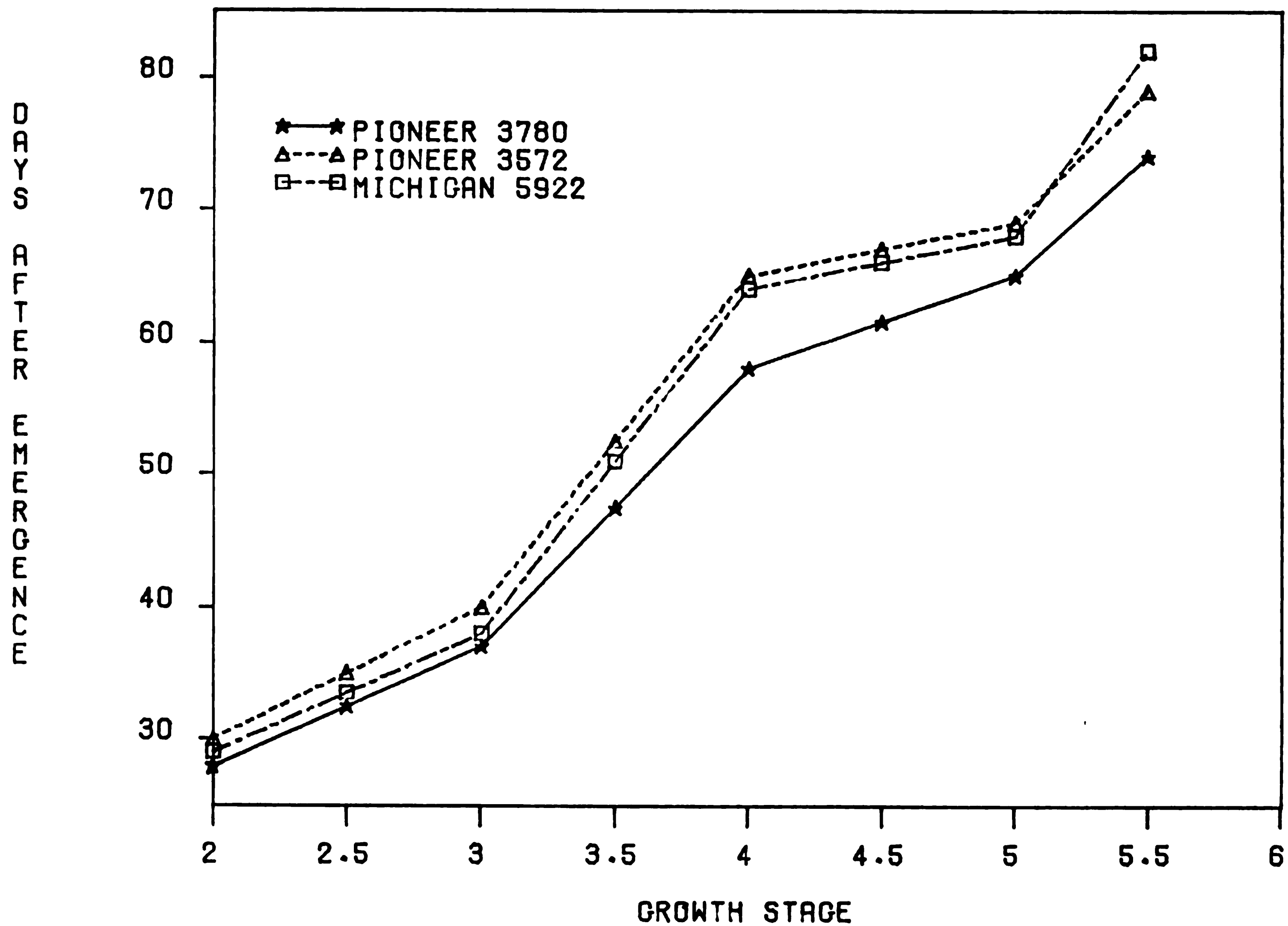

Figure 2-4. Effect of three corn hybrids on growth stage development at 84,000 plants/ha in 1981.

Table 2-4. Grain and stover yield for 1981 as affected by plant population, row spacing, and corn hybrid.

Hybrid	Row Spacing (cm)	Final Corn Population (plants/ha)	[1]Grain Yield (kg/ha)	Stover Yield (kg/ha)
Pioneer 3780	76	72,020	11,160	6,260
Michigan 5922	76	69,200	12,300	8,730
Pioneer 3572	76	66,770	11,580	8,260
Pioneer 3780	76	84,390	11,680	6,260
Michigan 5922	76	84,800	13,190	8,610
Pioneer 3572	76	81,100	12,180	9,420
Pioneer 3780	63-13	95,290	12,470	6,520
Michigan 5922	63-13	94,140	13,680	9,760
Pioneer 3572	63-13	90,780	12,980	8,690
Michigan 5922	63-13	88,560	13,510	9,750
$LSD_{(.05)}$		(1960)	(590)	(1,020)
Overall Means				
Final Plant Population (plants/ha)				
69,330			11,680	7,750
83,430			12,350	8,100
93,400			13,040	8,320
$LSD_{(.05)}$			(580)	(NS)
Hybrid				
Pioneer 3780			11,770	6,350
Michigan 5922			13,060	9,030
Pioneer 3572			12,240	8,790
$LSD_{(.05)}$			(580)	(1,080)

[1]Adjusted to 15.5% moisture

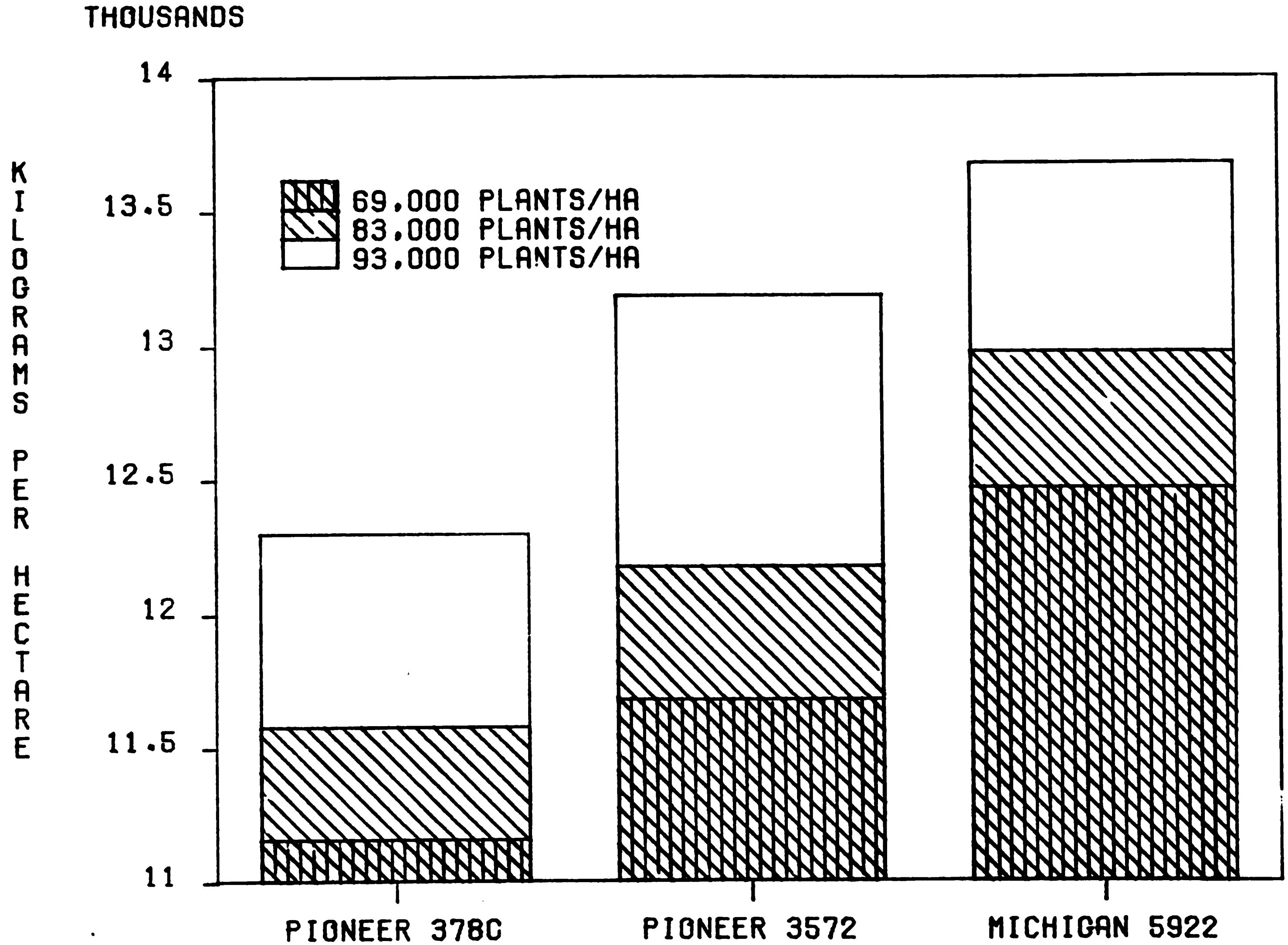

Figure 2-5. Effect of plant population on yield of three corn hybrids in 1981.

different, and hybrids have been reported to respond differently to plant population pressure (Lang et al., 1956). The overall means showed a significant yield response to increasing plant population (Table 2-4). Since this response was nearly linear up to the highest population, the plant population for maximum grain yield may not have been reached in 1981. The total yield increase over the population range averaged 1360 kg/ha. These results are very similar to those reported by Brown et al. (1970) for irrigated 51 cm row spacing corn. Fery and Janick (1971) and Williams et al. (1968) used plant populations higher than those here, but their maximum yields occurred at much lower populations (38,000 and 48,700 plants/ha, respectively). Comparison of the Michigan 5922 hybrid at approximately 84,000 plants/ha in 76 cm rows versus 63-13 cm rows showed no significant difference in grain yield.

The three corn hybrids were significantly different in grain yield when averaged over the three plant populations (Table 2-4). The latest maturing hybrid, Michigan 5922, had the highest average yield of 13,060 kg/ha. The earliest maturing hybrid, Pioneer 3780, had the lowest average grain yield in 1981.

