AN ABSTRACT OF THE THESIS OF

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Title: THE EFFECTS OF PLANTING DATE, NITROGEN AND BORON APPLICATION ON MINERAL ELEMENT CONCENTRATION, YIELD, DRY WEIGHT AND FRESH WEIGHT OF SWEET CORN

Abstract approved: ______________________________

M. H. Chaplin

The effects of planting date on mineral element concentration in sweet corn (Zea mays L. cv. Jubilee) at six developmental stages and on yield were investigated. Planting dates were chosen to correspond to early, mid-season, and late commercial plantings. Two nitrogen rates were applied since nitrogen is more often limiting than any other nutrient for sweet corn grown in Western Oregon. Boron was also applied since it has been shown to be limiting in many other crops grown in the Willamette Valley.

Planting date significantly affected N, P, K, Ca, Mg, Mn, Fe, Cu, B, and Zn concentration in the whole plants during the vegetative growth stages and in the ear leaves during the stages between tasseling and harvest. During the early stage of growth, N, P, K, Ca, Mg, B, and Zn tended to be higher in the early planted corn plants, while later in the development of corn the effects of planting date were

more variable. Planting date also affected the fresh and dry weight of whole plants; the later planting produced more dry weight than the earlier two plantings, while the early planted corn produced more fresh weight at harvest than the later two plantings. Consequently, when analyzing sweet corn for nutritional status, date of planting should be considered when interpreting the plant analysis data.

The application of B had no effect on yield, fresh weight or dry weight and only increased B concentration at the first developmental stage. The additional application of N, did not significantly increase yield for the late planted corn, but did for early planted corn. N concentration, as well as Mg, Mn, Cu, and Zn concentrations increased with the higher rate of N fertilizer applied (125 kg/ha). Fresh weight and dry weight were both higher in the plants receiving the higher rate of N, with the difference becoming greater as the plants matured.

The Effects of Planting Date, Nitrogen and Boron Application on Mineral Element Concentration, Yield, Dry Weight and Fresh Weight of Sweet Corn

by

Jonathan Anthony Sisson III

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APPROVED:

Associate Professor of Horticulture
in charge of major

Head of Department of Horticulture

Dean of Graduate School

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Typed by Opal Grossnicklaus and J. Sisson for
Jonathan Anthony Sisson III

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THE EFFECTS OF PLANTING DATE, NITROGEN AND BORON APPLICATION ON MINERAL ELEMENT CONCENTRATION, YIELD, DRY WEIGHT AND FRESH WEIGHT OF SWEET CORN

INTRODUCTION

Sweet corn is an important vegetable crop for prosessing and fresh market in Western Oregon. Total area for the past three years averaged about 17,000 hectares annually. Planting dates vary from May 1 to June 20 to insure an optimum flow of corn to processing plants. Planting dates are also affected by the amount and frequency of spring rainfall since seedbed preparation is dependent on proper soil moisture conditions.

Growers fertilize sweet corn with N, P, and K mixtures at either a prescribed amount or by an amount recommended after a soil test is performed. Soil tests are adequate for some elements, but not for others. For example, N is more often deficient than any other element, but there does not seem to be a well accepted method for testing available N (9) that is reliable for predicting N requirements for corn. Generally there are two major problems associated with soil testing (38): (1) errors due to failure of the method used to extract available nutrient forms and to poor correlations with crop responses and (2) to differences among soils in their capacity to supply nutrients (8).

Plant analysis has been an effective diagnostic tool for interpreting the nutritional status of many perennial crops; however, it has been used to a limited extent in vegetable crops (17) because (1) plants have a short life cycle, and (2) maturity and stage of development influence nutrient requirement and leaf content.

Although there is considerable literature on plant analysis data on field and sweet corn (18, 31, 37, 46), further work is particularly needed on effects of planting dates on mineral concentrations of sweet corn under Western Oregon conditions.

The objectives of this study were the following:

1. To determine the effect of planting date on yield and on mineral element concentration and fresh and dry weight at specific developmental stages.

2. To study the influence of nitrogen fertility on mineral concentration and yield, and any interactions with planting date.

3. To determine the influence of boron application on yield and boron concentration in the plant.

LITERATURE REVIEW

Effect of Planting Date on Corn

In many geographical areas, planting corn early in the season will result in higher yields than if planting were delayed (2, 11, 15, 19, 32, 33, 44, 47, 54, 59, 68, 69, 70, 71). It has also been noted that other aspects of corn growth are affected by date of planting, such as dry matter accumulation, nutrient concentration, plant height, leaf area, ear length, and number of kernels per row. The effect of planting date on corn growth was different between maturity groups and between cultivars within maturity groups. Environmental conditions associated with different planting dates such as soil and air temperature, water evaporation, solar radiation and photoperiod have been shown to affect growth.

In a two year study, Mikhail and Shalaby (39) observed that planting date affected total N uptake, N in stems, sheaths, leaf blades, and protein content in the kernels. In the first year, N uptake and utilization were greater in the first planting (late March) than the late planting (late July), while in the the second year there was little difference in plant performance between the two planting dates.

On Prince Edward Island, White (68) observed that N and

P leaf concentrations at silking and in the whole plant at harvest tended to be higher in the plants planted later than earlier. Grain yield and total dry weight at harvest were significantly higher for the early plantings; therefore, the low concentration of N and P for the early plantings as compared to the late plantings was at least partially due to dilution of these elements by the greater amount of dry matter. Generally, K at both silking and harvest was not affected by planting date.

In an experiment to determine elemental uptake efficiency of corn hybrids grown on a soil low in available Mg, Gallaher and Jellum (15) found that planting date affected the leaf element concentration of Mn, Fe, K, Ca, and Mg differently for each hybrid. Planting date had no effect on Zn and P levels for all hybrids studied. The influence of planting date on K/Ca, K/Mg, and K/(Ca+Mg) ratios also varied with hybrid. In another experiment by Gallaher and Jellum (16) with three hybrids planted at five different dates from March 5 to June 28; planting date affected Mn, Fe, K, Ca, Mg, K/Ca, K/Mg, and K/(Ca+Mg). The effect of planting date on these elements varied with each hybrid.

In a survey of 90 sweet corn fields in the mid-Willamette Valley, Jackson, et al (26) investigated the effect of three planting dates on P, K, Ca, Mg, Zn, Mn, Cu, and B at two stages of growth: when the plants were 50cm tall and at tasseling. As planting was delayed, the levels of B and Cu increased in the first stage, while there was no difference in B and Cu levels between the three planting dates at tasseling. Planting date had no influence on Ca, Mg, Zn, Mn, or N concentrations for either stage, but K in the late planted corn was higher than the earlier two plantings when the plants were 50cm in height.

Fribourg, et al (14) found that the removal of nutrients was related to the yield of corn. Early planted (30 April-15 May) corn produced higher yields than late planted corn (2-12 June), and N, P, K, Ca, and Mg concentrations were all higher in the early planting. In general, nutrient uptake of N, P, K, Ca, and Mg increased linearly with increasing yield.

In two experiments , Grogan, et at (19) observed that yields from longer maturity groups were affected more by planting dates than shorter maturity groups. Longer maturity groups benefited more by planting corn early than did the shorter maturity groups. Similar results of planting date effects on the yield of different maturity groups were observed by Zuber (70, 71), Dillon (11), and York (69).

Planting date has also been shown to affect other growth characteristics; as planting was delayed, plant height decreased (54, 57), number of ears per plant decreased (54, 58), length of ears and number of kernels per ear decreased (54, 58), leaf blade area decreased (57), and dry matter production decreased (59, 68).

Early planted corn produced higher yields of ears and grain than later plantings, while later plantings produced greater vegetative growth at the expense of grain yield (44, 47). Osafo and Milbourn (44) observed that as the date of planting was delayed, the peak vegetative dry matter and peak leaf-area index were higher and occurred progressively later after silking. They concluded that early planting leads to higher grain yields because the production of peak vegetative weight near to the time of silking allows photosynthate produced after that stage, still at a time of high radiation, to be transfered directly to the ears rather than being used for vegetative growth as was the case for the later plantings. Furthermore, the contribution of stem weight to the developing kernel (6, 10, 45, 55) occurred earlier and to a greater extent in the earlier planted corn.

Environmental conditions associated with planting date have been shown to affect the growth and development of corn. Ragland, et al (51) obvserved that soil and air temperature, solar radiation, and water evaporation were each positively correlated with corn ear growth. The rate of leaf area increase for early planted corn was more highly correlated with soil and air temperature than any other measured factor, while the rate of leaf area growth for the late planted corn was equally correlated with temperature and relative humidity.

In an experiment where corn plants were grown under different soil temperatures (5°, 12°, 20°, $29^{\circ}C$), Nielsen, et al (43) found that concentrations of N, P, Ca, Mg, and K in the tops 66 days after planting were highest in the plants grown at the lowest temperature, while there were no significant differences in elemental concentrations at the three highest temperature. Dry weight of the tops and roots and total amount of each nutrient increased proportionately with increase in soil temperature, so that the lower concentrations of N, P, Ca, Mg, and K in plants at the higher soil temperatures were due to dilution.

Benoit, et al (3) found that there was a linear relationship between the average air temperature for a 50-day period after silking and both corn yield (r=.87) and ear growth rate (r=.98). They concluded that effect of planting date on yields was related to the air temperature during the ear-formation period, where early plantings had higher temperatures than later plantings during this period.

Hunter et al (25) found that longer photoperiods delayed tassel initiation at all temperatures studied (20°, 25°,30°C), but the magnitude of the response was less at the high temperature. With longer photoperiods, there was an increase in amount of vegetative growth and development prior to tassel initiation, as evidenced by the greater number of emerged leaves, the longer stem length, and the greater plant dry weight. Temperature affected the amount of vegetative growth and development prior to tassel initiation, but the differences due to temperature were smaller than from photoperiod. Ragland, et al (52) also observed that longer photoperiods delayed tassel initiation. Supplemental light increased kernel initials per row, kernel initials per ear and number of rows per ear; but at maturity, kernels per row and kernels per ear were lower for plants receiving supplemental light. Grain weight per ear and grain weight per kernel were also low for the plants at longer photoperiods. Similar effects of photoperiod on yield have been observed by McClelland (36) and Lane (34).

Effect of N Application on Corn

Crops are usually more often deficient in N than any other element (9). For sweet corn grown in Western Oregon, nitrogen is recommended at a rate of 170-210 kg/ha (35). When N is limiting, total N, yield, other elements, and physiological responses are affected.

When the total amount of N in the corn plant is plotted against time, the resulting curve was sigmoidal in character (6, 21, 56). Total N in the leaves and stalks reached a peak soon after silking, then began to decline due to the translocation of N to the developing kernels (6, 21, 39, 56). Storage material was also translocated to the developing kernels from the leaves, cob, husk, and stalks (6, 20, 56).

N concentration in the leaves reached a peak early in the development of the corn plant, and then declined through harvest (22, 39). Terman and Noggle stated that the high N concentration in the very young corn plant apparently occurred as a result of more rapid uptake of N than of vegetative growth (64). Later, dry matter production increased and N concentration declined. After silking when the leaves are fully developed and N is translocated to the developing kernels, leaf N continues to decline. Hanway (22) concluded that the rate of decline in the corn leaves was proportional to the soil's nitrogen fertility; the higher the soil N, the greater the rate of leaf N decline.

Increasing the rate of nitrogen fertilizer application usually increased yield of corn ears (1, 33, 39, 54, 58, 59, 63). Once N supply was at a level for maximum yield, any additional N had no effect or in some cases decreased yields (1, 57, 58, 59). Satter, et al (54) observed that with an increase in N application there was an increase in plant height, number of matured ears, length of ears , and number of kernels per ear. Shalaby and Mikhail (57, 58, 59) noted an increase in plant height, leaf blade area, per cent of plants with two ears, ear length, number of kernels per row, average weight per 1000 kernels, and fodder yield with an increase in nitrogen application.

Nitrogen fertilizer application increased N concentration in plants as well as affected concentrations of other elements (22, 39, 60, 63, 64). Terman, et al (64) observed that Ca and Mg concentrations increased with increase in N applied, while K decreased. In a study by Smith, et al (60), Mn, Cu, B, and Ca increased and P, K, and B were unaffected as N was applied in greater quantities. Nelson (41) observed that leaf P was directly related to N application rate.

Effect of Boron Application on Corn

The differing ability of soils to adsorb added B was positively correlated with specific surface area and organic matter content of soils (23, 24, 27). Wear and Patterson (67) illustrated that alfalfa grown on coarse-textured soil had the highest uptake of B and the plants from the fine-textured soil had the least, with the medium-textured soil being intermediate.

The pH of the soil also influenced the availablilty of B in soils (2, 67). Wear and Patterson (67) found that the uptake of B by the alfala increased as pH decreased.

The application of B has either resulted in no increase in corn yield (27, 48, 50) or a decrease in corn yield due to toxicity (27, 28, 49, 65). Jones (28) observed that banding .3 kg/ha B significantly reduced yields. Yield reductions occured when B concentrations in the leaves were in excess of 40ppm in the third leaf at silking. In a pot experiment (27), the effect of applied B on yield was dependent on the soil type. Corn yields from the Annis (organic) and Monroe (alluvium) soils were not significantly lowered until at least 50ppm B had been applied to the soil; yield from Marble Hill (loess) soil was significantly depressed when only 0.5 ppm B was applied. This effect of soil on applied B and yield was attributed to the specific surface area of the three soils; the greater the area, the more adsorption of B to the soil particles.

In an experiment performed on Chehalis silty clay loam, Powers and Jordan (49) noted that the greatest yield of corn was obtained when 165 kg/ha of Borax was broadcasted. This was a high rate of applied boron. They concluded that the high B tolerance of Chehalis silty clay loam was related to its high base-exchange capactiy and buffer values.

The method of applying B affected the uptake of B in corn plants. Peterson and MacGregor (48) found that banding was most effective, then spraying, and lastly broadcasting in affecting B uptake while Powers and Jordan (49) observed that banding and spraying were equally effective, and both were superior to broadcasting.