Grain yields for 1982 are presented in Table 2-5. In all three studies the higher plant population tended to outyield the lower population, but only in the trickle irrigation study was this difference significant. The 100,000 plant population was not used in 1982 because of the problems with lodging in 1981.

Stover yields for 1981 are presented in Table 2-4. The response of the corn hybrids to increasing plant population was different for stover yield than for grain yield. Each hybrid responded differently. Pioneer 3780 showed no stover yield response to plant population

Table 2-5. Effect of plant population on grain yield, stover yield, grain moisture, and barren stalks in three 1982 corn studies.

	Plant Population plants/ha		
	69,000	84,000	$LSD_{(.05)}$
		Trickle Experiment	
Grain Yield (kg/ha)[1]	11,480	11,860	(260)
Stover Yield (kg/ha)	9,520	10,460	(NS)
Grain Moisture (%)	27.8	28.1	(NS)
Barren Stalks (%)	0.4	2.4	(1.9)
		Sprinkler Experiment	
Grain Yield (kg/ha)[1]	11,940	12,170	(NS)
Stover Yield (kg/ha)	9,970	10,750	(NS)
Grain Moisture (%)	28.8	29.1	(NS)
Barren Stalks (%)	0.6	2.4	(NS)
		Population Study	
Grain Yield (kg/ha)[1]	11,790	12,270	(NS)
Stover Yield (kg/ha)	9,390	9,140	(NS)
Grain Moisture (%)	30.6	30.8	(NS)
Barren Stalks (%)	1.3	3.3	(1.5)

[1] Adjusted to 15.5% moisture.

changes. Michigan 5922 showed no response at 84,000 plants/ha, but stover yield was significantly higher at 100,000 plants/ha. Stover yield for Michigan 5922 was also higher for the 63-13 cm double row than for the 76 cm row spacing. Pioneer 3572 showed a significant increase at 84,000 plants/ha, but then stover yield decreased when the plant population was increased above this level. Overall there was no effect of increased plant population on stover yield. Hybrids were significantly different for stover yield. Pioneer 3780 produced lower stover yields than the other hybrids.

Stover yields for 1982 are presented in Table 2-5. In all three studies stover yield was not significantly affected by plant population.

Grain moisture, barren stalks, and lodged stalks for 1981 are presented in Table 2-6. Plant population had no significant effect on grain moisture. This agrees with the findings of Lutz et al. (1971) and Moll and Kamprath (1977), but not with Hunter et al. (1970) or Rutger and Crowder (1967). The 63-13 cm versus 76 cm row spacing had no effect on grain moisture in this study. As expected Michigan 5922 was significantly higher in grain moisture than the two Pioneer hybrids. Barren stalks were not significantly affected by plant population in 1981. Rutger and Crowder (1967) reported similar findings. Row spacing also had no effect on barren stalks in this study. Michigan 5922 had significantly lower barren stalks than either of the Pioneer hybrids. Stalk lodging was a serious problem in 1981. Although the plots were treated for corn borer, some damage was done before treatment. Figure 2-6 shows the effectiveness of Furadan when applied in the whorls on controlling corn borer in Pioneer 3780. Lodging was only about 1/3 as bad on treated rows as on nontreated rows. Michigan 5922 suffered an

Table 2-6. Effect of plant population and corn hybrid on grain moisture, barren stalks, and lodged stalks in 1981.

Hybrid	Row Spacing	Final Corn Population	Grain Moisture	Barren Stalks	Lodged Stalks
	(cm)	(plants/ha)	(%)	(%)	(%)
Pioneer 3780	76	72,020	28.2	3.1	12.6
Michigan 5922	76	69,200	32.2	1.0	16.3
Pioneer 3572	76	66,770	28.6	2.3	4.0
Pioneer 3780	76	84,390	28.3	3.8	14.6
Michigan 5922	76	84,800	31.7	2.1	25.1
Pioneer 3572	76	81,100	28.9	3.8	4.5
Pioneer 3780	63-13	95,290	27.8	3.2	18.7
Michigan 5922	63-13	94,140	30.4	1.9	55.6
Pioneer 3572	63-13	90,780	29.9	4.5	8.6
Michigan 5922	63-13	88,560	31.4	2.2	38.3
$LSD_{(.05)}$		(1960)	(2.2)	(0.8)	(6.3)
Overall Means					
Final Plant Population (plants/ha)					
69,330			29.7	2.1	10.9
83,430			29.6	3.3	14.7
93,400			29.3	3.2	27.5
$LSD_{(.05)}$			(NS)	(NS)	(11.8)
Hybrid					
Pioneer 3780			28.1	3.4	15.2
Michigan 5922			31.4	1.7	32.3
Pioneer 3572			29.1	3.5	5.7
$LSD_{(.05)}$			(2.2)	(1.7)	(11.8)

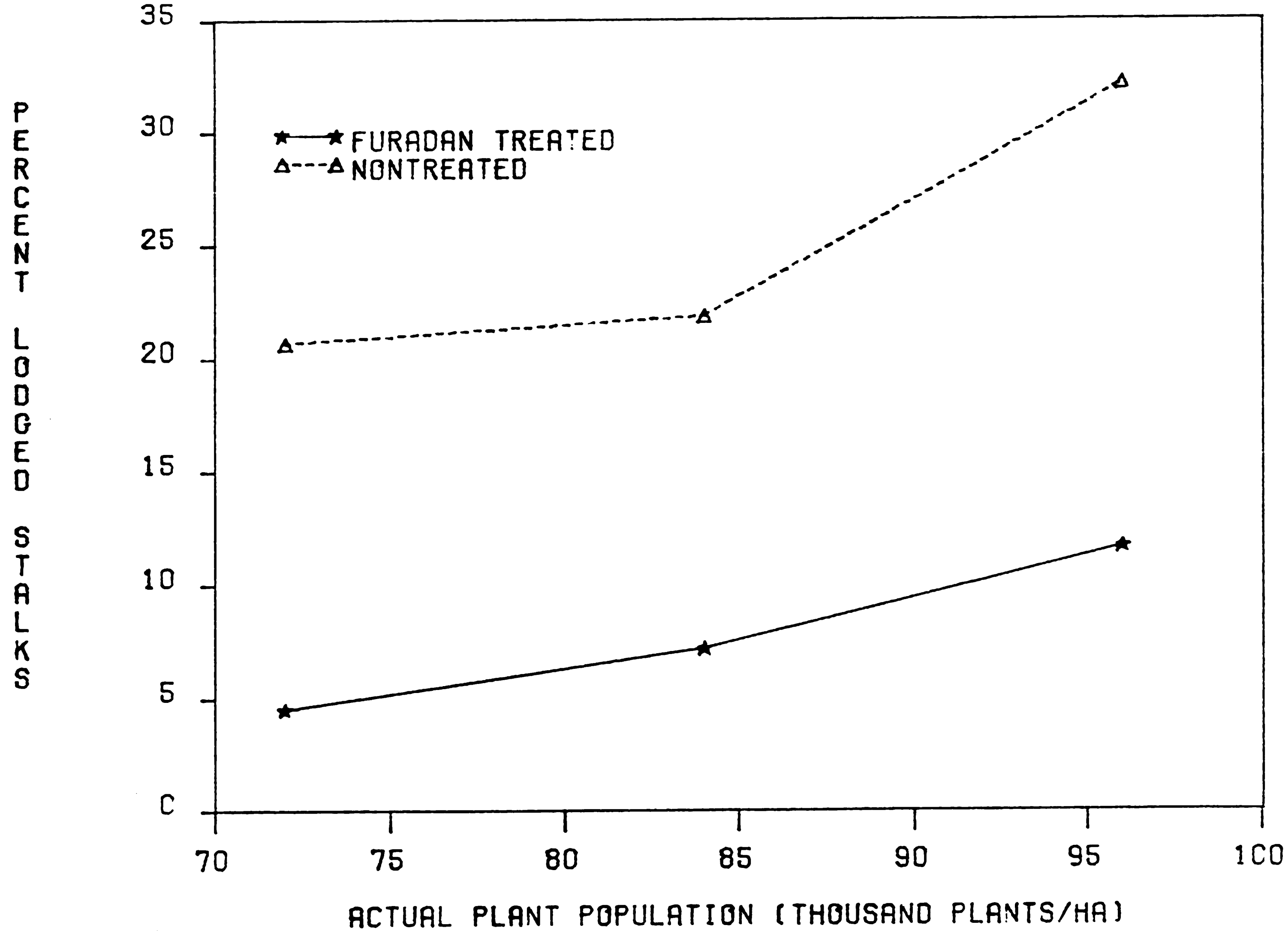

Figure 2-6. Lodged stalks as affected by corn borer treatment for Pioneer 3780 in 1981.

outbreak of stalk rot which caused considerable lodging in this hybrid. Lodging was significantly greater at the highest plant population than at either of the lower populations. However, only for Michigan 5922 was lodging significantly affected by plant population (Figure 2-7). This may be an indication that plant population pressure lowers the resistance of a susceptible hybrid to stalk rot. Michigan 5922 was significantly higher in lodged stalks than either Pioneer hybrid.

Grain moisture and barren stalks for 1982 are presented in Table 2-5. Grain moisture was not significantly affected by plant population in any of the three studies. Barren stalks were significantly higher at 84,000 plants/ha than at 69,000 plants/ha for the trickle experiment and the population study. Stalk lodging was not a problem in 1982.

Plant Analysis

The elemental composition for corn ear leaf in 1981 is presented in Table 2-7. Plant population had little effect on plant nutrient composition at early silking. Most of the differences in elemental composition were between hybrids. Pioneer 3780 and Michigan 5922 had N levels below the critical level of 2.76% suggested by Jones and Eck (1973). All three hybrids were below the suggested critical level of 0.25% for P. Pioneer 3572 was also below the suggested critical level of 0.21% for Mg content. Deficiency symptoms for any of the three elements, however, were not noticed during the growing season. Pioneer 3572 was significantly higher in Zn and Cu than the other two hybrids at two of the population levels.