Critical values for B in corn at various developmental stages have been suggested by several investigators. John, et al (27) determined that for Jubilee sweet corn B concentrations (in leaves four weeks after planting) must be between 23 and 30 ppm for normal growth to proceed. Critical values or ranges determined by others were as follows: toxicity when B concentration in the first mature leaf reached 95ppm (13), sufficiency range between 11 and 72 ppm in the whole plant (12), critical value of 18.3ppm in leaves at harvest (5); and sufficiency range between 4-25ppm in ear leaf at silking (31). In a pot experiment, Vaughn (66) found that B requirement was lower for vegetative growth than for silking and subsequent kernel development. B concentration of 3.4ppm for whole plants (three weeks after emergence) was sufficient for vegetative growth, but the silks were non-receptive at this level. Not until the whole plant B level reached 33ppm did the silks become receptive.

THE EFFECT OF PLANTING DATE, NITROGEN AND BORON APPLICATION RATES ON MINERAL CONCENTRATION AND YIELD OF SWEET CORN

KEY WORDS: *Zea mays* L. cv. Jubilee, developmental stage, mineral concentration.

Jonathan A. Sisson III

Department of Horticulture
Oregon State University
Corvallis, Oregon 97331

ABSTRACT

The effects of three planting dates on mineral concentration at six developmental stages and on yield of sweet corn (*Zea mays* L. cv. Jubilee) were investigated at two levels of nitrogen and two levels of boron during two seasons. Usually, N uptake increased with increased nitrogen fertilizer application, while B concentration increased with B application only at the first developmental stage sampled. Planting date significantly affected whole plant concentration of N, P, K, Ca, Mg, Mn, Fe, Cu, B, and Zn at the two vegetative stages sampled, with the mineral concentration for the early planting tending to be greater than for the later plantings. Planting date also affected leaf element concentration in the stages from tasseling to harvest, but the effects were less consistent than during the vegetative stages. Planting date and nitrogen rate both affected yield, with planting date influencing the yield response to nitrogen application-- the increase

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in yield due to the higher rate of nitrogen was greater for the earlier plantings than the late planting.

INTRODUCTION

Sweet corn is planted from May 1 to June 20 in Western Oregon to insure an optimum flow of corn to the processors. Planting dates are also determined by the amount and frequency of spring rainfall since seed bed preparation is dependent on proper soil moisture conditions.

In a review on plant analysis for vegetable crops, Geraldson, et al (17) stated that planting date may affect plant composition and correlated crop responses. Mikhail and Shalaby (39) observed significant differences in leaf N concentration between the late March planting and late July planting at 35, 55, and 75 days after planting for the first year of study, and at 55, 75, 95 and 115 days after planting during the second year of the study. In a four year investigation, White (68) found that the concentration of N, P and K was higher in both leaf and whole plant samples at harvest for late plantings when compared to earlier plantings. Fribourg, et al (14) observed that earlier planted corn removed more N, P, K, Ca, and Mg, and produced a greater amount of dry matter. Gallaher and Jellum (15, 16) also observed that planting date affected leaf element content at a given developmental stage, but that this effect varied with cultivar.

The objectives of this experiment were to determine effects of planting date on mineral element concentration at six developmental stages and on yield of husked ears. Plants were grown under two levels of N and B fertilizer since N was frequently reported deficient in sweet corn and B deficiency has been observed for many other crops in Western Oregon.

MATERIALS AND METHODS

Sweet corn (*Zea mays* L. cv. Jubilee) was planted on May 15, 30, and June 14 in 1979; and May 5, 20, and June 8 in 1980 to represent early, midseason and late season commercial planting dates.

The experimental design was a split-split plot with five replications of the main plots of two nitrogen treatments divided into three planting dates and further split into two boron treatments. All plots received 45 kg-N/ha as 8-24-8 fertilizer banded at planting. The high N treatment consisted of an additional side dressing of 80 kg-N/ha, as ammonium nitrate, when the plants were 15 cm tall. Boron treatments consisted of a control and 2.0 kg-B/ha, as solubor (20.5% B) mixed with sand for easier application, broadcast just after seeding. Soil type was a Chehalis silty clay loam with a pH of 6.2, CEC of

25meq/100g, and soil B of .63ppm.

Seeds were sown at 5cm spacing within rows, and later thinned to 18cm spacing when plants were 15cm tall, with rows 91cm apart. Boron plots consisted of three 10.7m rows; the outer rows were borders, while the center row was used for sampling.

Samples were taken at the following developmental stages: (1) when plants were 15 cm tall; (2) midpoint between the first sampling and tasseling, (3) at 90% tasseling, (4) at 90% silking, (5) midpoint between silking and harvest and 6) at harvest when the kernels contained 70-72% moisture. In 1979, the number of days between developmental stages averaged 35 days from planting to stage 1, 13 days between stages 1 and 2, 11 days between stages 2 and 3, 9 days between stages 3 and 4, 15 days between stages 4 and 5, and 19 days between stages 5 and 6. In 1980, the number of days between developmental stages was 30 days from planting to stage 1, 15 days between stages 1 and 2, 31 days between stages 2 and 3, 9 days between stages 3 and 4, 18 days between stages 4 and 5, and 15 days between stages 5 and 6.

Ten whole plants (above ground portion) per plot were randomly selected from the thinnings for the first sample, five whole plants for the second sample and ear leaves from five plants for each of the last four samples. These sampling procedures conform with the recommendation of Jones and Eck (31) for the first four developmental stages.

Samples were oven dried at 70°C, ground to pass a 40 mesh screen and analyzed by an automated Kjeldahl technique (56) for N and by spark emission spectroscopy (7) for K, P, Ca, Mg, Mn, Fe, Cu, B and Zn. Harvest was made when kernel moisture was 70 to 72% and the weight of husked marketable ears from 25 plants was taken for the yield.

Mineral element concentration and yield were statisticaly analyzed using appropriate analysis of variance (62) and regression analysis (42). Tukey's method of multiple comparision (42) was used to statistically compare the effects of planting date on each element at each of the six developmental stages.

RESULTS AND DISCUSSION

Application of 2.0 kg-B/ha increased B uptake (appendix table 5) only at the first developmental stage sampled (plants 15cm tall) and had no significant effect on yield. In general, the higher rate of N, 125 kg-N/ha, significantly increased N, Mg, Mn, Cu, and Zn concentrations (appendix tables 6-10) in the ear leaf (developmental stages 3-6). No interactions occured between planting date* nitrogen rate, planting date*boron rate, or planting date*nitrogen*boron rate on mineral element concentration; therefore, major emphasis will be given to effects of planting date on leaf element concentration.

During early development (stages 1 and 2), N, P, K, Mn, and Zn concentrations (figures 1, 2, 3, 6, and 10) in the whole plant tended to be higher in the first planting than in the second and third plantings. Calcium, Mg, B (1980 only), Cu (1979 only) were higher for the early planting when the plants were sampled at 15cm height, (figures 4, 5, 8, 9) while Fe (figure 7) was higher for the early planting at the second developmental stage. For both years, the higher nutrient concentrations for the early planting over the midseason planting were caused by greater uptake of nutrients as there was no significant difference in dry weight for the whole plants between these two planting dates at the early stages of growth. Dry weights of plants from the late planting were higher than the dry weights from the earlier two plantings, so the lower nutrient levels in the late planted corn were due to dilution rather than reduced uptake. Planting date therefore affected the mineral uptake and dry weights of plants at the early stages of development.