The elemental composition of corn grain at harvest in 1981 is shown in Table 2-8. Most of the differences in corn grain composition

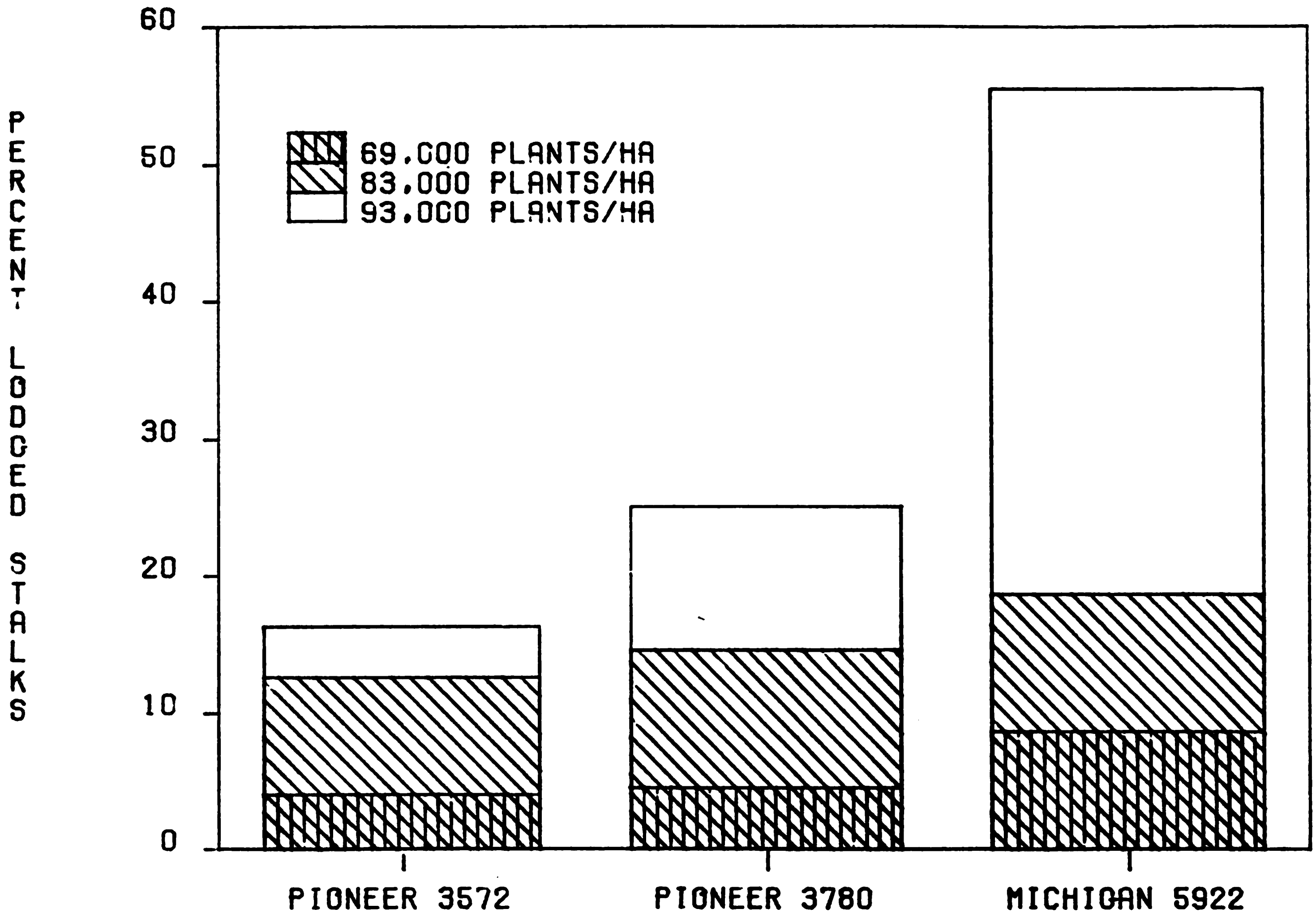

Figure 2-7. Lodged stalks as affected by plant population and corn hybrid in 1981.

Table 2-7. Elemental composition of ear leaf samples from three corn hybrids as affected by plant population and row spacing.

Hybrid	Row Spacing	Plant Population	Elements[1] N	P	K	Ca	Mg	Zn	Mn	Cu
			-----	-----	%	-----	-----	-----	ppm	-----
Pioneer 3780	76	L[2]	2.63	.22	2.29	.50	.22	25.5	38.0	12.3
Michigan 5922	76	L	2.43	.21	2.19	.47	.19	22.4	47.0	13.7
Pioneer 3572	76	L	3.22	.23	2.08	.47	.17	34.9	51.9	15.7
Pioneer 3780	76	M[3]	2.95	.20	2.03	.43	.20	22.3	45.3	12.5
Michigan 5922	76	M	2.42	.21	2.14	.48	.20	20.9	45.5	12.9
Pioneer 3572	76	M	2.89	.22	2.17	.46	.19	31.2	43.0	13.0
Pioneer 3780	63-13	H[4]	2.60	.21	2.42	.48	.23	22.0	45.7	11.8
Michigan 5922	63-13	H	2.41	.21	2.11	.49	.21	21.4	47.3	12.2
Pioneer 3572	63-13	H	2.72	.21	2.10	.42	.17	28.4	56.0	14.4
Michigan 5922	63-13	M	2.60	.22	2.19	.51	.22	22.1	46.9	14.1
LSD (.05)			(NS)	(NS)	(NS)	(NS)	(.04)	(9.3)	(NS)	(2.1)

[1] samples at early silking

[2] L = 69,000 plants/ha

[3] M = 84,000 plants/ha

[4] H = 100,000 plants/ha

Table 2-8. Elemental composition of corn grain from three hybrids as affected by plant density in 1981.

Hybrid	Row Spacing	Plant Population	Elements N	P	K	Ca	Mg	Zn	Mn	Cu
			%					ppm		
Pioneer 3780	76	L[1]	1.53	.29	.48	.03	.14	20	6	1.2
Michigan 5922	76	L	1.26	.22	.38	.03	.09	14	4	1.7
Pioneer 3572	76	L	1.49	.23	.41	.03	.11	14	5	1.1
Pioneer 3780	76	M[2]	1.34	.25	.44	.02	.12	15	5	1.0
Michigan 5922	76	M	1.20	.25	.42	.03	.10	17	5	1.8
Pioneer 3572	76	M	1.42	.25	.45	.03	.12	16	5	1.3
Pioneer 3780	63-13	H[3]	1.50	.27	.46	.03	.13	19	6	1.4
Michigan 5922	63-13	H	1.38	.23	.37	.02	.09	14	4	1.7
Pioneer 3572	63-13	H	1.43	.22	.41	.03	.10	13	5	1.1
Michigan 5922	63-13	M	1.34	.25	.40	.02	.10	15	4	1.8
LSD (.05)			(.18)	(NS)	(NS)	(NS)	(.03)	(NS)	(1)	(0.4)

[1]L = 69,000 plants/ha

[2]M = 84,000 plants/ha

[3]H = 100,000 plants/ha

were again between hybrids and not plant populations. For both N and Mg content, Michigan 5922 ranged from slightly to considerably lower than the two Pioneer hybrids. Significant differences between treatments were detected for N, Mg, Mn, Cu, and B.

The elemental composition of corn stover in 1981 is presented in Table 2-9. Plant population had little effect on the elemental composition of the stover. There were significant differences in hybrids for P, K, and Cu, although the differences were not consistent at all population levels.

Removal of N, P, and K by corn grain and stover for 1981 is presented in Table 2-10. The overall means for corn hybrid and plant population are given. The uptake by individual treatments is shown in Table 1a of the appendix.

Removal of N was significantly affected by plant population. Grain N and total N uptake by the corn were significantly higher at 100,000 plants/ha than at either of the lower plant populations. Uptake of N was equal at 69,000 and 84,000 plants/ha, and this may be an indication of luxury consumption at the low population. Uptake of P and K was not significantly affected by plant population.

Uptake of N, P, and K was significantly affected by hybrid. Stover N and total N uptake were significantly lower for Pioneer 3780 than the other two hybrids. The total amount of N in the grain was very similar for all three hybrids. This would appear to indicate that all three hybrids divert an equal amount of nitrogen to the ear, but Michigan 5922 produces more grain per plant, and thus the grain N content is much lower (Table 2-8). Total P retained in the stover was significantly different for all three hybrids, even though the amount of

Table 2-9. Elemental composition of corn stover from three hybrids as affected by plant density.

Hybrid	Row Spacing	Plant Population	Elements N	P	K	Ca	Mg	Zn	Mn	Cu
			%					ppm		
Pioneer 3780	76	L[1]	.76	.06	1.82	.34	.19	17	39	5.2
Michigan 5922	76	L	.86	.06	1.89	.36	.20	17	49	4.9
Pioneer 3572	76	L	.83	.06	1.60	.32	.18	16	40	4.7
Pioneer 3780	76	M[2]	.80	.06	1.90	.34	.20	13	52	4.9
Michigan 5922	76	M	.80	.05	2.00	.33	.18	16	42	4.4
Pioneer 3572	76	M	.74	.07	1.56	.36	.18	21	38	5.4
Pioneer 3780	63-13	H[3]	.82	.05	2.05	.33	.20	19	51	5.1
Michigan 5922	63-13	H	.80	.05	1.69	.35	.18	14	42	4.5
Pioneer 3572	63-13	H	.82	.06	1.72	.33	.19	12	43	4.2
Michigan 5922	63-13	M	.78	.06	1.70	.36	.19	16	46	4.9
	LSD (.05)		(NS)	(.01)	(0.28)	(NS)	(NS)	(NS)	(NS)	(0.7)

[1] L = 69,000 plants/ha

[2] M = 84,000 plants/ha

[3] H = 100,000 plants/ha

Table 2-10. Overall means for removal of N, P, and K in 1981 by three corn hybrids grown at three plant population levels.

Hybrid[1]	Nitrogen			Phosphorus			Potassium		
	Stover	Grain	Total	Stover	Grain	Total	Stover	Grain	Total
	kg/ha								
Pioneer 3780	50	146	196	3	27	30	122	46	168
Michigan 5922	74	141	215	5	25	30	167	43	210
Pioneer 3572	70	150	220	6	24	30	143	44	187
LSD (.05)	(10)	(NS)	(17)	(1)	(NS)	(NS)	(15)	(NS)	(15)
Plant[2] Population (plants/ha)									
69,000	64	140	204	5	24	29	138	41	179
84,000	63	138	201	5	26	31	146	45	191
100,000	68	159	227	5	26	31	149	46	195
LSD (.05)	(NS)	(13)	(17)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)

[1]Averaged over plant populations

[2]Averaged over hybrids

P in the stover was very small. Total P uptake was equal for all three hybrids. Stover K and total K uptake were significantly different for all three hybrids. Michigan 5922 had the highest uptake and Pioneer 3780 the lowest. Uptake of the three elements by the corn in this study was generally lower than expected for the yields attained. Lucas and Vitosh (1978) suggested that a 12,500 kg/ha corn grain yield removes 300 + 60 + 210 kg/ha of N, P, and K, respectively, for the grain and stover.

SUMMARY AND CONCLUSIONS

The results of this study in 1981 showed promise for the use of higher plant populations than those currently recommended for irrigated corn. All three hybrids showed significant yield responses when final plant populations were increased from approximately 69,000 plants/ha to over 90,000 plants/ha. These results were particularly encouraging because most of the literature suggests that maximum yields are attained at much lower plant populations. Since most of the research in the literature was conducted in the late 1960's and early 1970's it may be that the development of new hybrids and better management practices (and better equipment) have allowed us to plant higher populations and increase yields. Also, many of the studies in the literature were not irrigated. Irrigation may be an important ingredient for higher plant populations. Brown et al. (1970) noted yield increases from higher plant populations when the corn was irrigated, but little response for nonirrigated corn. It may be that the plant cannot withstand the added stress from moisture competition along with light competition. The main problem in the past with higher plant populations has been the dramatic increase in barren stalks (Rutger and Crowder, 1967; Giesbrecht, 1969; Williams et al., 1968), but this was not a problem in this study. One negative aspect of the study in 1981 was the high proportion of lodged stalks. This makes variety selection very important at high plant populations. Lodged stalks were not significantly higher at 90,000 plants/ha than at 67,000 plants/ha for either Pioneer hybrid.

Plant population had little effect on the elemental composition of the plants at ear leaf or at harvest. There were differences in elemental composition between the hybrids at ear leaf sampling and harvest. Total N uptake was significantly higher at 100,000 plants/ha than at either of the lower populations. Total uptake of N and K was significantly affected by corn hybrid.

In 1982 the results were not as impressive. Although all three studies tended to have higher grain yields with increased populations, only in the trickle irrigation study was grain yield significantly higher with higher plant populations. Rutger and Crowder (1967) found a location by plant population interaction in their study. It may be that the changing microclimate from year to year has an effect on response to plant population. Barren stalks were significantly higher at the high plant population for two of the studies in 1982. This is contrary to the results of 1981 and may be related to insufficient irrigation water applied in 1982 (Table 2-3). DeKalb 55A stood up well to the population pressures in 1982 and yielded well.

CHAPTER 3

TRICKLE VERSUS SPRINKLER IRRIGATION OF CORN

INTRODUCTION

This study was established in 1982 to compare trickle with an overhead sprinkler irrigation system. In 1979 an adjacent area produced 15,300 kg/ha of corn grain using trickle irrigation. Sprinkler irrigated plots have not matched this level since, so this study was initiated to determine if one irrigation method was superior to the other. Bresler (1977) cited several advantages of trickle irrigation. These include improving the soil-water regime, reducing salinity hazards, partial wetting of the soil volume, maintaining dry foliage, improving nutrient availability, and surface-soil structure improvement. A secondary objective of this study was to examine nutrient uptake for trickle and sprinkler irrigation.

MATERIALS AND METHODS

Management Practices and Experimental Design

The management practices used for this experiment were the same as those described in Chapter 2 for 1982. The trickle irrigation line was set out on June 18. A twin-wall plastic line with outlets spaced every 10.2 cm was used for the trickle irrigation. One line was placed next to each corn row. Water was supplied to the trickle line from a tank beside the field with a tractor driven centrifugal pump at a rate of 0.7 cm per hour. A total of 7.5 cm of water was applied for the season.

Since it was impossible to randomize trickle with sprinkler irrigation treatments, two adjacent experiments were established with a border of 6.1 m between them. The experimental design in each experiment was a split plot with four replications. The whole plots consisted of two corn hybrids, Pioneer 3780 and DeKalb 55A. The subplots were population levels of 69,000 and 84,000 plants/ha.

Growth and Yield

Observations and data recorded were the same as those described in Chapter 2.

Soil Sampling and Analysis

Procedures and results of soil sampling are reported in Chapter 2.

Plant Sampling and Analysis

In 1982 only the plants at the 84,000 plants/ha population level were sampled. Ear leaf samples were taken at early silking. Grain and stover samples were collected at harvest.

All samples were sent to the Ohio Plant Analysis Laboratory for complete spectographic analysis. Results are reported for N, P, K, Ca, Mg, Zn, Mn, Cu, B, and Fe.

Statistical Analysis

Statistical analysis was performed on a Cyber 750 computer using the Genstat statistical package (Alvey et al., 1980). Statistical procedures used are those given by Steel and Torrie (1980).

RESULTS AND DISCUSSION

Growing Conditions

The growing conditions for 1982 are described in Chapter 2. A difference in pollination between the two hybrids was noted in August. Many of the Pioneer 3780 stalks failed to pollinate the final 5 cm of the ear tips. This hybrid has a history of silking problems, especially when placed under stress such as soil moisture shortages or high plant populations (personal communication with Dr. Elmer Rossman, corn breeder at Michigan State University). DeKalb 55A was well pollinated. It was observed during ear leaf sampling that much more pollen was disseminated by DeKalb 55A than Pioneer 3780.

Effect of Trickle Irrigation on Yield of Two Corn Hybrids

Results for grain yield, stover yield, grain moisture, and barren stalks are presented in Table 3-1. Grain and stover yields for trickle irrigation were comparable to those for sprinkler irrigation. These yields were attained with 45% less water applied by trickle irrigation than for sprinkler irrigation. Bernstein and Francois (1975) reported similar results with bell peppers. Trickle irrigation produced 1560 kg/ha of grain per cm of irrigation water applied.

Hybrids were significantly different in grain yield and grain moisture, but not stover yield or barren stalks. DeKalb 55A had higher grain yield and grain moisture than Pioneer 3780. Final plant population was higher for Pioneer 3780 than DeKalb 55A (Table 3-1). This would seem to indicate that germination percentage or survival of

Table 3-1. Effect of trickle and sprinkler irrigation methods on grain and stover yield and grain moisture of two corn hybrids averaged over two plant population levels.

Hybrid	[1]Plant Population	[2]Grain Yield	Stover Yield	Grain Moisture	Barren Stalks
	(plants/ha)	(kg/ha)	(kg/ha)	(%)	(%)
		Trickle Experiment			
Pioneer 3780	78,000	11,110	9,590	27.0	1.1
DeKalb 55A	71,550	12,230	10,390	28.9	1.7
$LSD_{(.05)}$	(2,670)	(580)	(NS)	(0.6)	(NS)
		Sprinkler Experiment			
Pioneer 3780	77,800	11,530	9,480	28.6	1.2
DeKalb 55A	73,570	12,570	11,270	29.3	1.8
$LSD_{(.05)}$	(1,930)	(480)	(NS)	(0.6)	(NS)

[1]Final population averaged over two levels.
[2]Adjusted to 15.5% moisture.

Pioneer 3780 was higher.

Effect of Sprinkler Irrigation on Yield of Two Corn Hybrids

Results for grain yield, stover yield, and grain moisture are shown in Table 3-1. Yields were comparable to those produced by trickle irrigation, but only 860 kg/ha of grain were produced per cm of irrigation water applied as compared to 1560 kg/ha/cm of water applied by the trickle irrigation system. The DeKalb 55A hybrid was significantly higher than Pioneer 3780 for grain yield and moisture. Part of the difference in grain yield may be attributable to the pollination problems experienced by Pioneer 3780. Stover yields were not significantly different between the two hybrids.

Plant Analysis

Corn ear leaf chemical analysis for the trickle and sprinkler experiments is presented in Table 3-2. For both experiments all elements were well within the sufficiency range suggested by Jones and Eck (1973), except for B which was low in all treatments tested. In both experiments Ca was significantly higher in Pioneer 3780 than DeKalb 55A. Other significant hybrid differences in the trickle experiment were detected for P and Zn. A significantly higher P content for DeKalb 55A may be related to the reduction in Zn content for this hybrid. The Zn-P interactions have been widely studied, but the exact relationship is not well defined (Mengel and Kirkby, 1982). Pioneer 3780 was significantly higher in Mg content in the sprinkler experiment.

Elemental composition of corn grain for the trickle and sprinkler experiments is presented in Table 3-3. No significant differences were

Table 3-2. Elemental composition of corn ear leaf at 84,000 plants/ha as affected by corn hybrid.

Hybrid	N'	P	K	Ca	Mg	Zn	Mn	Cu	B	Fe
			%					ppm		
Trickle Experiment										
Pioneer 3780	3.40	.29	2.14	.63	.32	41	56	12	3	100
DeKalb 55A	3.32	.34	2.11	.57	.31	35	51	14	3	115
LSD (.05)	(NS)	(.04)	(NS)	(.05)	(NS)	(5)	(NS)	(NS)	(NS)	(NS)
Sprinkler Experiment										
Pioneer 3780	3.45	.31	2.15	.65	.31	49	70	13	2	195
DeKalb 55A	3.38	.33	2.20	.51	.27	36	85	14	2	178
LSD (.05)	(NS)	(NS)	(NS)	(.10)	(.02)	(NS)	(NS)	(NS)	(NS)	(NS)

Table 3-3. Elemental composition of corn grain at 84,000 plants/ha as affected by corn hybrid.