For the last four developmental stages (tasseling, silking, between silking and harvest, and harvest), the effect of planting date on mineral concentration was variable depending on the developmental stage and year

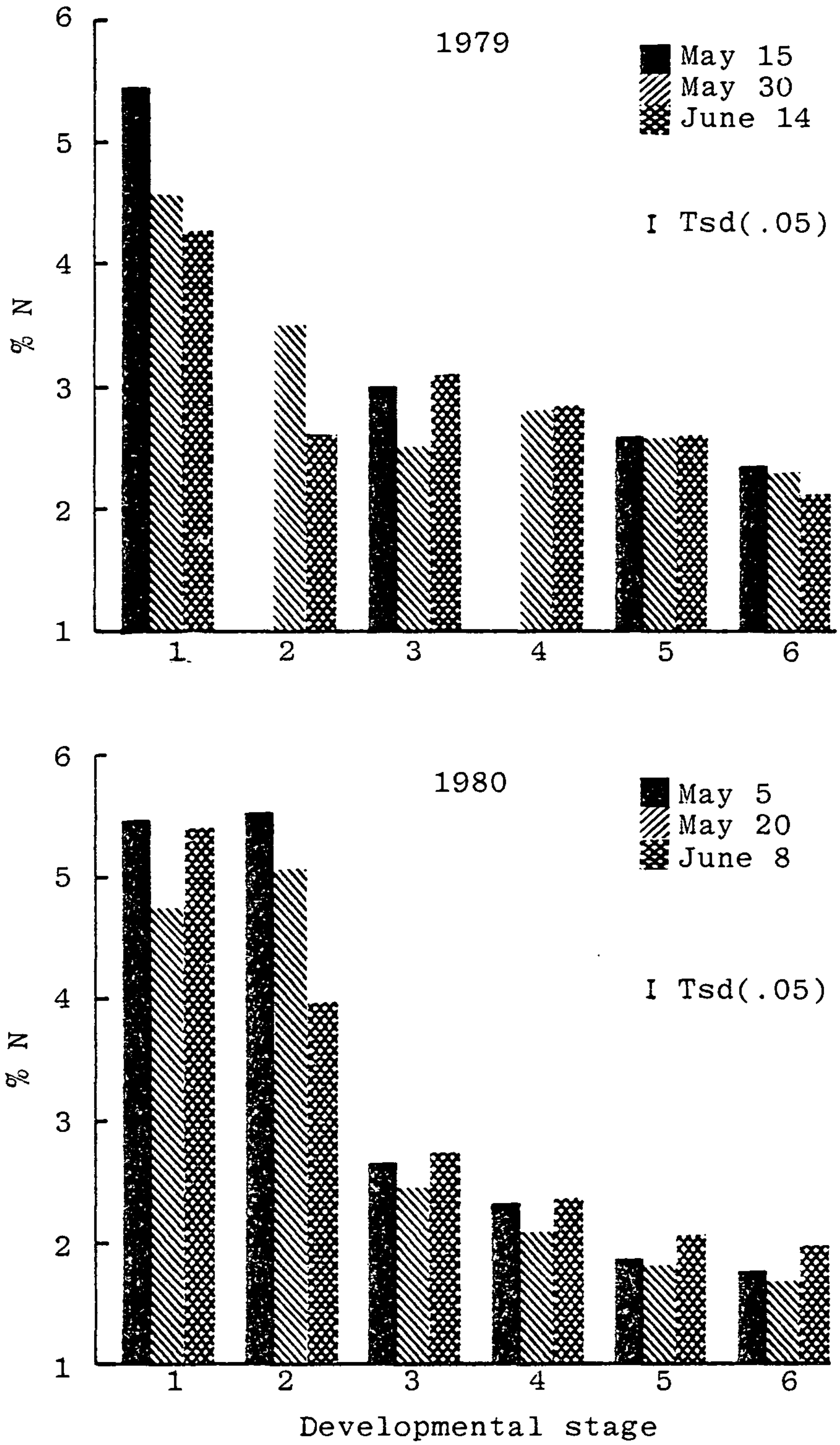


FIG. 1

Effect of planting date on N concentration at six developmental stages for two years. Tsd: Tukey's significant difference.