Hybrid	N	P	K	Ca	Mg	Zn	Mn	Cu	B	Fe
	--------	--------	%	--------	--------	--------	--------	ppm	--------	--------
Trickle Experiment										
Pioneer 3780	1.65	.34	.45	.005	.15	30	9	2	2	25
DeKalb 55A	1.64	.41	.45	.005	.16	32	8	3	3	29
LSD (.05)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)
Sprinkler Experiment										
Pioneer 3780	1.65	.40	.51	.006	.18	34	10	2	3	29
DeKalb 55A	1.63	.37	.42	.005	.15	29	8	2	3	24
LSD (.05)	(NS)	(NS)	(.03)	(NS)	(.01)	(3)	(.5)	(NS)	(NS)	(2)

detected in the trickle experiment. For the sprinkler experiment, Pioneer 3780 was significantly higher than DeKalb 55A for content of K, Mg, Zn, Mn, and Fe. We can not explain why these differences occurred in the sprinkler experiment and not the trickle experiment.

Elemental composition of corn stover for the trickle and sprinkler experiments is shown in Table 3-4. For both experiments DeKalb 55A was significantly higher in P content than Pioneer 3780. DeKalb 55A was significantly higher in Cu content in the trickle study. In the sprinkler experiment DeKalb 55A was significantly higher in N content, but lower in Mg content.

Uptake of N, P, and K for both the trickle and sprinkler experiments is presented in Table 3-5. For both experiments DeKalb 55A removed a larger amount of N, P, and K than Pioneer 3780. This was mainly due to the higher yields attained for DeKalb 55A. Only nitrogen removed by the grain was significantly higher for DeKalb 55A in both experiments. Phosphorus removed by the stover was significantly higher for DeKalb 55A in the sprinkler study. Removal of N, P, and K by DeKalb 55A was very close to the values suggested by Lucas and Vitosh (1978) for the yield level attained.

SUMMARY AND CONCLUSIONS

Trickle irrigation may offer many advantages for crop production, but based on these experiments in 1982 corn grain yield is little affected by irrigation method. The big benefit to trickle irrigation in this study was the efficiency of water use. The main advantage of the sprinkler irrigation in this study was the savings in labor, and ease of

Table 3-4. Elemental composition of corn stover at 84,000 plants/ha as affected by corn hybrid.

Hybrid	N	P	K	Ca	Mg	Zn	Mn	Cu	B	Fe
	%					ppm				
Trickle Experiment										
Pioneer 3780	.97	.09	1.48	.49	.29	26	56	8	8	123
DeKalb 55A	1.05	.14	1.59	.50	.27	20	38	10	8	149
LSD (.05)	(NS)	(.03)	(NS)	(NS)	(NS)	(NS)	(NS)	(2)	(NS)	(NS)
Sprinkler Experiment										
Pioneer 3780	.99	.10	1.67	.51	.27	28	60	8	9	158
DeKalb 55A	1.07	.13	1.78	.48	.24	24	64	11	8	171
LSD (.05)	(.06)	(.08)	(NS)	(NS)	(.01)	(NS)	(NS)	(NS)	(NS)	(NS)

Table 3-5. Removal of N, P, and K as affected by corn hybrid for the trickle and sprinkler irrigated experiments in 1982.

Hybrid	Nitrogen			Phosphorus			Potassium		
	Stover	Grain	Total	Stover	Grain	Total	Stover	Grain	Total
	kg/ha								
					Trickle Experiment				
Pioneer 3780	102	159	261	9	33	42	156	43	199
DeKalb 55A	109	172	281	15	43	58	164	47	211
LSD (.05)	(NS)	(4)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)
					Sprinkler Experiment				
Pioneer 3780	95	163	258	9	40	49	160	50	210
DeKalb 55A	128	175	303	16	40	56	212	45	257
LSD (.05)	(NS)	(NS)	(NS)	(5)	(NS)	(NS)	(NS)	(NS)	(NS)

operation. DeKalb 55A performed very well in these studies and seems well suited to high yield environments.

Differences in elemental composition were noted between hybrids for Ca in both experiments at ear leaf sampling. At harvest only stover P content was significantly different between hybrids in both studies. Significant differences in total uptake of N, P, or K between hybrids were not detected for either experiment in 1982.

CHAPTER 4

EFFECT OF A PLASTIC MULCH, ZINC PLUS SULFUR, AND A GEL ON GROWTH AND YIELD OF CORN

INTRODUCTION

This study was established in 1982 immediately adjacent to the corn irrigation study. Springtime in Michigan is often characterized by cool, wet weather, generally not very conducive to early corn growth. A plastic mulch treatment and a gel treatment were utilized in this experiment in an attempt to speed up seed germination and enhance early growth of corn. These practices may not seem economical to farmers, but they do represent alternatives that may prove more feasible in the future. An additional treatment involved the addition of Zinc (Zn) and Sulfur (S). Since cattle manure had not been applied for two years, it was felt that additional minor elements might be necessary for maximum yield.

MATERIALS AND METHODS

Management Practices and Experimental Design

The management practices for this experiment were the same as described in Chapter 2 for 1982. A black plastic mulch was laid down two days before planting to provide a warmer environment for seed germination. The plastic mulch was laid over all four rows of each plot. Because it was not possible to plant these treatments with standard farm equipment, they were hand planted by punching holes through the black plastic. These treatments did not receive the starter fertilizer and therefore cannot be compared statistically with the machine planted treatments. The plastic mulch was removed the first week of June. The control treatment received 8-32-16 starter fertilizer at 168 kg/ha. The remaining treatments received 8-32-14 + 4S + 2Zn starter fertilizer at 168 kg/ha. In addition, the last treatment received a Liqua-Gel^{TM} material manufactured by Miller Chemical and Fertilizer Corporation at a rate of 5.0 kg of product in 113 liters of water per hectare banded over the seed. DeKalb 55A was the hybrid used in the experiment.

Growth and Yield

Soil temperatures were measured early in the season to compare the plastic mulch treatments with nonmulched treatments. Additional observations and data recorded were the same as described in Chapter 2.

Soil Sampling and Analysis

Procedures and results of soil sampling are reported in Chapter 2.

Plant Sampling and Analysis

Procedures, time of sampling, and method of analysis were the same as described in Chapter 3.

Statistical Analysis

Statistical analysis was performed on a Cyber 750 computer using the Genstat statistical package (Alvey et al., 1980). Statistical procedures used are those given by Steel and Torrie (1980).

RESULTS AND DISCUSSION

Growing Conditions

The growing conditions in 1982 are described in Chapter 2. It was noted at planting that the soil under the plastic mulch had a higher moisture content than the no plastic treatments. Soil temperatures the day after planting (10:00 a.m.) were equal for the plastic mulch and no plastic mulch treatments (13.3 degrees C at 5 cm depth). On May 5 the corn began to emerge. Percent emergence was estimated at 50-60% for the plastic mulch treatments and less than 10% for all other treatments on this date. Soil temperature at 1:00 p.m. at 10 cm depth was 19.8 degrees C for plastic mulched treatments and 19.4 degrees C for no plastic mulch. Both were 22.8 degrees C at the 5 cm depth. The main reason for faster emergence by the plastic mulched treatments appeared to be the greater amount of moisture held below the plastic. Based on the results of other researchers a clear plastic mulch would have been more beneficial in warming the soil (Adams, 1967; Lee et al., 1978; Iremiren and Milbourn, 1979). This is similar to the results reported by Free and Bay (1965). Total emergence of plastic mulched treatments was one to two days ahead of the no plastic mulch treatments. Soil temperatures on May 14 (7:00 a.m.) averaged 0.5 degrees C higher for both 5 and 10 cm depths for the plastic mulched treatments. Plants in the plastic mulch generally looked taller than the other plots until the beginning of June when all of the hand planted treatments began to lag behind the machine planted plots. It appeared that the starter fertilizer was benefiting the machine planted treatments. For the spring season the benefit of plastic mulch was not as great as expected, and this was probably due to the unusually warm spring. Time to silking was not measured to determine if the plastic mulch affected this. At harvest grain moisture was significantly lower for the plastic mulch treatment than the no plastic treatment (Table 4-1). This seems to indicate that plastic mulching did reduce the time to maturity. Other researchers reported similar findings (Andrew et al., 1976; Lee et al., 1978).

It was difficult to determine if the gel had any beneficial effect on germination or early growth. It did not appear to.

Effect of a Plastic Mulch, Zinc plus Sulfur, and a Gel Treatment on Yield of Corn

The effect of the various soil treatments on grain yield, stover yield, grain moisture, and barren stalks is presented in Table 4-1. Only the three meaningful comparisons will be discussed for this study (plastic mulch versus no plastic mulch; control versus Zn + S; and Zn + S versus Zn + S + gel).

The plastic mulch treatment tended to increase grain yield in 1982, but not significantly. Based on the studies by Free and Bay (1965), Iremiren and Milbourn (1979), and Rykbost et al. (1975), I expected a larger grain yield increase from the plastic mulch. The unusually warm spring in 1982 probably reduced the yield difference. Free and Bay (1965) reported that growth and yield were less affected by a plastic mulch when spring temperatures were warm. Stover yields were not significantly affected by the plastic mulch. Grain moisture, as mentioned previously, was lower for the plastic mulch. Barren stalks

Table 4-1. Effect of various soil treatments on grain and stover yield, grain moisture, and barren stalks of DeKalb 55A averaged over two plant populations.

Treatment	[1]Final Corn Population	[2]Grain Yield	Stover Yield	Grain Moisture	Barren Stalks
	(plants/ha)	(kg/ha)	(kg/ha)	(%)	(%)
[3]No Plastic Mulch	74,240	11,820	10,000	31.3	3.1
[3]Plastic Mulch	76,320	12,320	9,500	30.0	2.4
[4]Control	70,940	11,930	8,780	31.0	2.1
[4]Zn + S	72,360	12,020	8,770	30.7	2.0
[4]Zn + S + Gel	72,890	12,050	9,320	30.5	1.8
$LSD_{(.05)}$	(2770)	(NS)	(NS)	(0.8)	(NS)

[1]Averaged over 2 population levels.
[2]Adjusted to 15.5% moisture.
[3]Hand planted.
[4]Machine planted.

were not significantly affected by the plastic mulch.