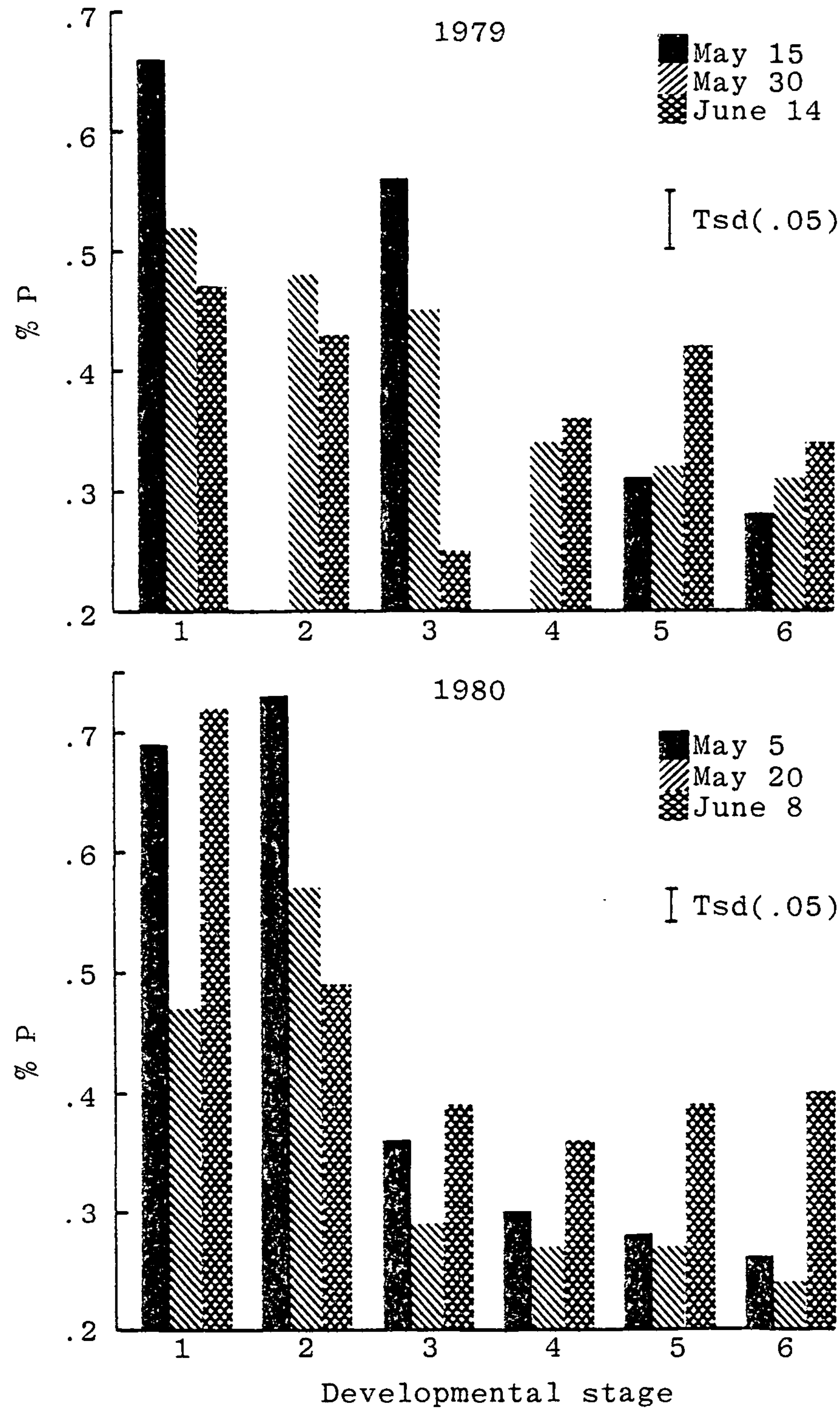


FIG. 2

Effect of planting date on P concentration at six developmental stages for two years.
Tsd: Tukey's significant difference.

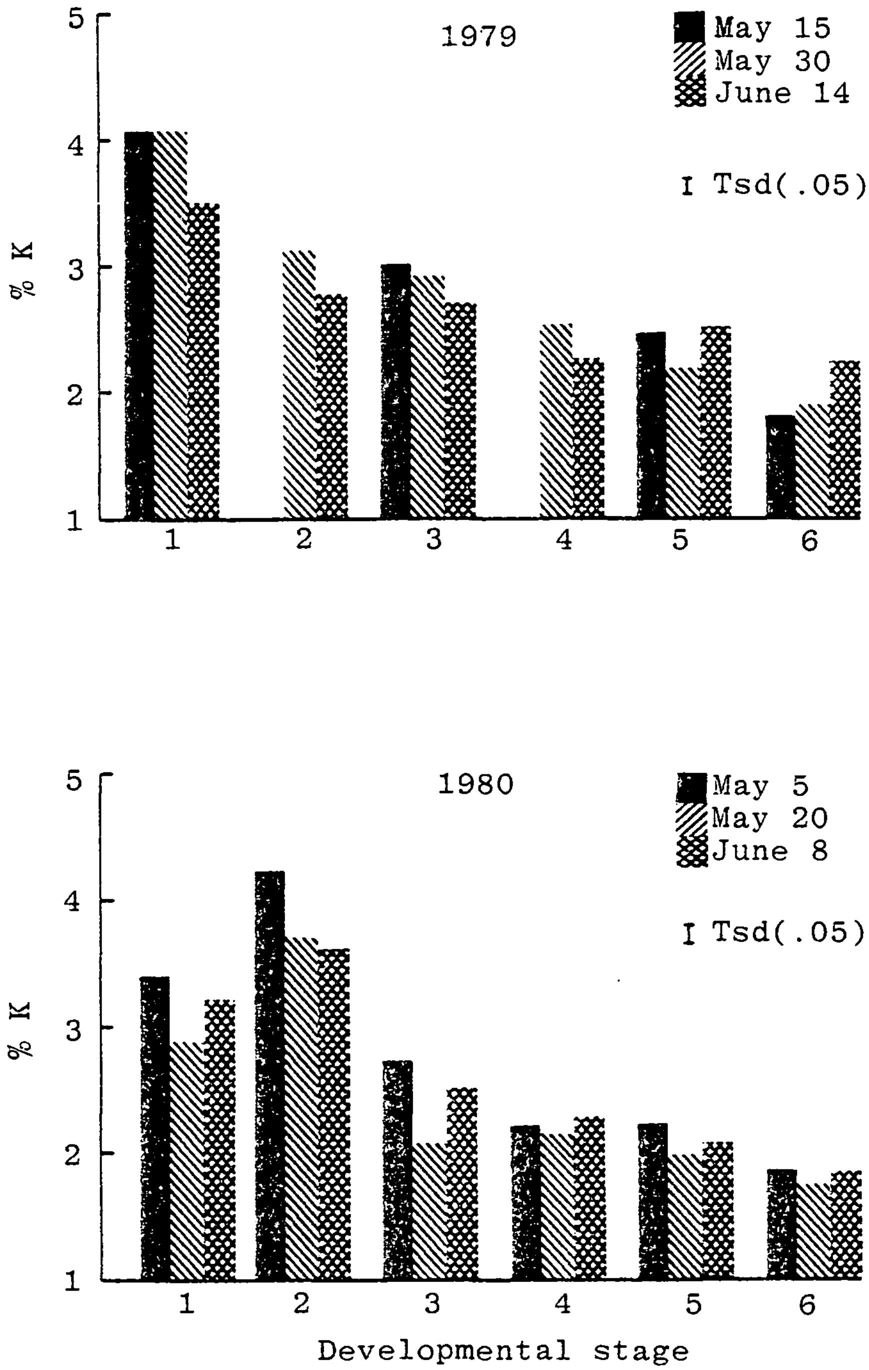


FIG. 3

Effect of planting date on K concentration at six developmental stages for two years. Tsd: Tukey's significant difference.