Addition of Zn + S had no significant effect on grain yield, stover yield, grain moisture, or barren stalks. Apparently there were sufficient levels of these elements in the soil for the yield level attained. The gel treatment had no significant effect on grain yield, stover yield, grain moisture, or barren stalks.

Plant Analysis

The elemental composition of corn ear leaf, grain, and stover is presented in Tables 4-2, 4-3, and 4-4. Uptake of N, P, and K for the various soil treatments is shown in Table 4-5.

There was no significant effect of plastic mulch on elemental composition of corn ear leaf, grain, stover; or on N, P, and K uptake. Phosphorus was significantly reduced in the ear leaf by addition of Zn + S. At harvest time these differences were not found in grain or stover. Zinc addition did not increase Zn levels in the plant at silking or at harvest. Uptake of N, P, and K were not significantly affected by addition of Zn + S in this study. The gel treatment had no significant effect on any of the elements at silking, or at harvest in the stover. The gel treatment resulted in significantly lower grain N at harvest, but uptake of N, P, and K were not significantly different from the other treatments. Boron levels were very low in all treatments at silking. Interestingly, there was essentially no difference in uptake of N, P, and K between the hand and machine planted treatments, even though the hand planted treatments received no starter fertilizer.

Table 4-2. Elemental composition of corn ear leaf at 84,000 plants/ha as affected by soil treatment.

Treatment	Planting Method[1]	N	P	K	Ca	Mg	Zn	Mn	Cu	B	Fe
		-------	-------	%	-------	-------	-------	-------	ppm	-------	-------
No Plastic Mulch	H	3.27	.34	2.51	.53	.28	40	100	13	2	182
Plastic Mulch	H	3.32	.34	2.56	.53	.26	37	95	13	2	181
Control	M	3.46	.36	2.47	.56	.28	41	120	15	1	201
Zn + S	M	3.28	.32	2.39	.49	.26	35	106	15	2	175
Zn + S + Gel	M	3.31	.32	2.28	.50	.26	37	115	14	1	178
LSD (.05)		(NS)	(.02)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)

[1]H = Hand planted. M = Machine planted.

Table 4-3. Elemental composition of corn grain at 84,000 plants/ha as affected by soil treatment.

Treatment	Planting Method[1]	N	P	K	Ca	Mg	Zn	Mn	Cu	B	Fe
		%					ppm				
No Plastic Mulch	H	1.66	.49	.51	.006	.20	40	10	2	4	31
Plastic Mulch	H	1.64	.43	.47	.006	.18	35	9	2	4	29
Control	M	1.62	.41	.46	.006	.17	34	9	2	3	27
Zn + S	M	1.65	.50	.54	.006	.20	40	11	2	4	31
Zn + S + Gel	M	1.58	.34	.40	.005	.14	29	8	2	3	24
LSD (.05)		(.04)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)

[1]H = Hand planted. M = Machine planted.

Table 4-4. Elemental composition of corn stover at 84,000 plants/ha as affected by soil treatment.

Treatment	Planting Method[1]	N	P	K	Ca	Mg	Zn	Mn	Cu	B	Fe
		%					ppm				
No Plastic Mulch	H	1.01	.12	2.11	.45	.24	19	67	8	7	154
Plastic Mulch	H	1.00	.12	2.22	.43	.21	18	63	7	7	149
Control	M	1.05	.12	2.15	.43	.22	20	75	8	7	152
Zn + S	M	1.03	.11	2.22	.37	.23	17	78	7	7	175
Zn + S + Gel	M	1.08	.12	2.21	.45	.24	23	96	9	8	169
LSD (.05)		(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)

[1]H = Hand planted. M = Machine planted.

Table 4-5. Uptake of N, P, and K by DeKalb 55A as affected by several soil treatments at 84,000 plants/ha in 1982.

Treatment	Nitrogen			Phosphorus			Potassium		
	Stover	Grain	Total	Stover	Grain	Total	Stover	Grain	Total
	kg/ha								
No Plastic Mulch	102	167	269	12	49	61	211	52	263
Plastic Mulch	93	172	265	11	45	56	208	50	258
Check	93	169	262	10	43	53	190	48	238
Zn+S	86	173	259	9	52	61	185	57	242
Zn+S+Gel	97	163	260	11	35	46	199	41	240
LSD (.05)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)

SUMMARY AND CONCLUSIONS

The results of this study in 1982 showed no real benefit to grain yield from Zn + S, or a gel. The plastic mulch enhanced early growth and reduced grain moisture content at harvest, but did not affect yield. In a year with cooler spring conditions the grain yield benefits would be expected to be greater based on the results of other researchers. Also, the addition of a starter fertilizer may have been beneficial. A clear plastic mulch may also have been more beneficial in heating the soil.

Plastic mulching, Zn + S, or gel treatment had little effect on elemental composition at ear leaf sampling or harvest. Addition of Zn and S suppressed P content of the ear leaf, and this may be related to the Zn-P interaction dicussed in Chapter 3. None of the treatments had any significant effect on total uptake of N, P, or K.

CHAPTER 5

EFFECT OF NITROGEN FERTILIZATION ON YIELD AND ELEMENTAL COMPOSITION OF SOYBEANS

INTRODUCTION

A study was initiated in 1981 to evaluate the effect of nitrogen fertilization on yield and elemental composition of three soybean varieties. Results in other parts of the country have shown that application of nitrogen fertilizers can lead to higher soybean yields (Ham et al., 1975; Sorensen and Penas, 1978; Bhangoo and Albritton, 1976; Al-Ithawi et al., 1980). Other studies have shown no such responses (Beard and Hoover, 1974; Welch et al., 1973; Hinson, 1975). This study was initiated to evaluate the effect of nitrogen fertilization in a high yield environment. By optimizing as many factors as possible and reducing stresses on the plants, soybeans may be able to utilize additional nitrogen more effectively.

MATERIALS AND METHODS

Management Practices and Experimental Design

The soybean studies were conducted on the Michigan State University Soil Research Farm in 1981 and 1982. The soil used for the studies was a Metea loamy sand. The study was rotated each year with the corn studies described previously.

The experimental design in 1981 was a modified split-plot. There were two planting dates studied. The early planting contained three soybean varieties (Sprite, Gnome, and Harcor) as the whole plot treatments and four nitrogen treatments as the subplots. The late planting was the same, except that two soybean varieties (Gnome and Harcor) were used. Four replications were used in each study.

The plots were moldboard plowed in the fall of 1980 to a depth of 20 cm. Spring tillage consisted of disking, and twice over with a field cultivator.

Weed control was accomplished with a preplant incorporated application of Treflan (0.28 kg a.i./ha) plus Sencore (0.42 kg a.i./ha) plus Amiben (2.24 kg a.i./ha).

A broadcast application of 448 kg/ha of 5-20-20 was applied preplant and incorporated. A starter fertilizer of 15 kg/ha of 8-32-16 was applied at planting. Total N + P_2O_5 + K_2O applied was 24 + 216 + 111 kg/ha. Additional nitrogen was applied as urea. The total N applied and time of application for the four treatments were: (1) 0 N applied; (2) 200 kg N/ha at spring tillage; (3) 200 kg N/ha at prebloom; or (4) 100 kg N/ha at spring tillage plus 100 kg N/ha at prebloom. The prebloom treatments were hand applied.

The first planting was on May 6 with a John Deere soybean drill equipped with True-Vee double disk openers for independent depth placement of the seed for each row. Row width was 25.4 cm and seed depth was 3.8 cm. Plot size was 1372 cm by 305 cm. Plant populations per hectare after emergence were 510,000 for Sprite; 523,000 for Gnome; and 400,000 for Harcor. The second planting date was May 18.

Irrigation was scheduled with the aid of tensiometers placed at two depths, 31 and 46 cm. Water was applied when the tensiometers averaged 50 centibars suction. An overhead sprinkler irrigation system was used to apply 15.0 cm of water to the plots.

The plots were combine harvested on October 30. The harvest area was 1250 cm by 244 cm. Grain yields were adjusted to 13% moisture.

Soil Sampling and Analysis

Composite soil samples were taken before planting and analyzed as described in Chapter 2.

The soil pH was 6.9 and Bray P was 98 ppm. Exchangeable K, Ca, and Mg were 118, 600, and 101 ppm, respectively. Organic matter was 2.0%.

Plant Sampling and Analysis

In 1981 all plots in the first planting were sampled at the early bloom stage (R2). The uppermost fully-developed leaf was used for sampling. Sample preparation and analysis procedure were the same as described in Chapter 2. Analysis was performed at the Michigan State University plant analysis laboratory.

Statistical Analysis

Statistical analysis was performed using a Cyber 750 computer. Statistical procedures used are those given by Steel and Torrie (1980).

RESULTS AND DISCUSSION

Growing Conditions

The growing conditions in 1981 are detailed in Chapter 2. Leaf diseases, stem blight, and stem rot were prevalent late in the season to cause lower than expected yields. Early irrigation of the soybeans because of droughthy conditions may have caused early lodging of the Harcor variety. The soybeans grew very rapidly after the irrigation and Harcor, the tallest of the three varieties, was most susceptible to lodging. Sprite and Gnome stood much better and only a small amount of lodging occurred. The extreme wet weather in September and October hindered the development of the seed and may have depressed yields.

Effect of Nitrogen Fertilization on Soybean Yield

Soybean grain yields for 1981 are presented in Tables 5-1 and 5-2. For the early planting (Table 5-1) only varieties were significantly different in yield. Sprite was the highest yielding of the three varieties, but only for the 200 kg N/ha treatment at prebloom was the difference significant. Gnome and Harcor were essentially equal in yield. For the late planting (Table 5-2) Gnome and Harcor were not significantly different in yield. Although the early and late planting cannot be compared statistically, yields for the late planting were much lower. Nitrogen rate and time of application for early planting had no significant effect on soybean yield in 1981. For the late planting significant yield increases from application of 200 kg N/ha at either spring tillage or prebloom were noted for the Gnome variety. Lodging of

Table 5-1. Soybean grain yield as affected by rate and time of nitrogen fertilizer application (early planting).

Variety	Nitrogen Rate (kg/ha) and Time 0	200ST[1]	200PB[2]	100ST + 100PB	$LSD_{(.05)}$
	-----------------(yield[3] kg/ha)			---------	
Sprite	3,050	3,150	3,200	3,210	(NS)
Gnome	2,680	3,000	2,920	2,870	(NS)
Harcor	2,830	2,930	2,760	2,890	(NS)
$LSD_{(.05)}$	(380)	(380)	(380)	(380)	

Overall Means

Variety	Soybean Yield (kg/ha)	Nitrogen Rate and Time	Soybean Yield (kg/ha)
Sprite	3,150	0	2,850
Gnome	2,870	200ST	3,030
Harcor	2,850	200PB	2,920
		100ST + 100PB	2,990
$LSD_{(.05)}$	(NS)		
		$LSD_{(.05)}$	(NS)

[1]ST= Spring Tillage
[2]PB= Prebloom
[3]Adjusted to 13% moisture.

Table 5-2. Soybean grain yield as affected by rate and time of nitrogen fertilizer application (late planting).

Variety	Nitrogen Rate (kg/ha) and Time 0	200ST[1]	200PB[2]	100ST + 100PB	$LSD_{(.05)}$
	------------------(yield[3] kg/ha)---------				
Gnome	2,130	2,560	2,490	2,320	(300)
Harcor	2,080	2,310	2,240	2,290	(300)
$LSD_{(.05)}$	(NS)	(NS)	(NS)	(NS)	

Overall Means

Variety	Soybean Yield (kg/ha)	Nitrogen Rate and Time	Soybean Yield (kg/ha)
Gnome	2,380	0	2,110
Harcor	2,230	200ST	2,430
		200PB	2,360
$LSD_{(.05)}$	(NS)	100ST + 100PB	2,310
		$LSD_{(.05)}$	(300)

[1]ST= Spring Till
[2]PB= Prebloom
[3]Adjusted to 13% moisture.

Harcor in the early bloom stage may have depressed the response for this variety. For both varieties all nitrogen treatments yielded better than the controls. The overall means showed only a significant yield increase from 200 kg N/ha at spring tillage. These results tend to agree with the findings of Sorensen and Penas (1978). They noted yield increases from nitrogen fertilization as the yield level declined, also. Two other factors they found important in determining a yield response, percent organic matter and pH, did not appear to be related to the yield response in this study. Soil nitrate levels were not measured, so this factor cannot be related to yield in this study.

Plant Analysis

The overall means for the elemental composition of leaf samples for the early planting are presented in Table 5-3. The individual treatments are shown in Table 2a of the appendix.

All three varieties had sufficient levels of all elements (Small and Ohlrogge, 1973). Nitrogen contents for Gnome and Harcor were above the suggested sufficiency range. Phosphorus content was significantly different for all three varieties, with Harcor being the highest and Sprite the lowest. Sprite was significantly higher than the other two varieties in Ca content, and higher than Harcor in Mg content.

There were no significant differences detected in nutrient composition from nitrogen application. Since nitrogen levels were high for the control treatment, a significant increase in N content from nitrogen fertilization would not be expected.

Table 5-3. Elemental composition of soybean leaf samples as affected by variety and nitrogen treatment at the prebloom stage (R2) in 1981 (early planting).

OVERALL MEANS Soybean Variety	N	P	K	Ca	Mg	Zn	Mn	Cu
	%					ppm		
Sprite	5.42	.361	2.07	.82	.340	42	71	12
Gnome	5.73	.382	2.09	.73	.333	44	72	11
Harcor	5.74	.406	2.09	.74	.325	44	67	20
LSD (.05)	(NS)	(.017)	(NS)	(.03)	(.010)	(NS)	(NS)	(NS)
Nitrogen Rate and Time								
0	5.50	.374	2.11	.77	.323	43	68	18
200ST[1]	5.58	.383	2.08	.76	.332	45	71	12
200PB[2]	5.64	.391	2.08	.76	.336	42	70	17
100ST + 100PB	5.78	.385	2.08	.78	.338	43	72	11
LSD (.05)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)

[1]ST = Spring Tillage

[2]PB = Prebloom

SUMMARY AND CONCLUSIONS

Soybean yields in 1981 were not as high as expected due to disease problems and a very wet fall. Yields for the early planting date were higher than for the later planting date. This was somewhat surprising because the late planting date (May 18) was not much later than is normally recommended. Varieties were generally not significantly different in yield for either planting date.

Application of nitrogen fertilizer did not significantly increase yields for the early planting, but did for the Gnome variety in the later planting. This may be an indication that variety selection alone is not enough to determine a yield response to nitrogen fertilization. Planting date may also be important.

The fairly high nitrogen content in the leaves of the control treatment may be the reason little response was noted to nitrogen fertilization in the early planting. Nitrogen fixation was probably sufficient to satisfy the needs of the plant and added nitrogen was of little benefit. Similarly, Parker and Harris (1977) saw no response in leaf N to nitrogen fertilization when the controls had levels above 5.0%. The late planted soybeans were not sampled in this study, so there is no indication of what the leaf N levels were. Significant differences were noted between varieties for leaf elemental composition of P, Ca, and Mg. No elemental differences were detected between nitrogen treatments.

CHAPTER 6

EFFECT OF FOLIAR FERTILIZATION ON YIELD AND ELEMENTAL COMPOSITION OF SOYBEANS

INTRODUCTION

Considerable research has been conducted in Iowa and other states in recent years on the use of foliar fertilizers to increase soybean yields. In some instances very substantial yield increases have been realized, whereas in other studies no response or yield reductions have been noted (Garcia and Hanway, 1976; Vasilas et al., 1980; Syverud et al., 1980; Boote et al., 1977; Parker and Boswell, 1980). In this present experiment the effects of foliar fertilizers were studied under a high yield environment. By optimizing as many factors as possible the effects of foliar fertilization can more closely be examined. The biggest problem with foliar fertilizers appears to be determination of the conditions necessary for a yield response. Once this problem is solved, foliar fertilizers may become very practical on soybeans. Two plant population levels were evaluated to determine the effect of increased plant density on seed yield. Because of the problems with diseases in 1981 a fungicide treatment was also studied. Seed elemental composition as affected by soybean variety, foliar fertilization, and plant population was also examined.

MATERIALS AND METHODS

Management Practices and Experimental Design

This study was initiated in 1982 on a Metea loamy sand following the 1981 corn population study. The experimental design was a split-plot with four replications. Two varieties (Wells II and Corsoy 79) and two seeding rates (387,000 and 516,000 plants/ha) were used as the whole plot treatments. The subplot treatments were foliar fertilization and/or fungicide application.

The plots were moldboard plowed in the fall of 1981 to a depth of 20 cm. Spring tillage consisted of disking, and twice over with a field cultivator.

Weed control was accomplished with a preplant incorporated application of Amiben (2.24 kg a.i./ha) plus Lasso (2.24 kg a.i./ha).

A broadcast application of 448 kg of 10-20-20 per hectare was applied and incorporated. A starter fertilizer of 28 kg of 8-32-16 per hectare was applied at planting. Total N + P_2O_5 + K_2O applied was 47 + 226 + 113 kg/ha.

Planting was done on May 11 with a John Deere soybean drill equipped with Tru-Vee double disk openers for independent depth placement of seed for each row. Row width was 25.4 cm and seed depth was 3.8 cm. A 244 cm border area was planted next to each plot to allow room to turn the foliar fertilizer sprayer on and off.

The four subplot treatments were: (1) a control; (2) foliar fertilization; (3) fungicide application; and (4) foliar fertilization plus fungicide application. The foliar ferilizer was applied beginning at the R5 growth stage (initial pod-fill). The materials supplying N-P-K-S were urea (46-0-0), potassium polyphosphate (0-46-47), and potassium sulfate (0-0-50-17S).

The materials were mixed in water to dissolve them. A nonionic surfactant (WEX) (0.05 kg) was added to 31.7 kg of water first, and then 1.4 kg of potassium sulfate was added and dissolved. The surfactant was necessary to keep the nondissolved fine particles suspended, and also to aid in absorption of the fertilizer spray by the leaves. The potassium polyphosphate (2.4 kg) was next dissolved and added to the solution. Urea (9.9 kg) was added last and dissolved. This order of mixing was necessary to assure all materials would dissolve. The final mixture was 10% N, 2.4% P, 4.0% K, and 0.5% S.

Three spray applications were made on the soybeans between August 1 and August 18. The fertilizer was sprayed in the evening with a micromax rotary nozzle sprayer at a rate of 140 liters/ha. The total nutrients applied for the three sprays was 42.6 + 10.2 + 17.0 + 2.1 kg/ha for N + P + K + S, respectively.

The fungicide treatment consisted of two sprays, one of Topcop (1.0 liters/ha) and another of Benlate (0.84 kg/ha). These materials were also applied during the pod-filling stage, the Topcop on August 5, and the Benlate on August 27. The micromax rotary nozzle sprayer was used to apply the fungicides.

Previous years of research by Dr. Maurice Vitosh have indicated that the most effective irrigation schedule for soybeans is to delay early watering and then supply an adequate to high level of irrigation later. This program was followed in 1982. Early in the season the tensiometers were allowed to reach 70 centibars suction before irrigating. Near the bloom stage irrigation was begun at 50 centibars suction. An overhead sprinkler irrigation system was used to apply 7.1 cm of water to the study.

The plots were combine harvested on October 8. The harvest area was 457 cm by 488 cm. Grain yields were adjusted to 13% moisture.

Soil Sampling and Analysis

Composite soil samples were taken in April and analyzed in 1982 as described in Chapter 2.

The results indicated a pH of 6.6, Bray P was 140 ppm, exchangeable K was 112 ppm, exchangeable Ca was 503 ppm, and exchangeable Mg was 67 ppm. Organic matter content was 2.0%.

Soybean Grain Analysis

The elemental composition of the soybean grain was determined for the control and foliar fertilized plots. Samples were dried in a forced air oven at 60 degrees C for 7 days. The samples were then ground to pass a 20 mesh screen. All samples were sent to the Ohio Plant Analysis Laboratory for complete spectographic analysis. Results are reported for N, P, K, Ca, Mg, Zn, Mn, Cu, B, and Fe.