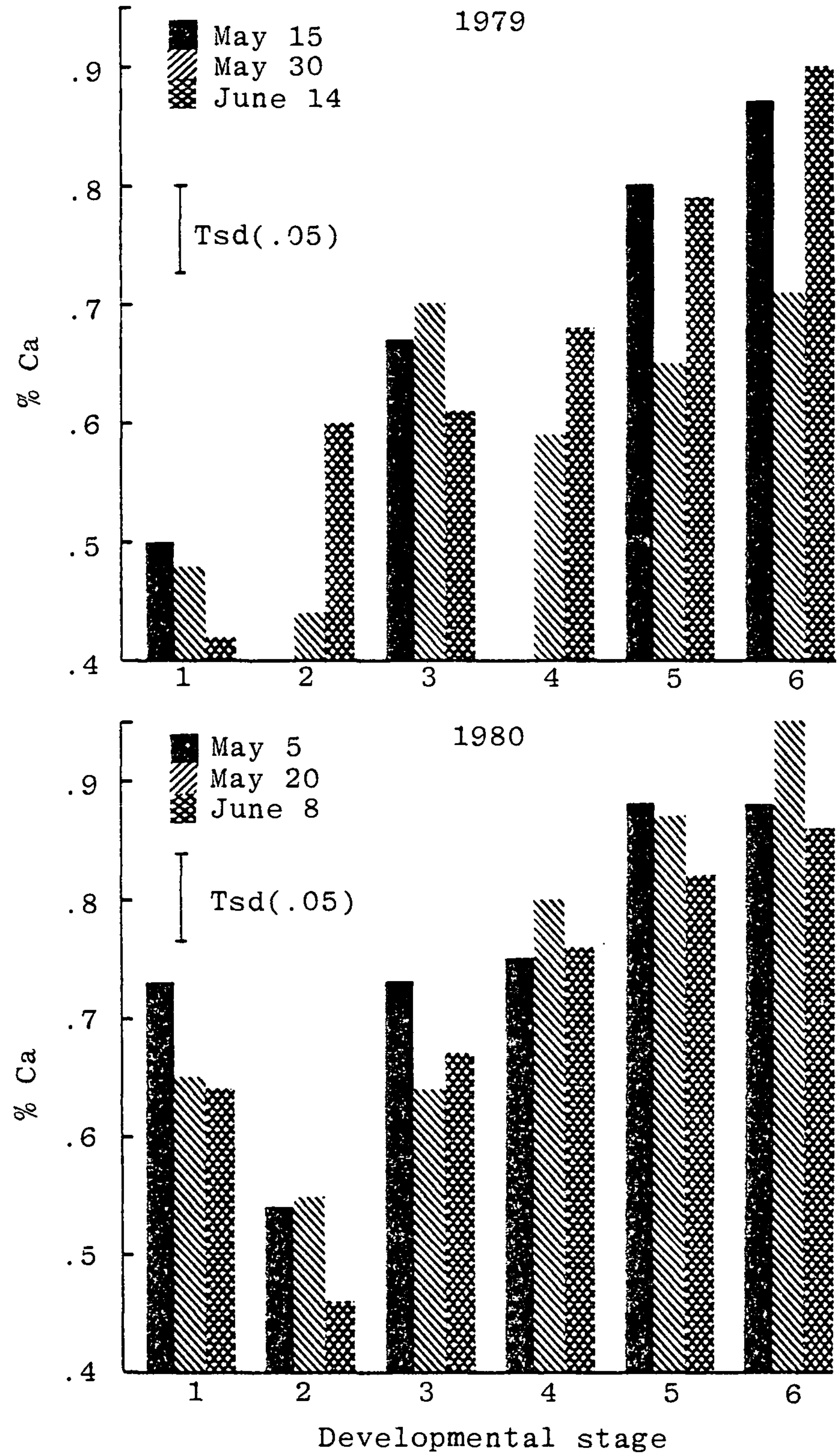
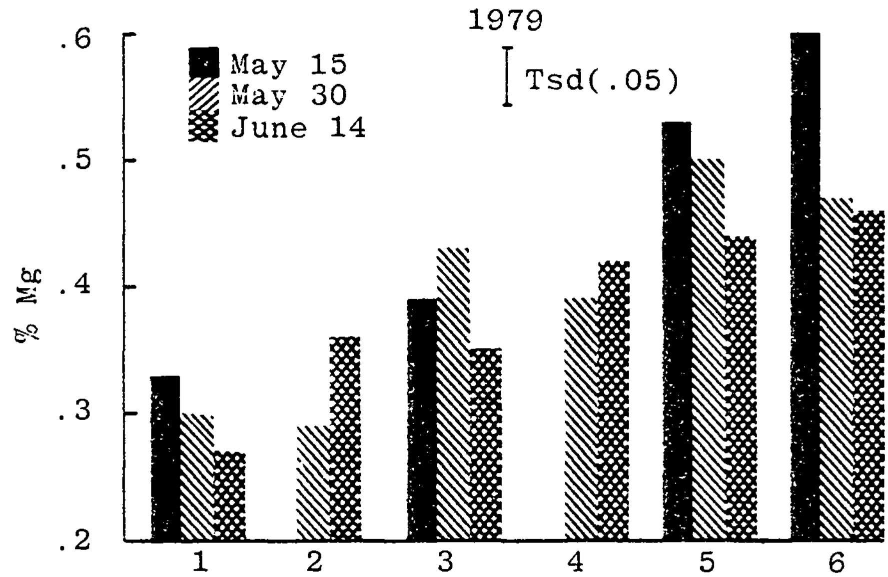


FIG. 4

Effect of planting date on Ca concentration at six developmental stages for two years.
Tsd: Tukey's significant difference.



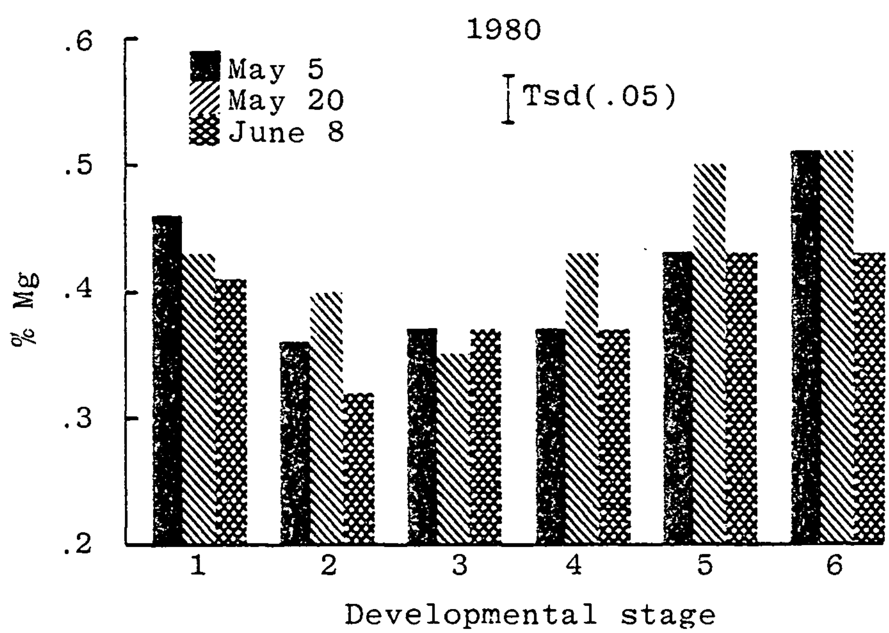


FIG. 5

Effect of planting date on Mg concentration at six developmental stages for two years.
Tsd: Tukey's significant difference.

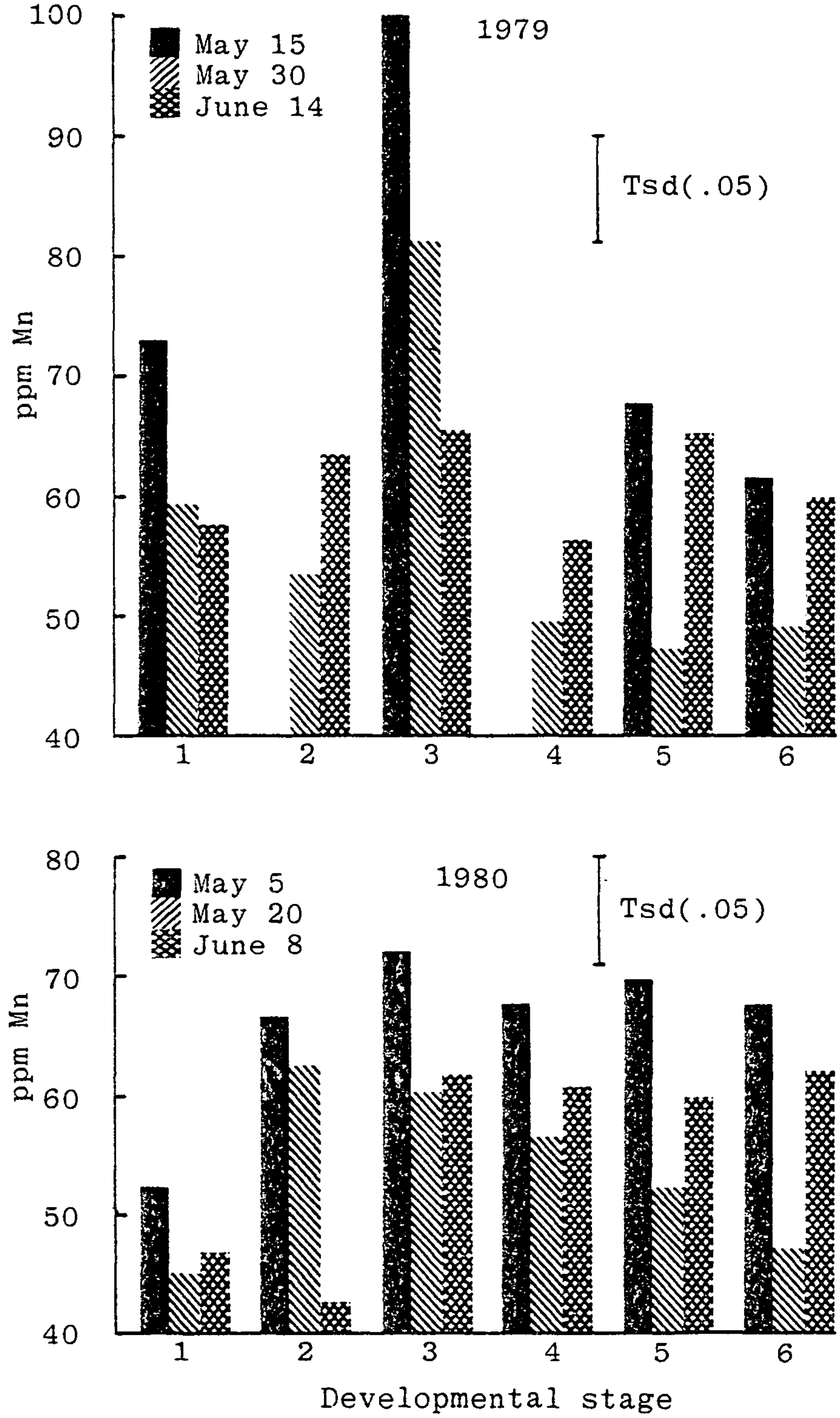


FIG. 6

Effect of planting date on Mn concentration at six developmental stages for two years.
Tsd: Tukey's significant difference.

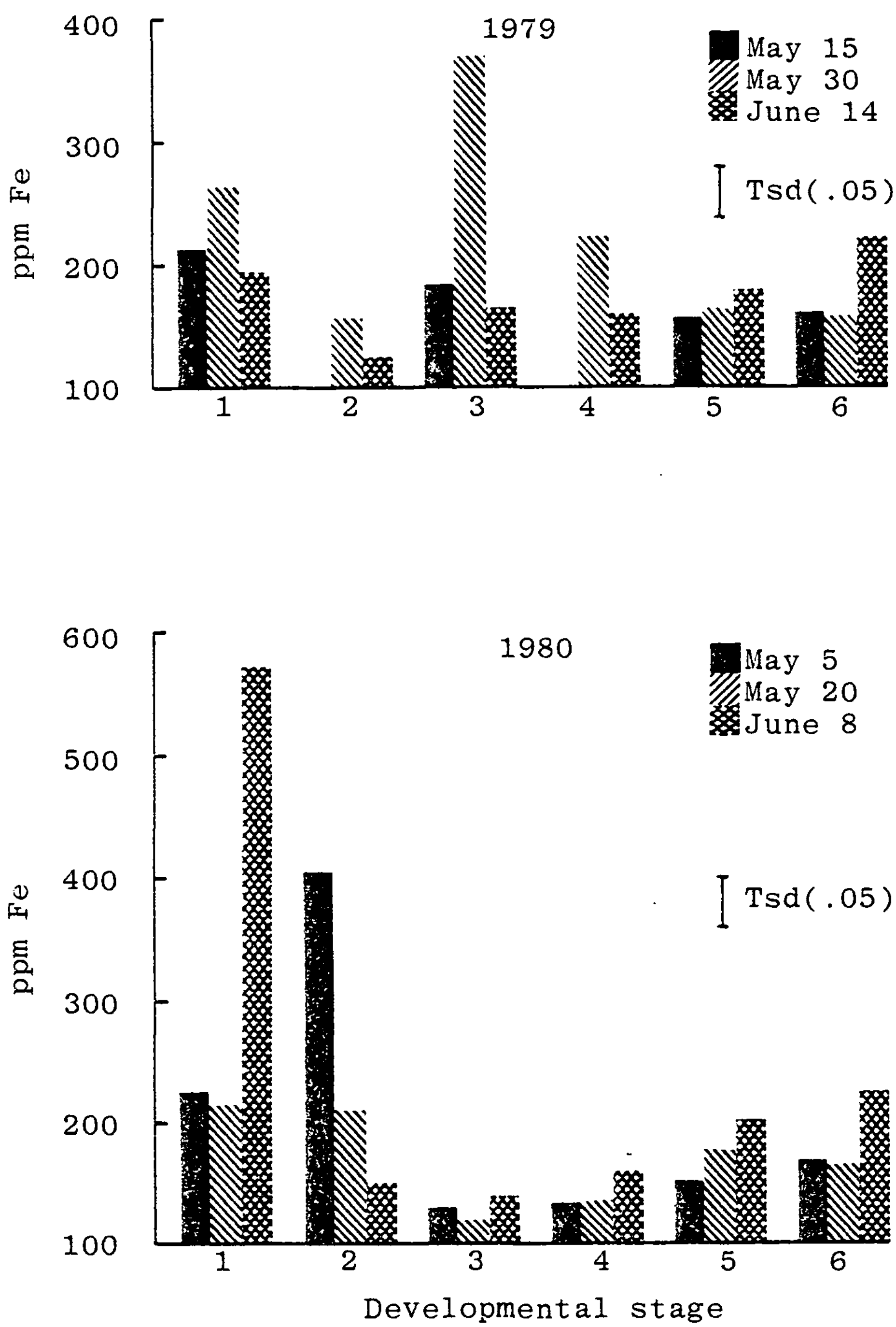


FIG. 7

Effect of planting date on Fe concentration at six developmental stages for two years.
Tsd: Tukey's significant difference.