Statistical Analysis

Statistical analysis was performed using a Cyber 750 computer and the Genstat statistical package (Alvey et al., 1980). Statistical procedures used are those given by Steel and Torrie (1980).

RESULTS AND DISCUSSION

Growing Conditions

The growing conditions for 1982 are detailed in Chapter 2. Minor leaf burn was noted on some plots after each fertilizer spray application, but overall was not a serious problem. Senescence of the soybeans began on September 2, which seemed early compared to other soybeans in the area planted at approximately the same time.

Effect of Foliar Fertilization, Fungicide Application, and Plant Population on Yield of Soybeans

Soybean yield and final plant population in 1982 are presented in Table 6-1. Yields were lower than expected again in 1982. Foliar fertilization had no significant effect on yields. These results are similar to those reported by Boote et al. (1977) and Syverud et al. (1980). The foliar fertilizer rates used in this experiment were one half those recommended by Hanway (1980).

Fungicide application in 1982 had no significant effect on soybean yield. In most treatments the fungicides tended to depress yields. Foliar fertilization plus the fungicides also did not affect yields.

Plant population levels were about what was expected in 1982 for the Wells II variety, but Corsoy 79 was much lower than expected (Table 6-1). The seed coats of Corsoy 79 appeared to be more susceptible to cracking during planting. This may have contributed to the lower plant populations. Plant population had no effect on yield for either variety. This agrees with the findings of other researchers (Hicks et

Table 6-1. Effect of plant population, foliar fertilizer and fungicide treatment on yield of two soybean varieties.

Treatment	Soybean Variety/Plant Population: Wells II 406,000	Wells II 523,000	Corsoy 79 303,000	Corsoy 79 352,000	$LSD_{(.05)}$
	yield kg/ha[1]				
Control	2,940	3,180	3,260	3,080	(NS)
Foliar Fertilizer	3,040	3,010	3,090	3,330	(NS)
Fungicide	3,120	2,930	3,010	2,800	(NS)
Foliar Fertilizer + Fungicide	3,030	3,120	3,170	3,180	(NS)

Overall Means

Variety	Soybean Yield (kg/ha)	Treatment	Soybean Yield (kg/ha)
Wells II	3,050	Control	3,110
Corsoy 79	3,120	Foliar Fertilizer	3,120
$LSD_{(.05)}$	(NS)	Fungicide	2,960
Plant Population		Foliar Fertilizer + Fungicide	3,120
Low	3,080	$LSD_{(.05)}$	(NS)
High	3,080		
$LSD_{(.05)}$	(NS)		

[1]Adjusted to 13% moisture.

al., 1969; Costa et al., 1980; Lueschen and Hicks, 1977). The two varieties were not significantly different in yield.

Soybean Seed Analysis

The overall effect of variety, plant population, and foliar fertilization on elemental composition of soybean seed is presented in Table 6-2. The data for individual treatments is presented in Table 3a of the appendix.

The varieties were significantly different in seed composition of N, Ca, Mg, Cu, B, and Fe. The Wells II variety was higher than Corsoy 79 for each of these elements.

Plant populations significantly affected N and Fe content of the seed. The high population was higher in N content, but lower in Fe content.

Foliar fertilization significantly affected Mg, B, and Fe content of the seed. Each of the three elements was decreased by foliar fertilization. Seed N was not increased by foliar fertilization. This disagrees with the findings of Parker and Boswell (1980) and Syverud et al., (1980). The interaction effects of variety and foliar fertilization on N, P, and K content of the seed is presented in Table 6-3. Only varieties were significantly different in N content. Foliar fertilization significantly increased the seed P for Corsoy 79, but not for Wells II. The varieties were significantly different in P content for the controls, but not when foliar fertilizers were applied. Apparently foliar fertilization brought the seed P level of Corsoy 79 up to that of Wells II. Seed K content was not significantly affected by foliar fertilization. However, Corsoy 79 was significantly higher in

Table 6-2. Elemental composition of soybean seed as affected by variety, population, and foliar fertilizer application.

Hybrid	N	P	K	Ca	Mg	Zn	Mn	Cu	B	Fe
			%					ppm		
Variety:										
Wells II	7.25	.63	1.99	.16	.25	51	21	13	25	71
Corsoy 79	6.95	.64	2.01	.15	.22	50	21	12	24	63
LSD (.05)	(.11)	(NS)	(NS)	(.01)	(.01)	(NS)	(NS)	(1)	(1)	(4)
Population:										
Low	7.03	.64	2.00	.16	.23	52	21	13	24	70
High	7.16	.65	1.99	.15	.23	49	22	13	24	66
LSD (.05)	(.11)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(4)
Foliar Fertilizer:										
None	7.09	.64	2.00	.16	.24	51	21	13	25	71
Applied	7.11	.65	1.99	.15	.23	50	21	13	24	65
LSD (.05)	(NS)	(NS)	(NS)	(NS)	(.01)	(NS)	(NS)	(NS)	(1)	(3)

Table 6-3. Effect of variety and foliar fertilization on the N, P, and K composition of soybean seed (interaction effects).

Variety	Foliar Fertilizer	Element		
		N	P	K
Wells II	None	7.22	.66	2.01
	Applied	7.27	.65	1.96
Corsoy 79	None	6.95	.62	1.99
	Applied	6.94	.65	2.02
LSD(.05)		(0.11)	(.03)	(.05)

seed K than Wells II only when foliar fertilizers were applied.

SUMMARY AND CONCLUSIONS

Foliar fertilization had no significant affect on soybean grain yield in 1982. The rates of foliar fertilizers used were lower than in other studies, and this may have contributed to the lack of yield response. Use of 25 cm row spacings instead of 76 cm row spacings may have prevented the sprays from getting good penetration into the crop canopy. There was no increase in seed N in this study, contrary to the results of other researchers, and it may be that the plants could not use the additional N for some reason. It did appear that the Corsoy 79 took up the P and K from the foliar fertilizers. Evidence of this is that seed P was significantly increased by foliar fertilization, and only when foliar fertilizers were applied was the seed K content of Corsoy 79 higher than for Wells II. Wells II was not responsive to foliar fertilization in yield or uptake of the nutrients into the seed. Fungicide treatment or the two plant population levels had no effect on yields in 1982.

If further study on foliar fertilizers is conducted here at Michigan State University, there are some factors that should be tested. Higher rates of foliar fertilizers should be tried. Uptake of foliar fertilizers should be compared for the 25 cm row spacing versus a 76 cm row spacing. Several varieties should be tested for yield response to foliar fertilization.

APPENDIX

Table 1a. Removal of N, P, and K in 1981 by three corn hybrids grown at three plant population levels.

Hybrid	Row Spacing	Plant Population	Nitrogen Stover	Nitrogen Grain	Nitrogen Total	Phosphorus Stover	Phosphorus Grain	Phosphorus Total	Potassium Stover	Potassium Grain	Potassium Total
	(cm)	(plants/ha)	Kg/ha								
Pioneer 3780	76	72,020	48	145	193	4	27	31	114	45	159
Michigan 5922	76	69,200	74	131	205	5	23	28	166	40	206
Pioneer 3572	76	66,770	69	146	215	5	23	28	132	40	172
Pioneer 3780	76	84,390	50	133	183	4	24	28	119	43	162
Michigan 5922	76	84,800	68	134	202	4	28	32	172	46	218
Pioneer 3572	76	81,100	70	146	216	6	26	32	146	46	192
Pioneer 3780	63-13	95,280	53	159	212	4	28	32	133	49	182
Michigan 5922	63-13	94,140	78	160	238	5	26	31	164	43	207
Pioneer 3572	63-13	90,780	72	157	229	5	25	30	150	45	195
Michigan 5922	63-13	88,560	76	153	229	5	28	33	166	45	211

Table 2a. Elemental composition of soybean leaf samples at the prebloom stage (R2) as affected by variety and nitrogen treatment in 1981 (early planting).

Soybean Variety	Nitrogen Rate and Time	Elements							
		N	P	K	Ca	Mg	Zn	Mn	Cu
		%					ppm		
Sprite	0	5.50	.37	2.11	.84	.34	45	69	13
	200 ST[1]	5.46	.34	2.05	.83	.34	40	74	12
	200 PB[2]	5.37	.38	2.06	.78	.33	45	71	12
	100ST + 100PB	5.33	.36	2.08	.82	.34	39	70	12
Gnome	0	5.30	.35	2.12	.79	.32	41	70	11
	200ST	5.53	.39	2.09	.70	.32	48	71	12
	200PB	5.81	.40	2.08	.71	.34	42	69	11
	100ST + 100PB	6.27	.39	2.08	.79	.35	43	78	11
Harcor	0	5.70	.40	2.09	.67	.32	44	66	30
	200ST	5.76	.42	2.12	.75	.33	47	67	12
	200PB	5.78	.40	2.09	.80	.34	39	70	27
	100ST + 100PB	5.72	.41	2.07	.74	.32	45	66	10
LSD (.05)		(NS)	(.04)	(NS)	(.09)	(.02)	(NS)	(NS)	(NS)

[1]ST = Spring Tillage

[2]PB = Prebloom

Table 3a. Elemental composition of soybean seed as affected by variety, population, and foliar fertilizer application in 1982.

Variety	Foliar Fertilizer	Plant Population	Element									
			N	P	K	Ca	Mg	Zn	Mn	Cu	B	Fe
			%					ppm				
Wells II	None	L[1]	7.23	.66	2.02	.16	.25	54	22	13	26	74
	Applied	L	7.20	.65	1.99	.16	.24	54	22	14	23	74
	None	H[2]	7.22	.66	1.99	.16	.25	49	21	12	26	73
	Applied	H	7.34	.64	1.94	.15	.24	49	21	13	24	64
Corsoy 79	None	L	6.87	.61	1.99	.16	.22	51	21	13	24	69
	Applied	L	6.82	.63	2.00	.15	.21	50	20	11	23	63
	None	H	7.04	.63	1.99	.15	.22	51	22	12	24	68
	Applied	H	7.07	.67	2.04	.14	.22	48	22	13	23	58

[1] L = Low

[2] H = High

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