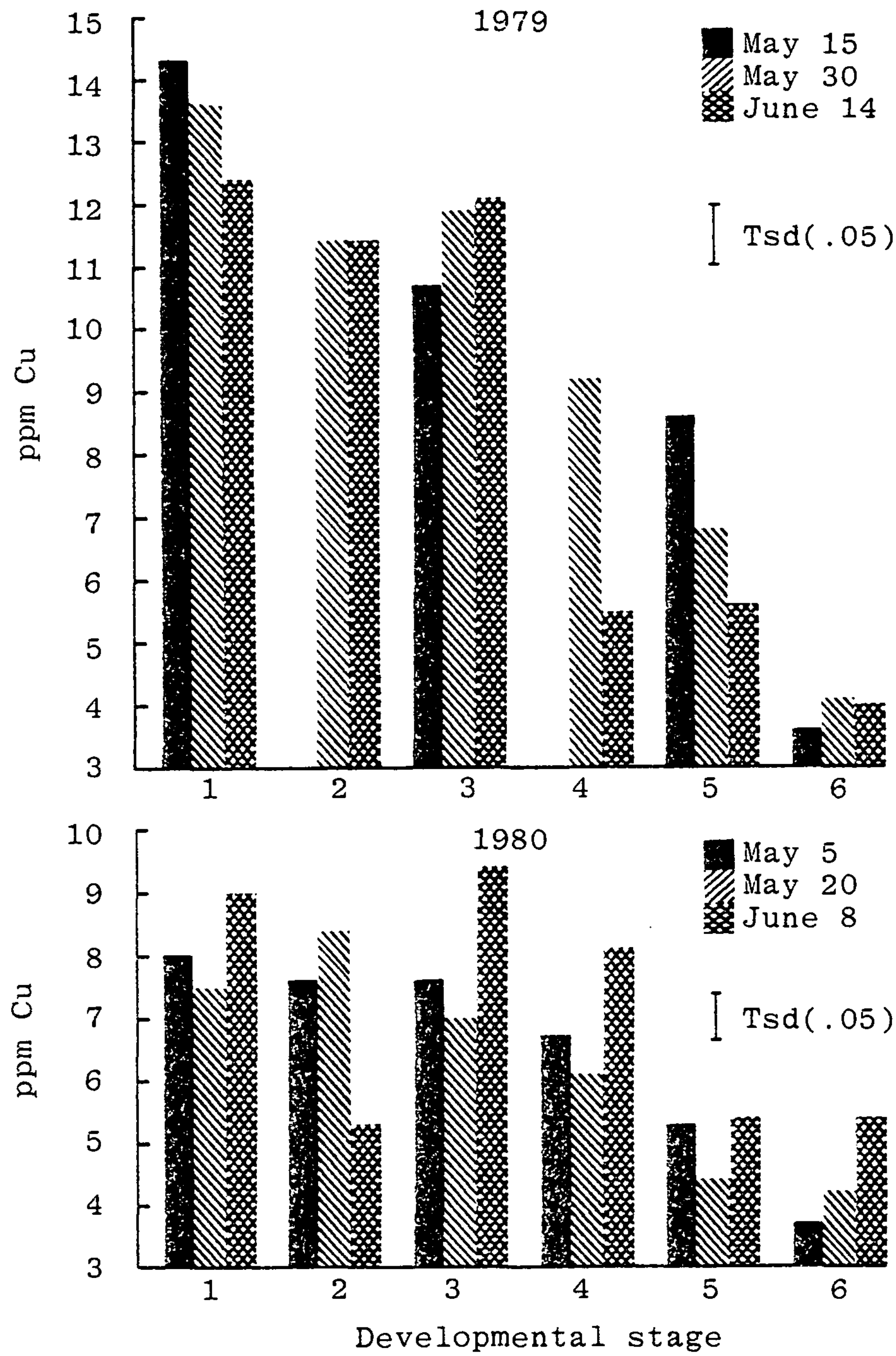


FIG. 8

Effect of planting date on Cu concentration at six developmental stages for two years.
Tsd: Tukey's significant difference.

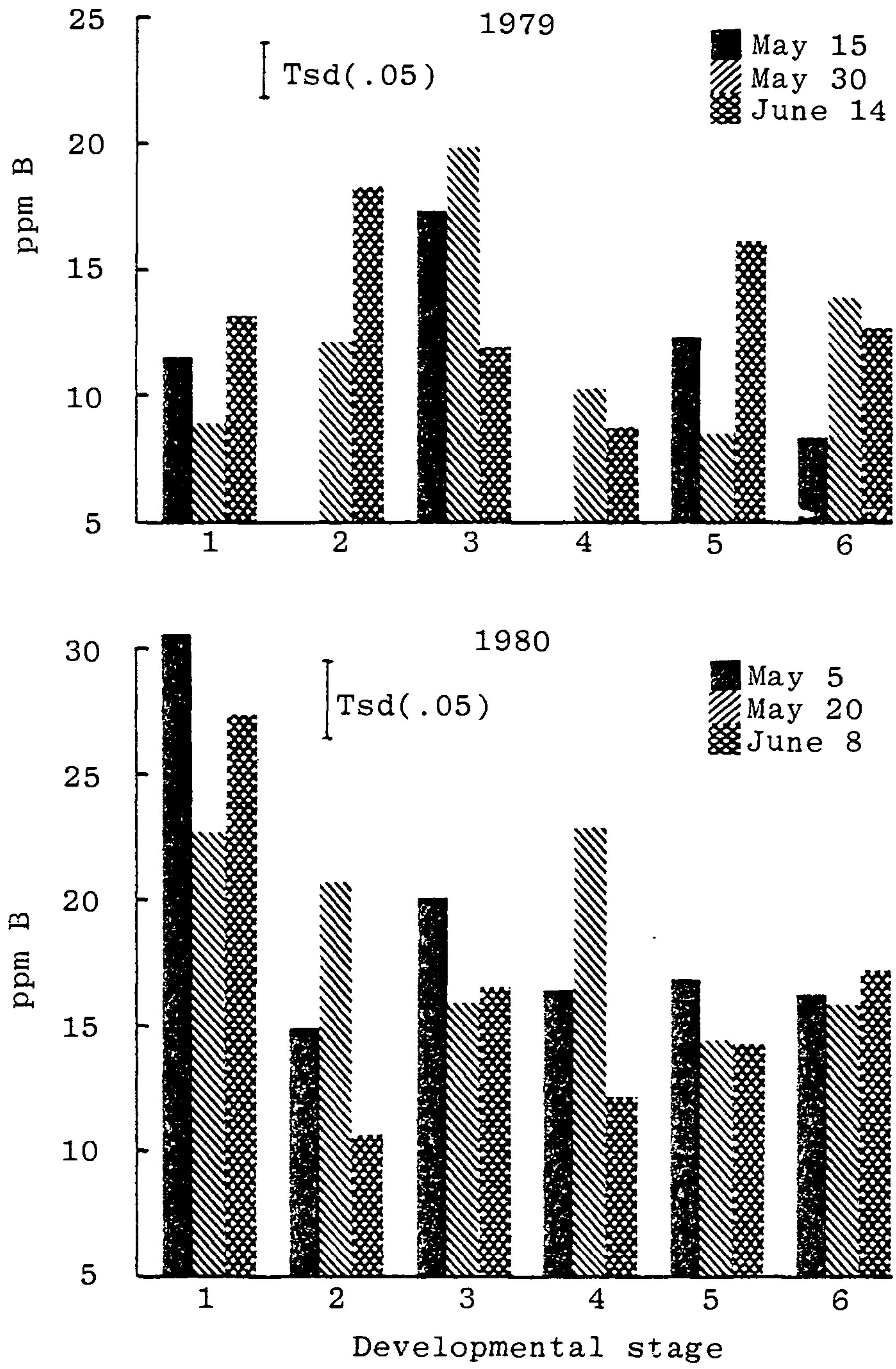


FIG. 9

Effect of planting date on B concentration at six developmental stages for two years.
Tsd: Tukey's significant difference.

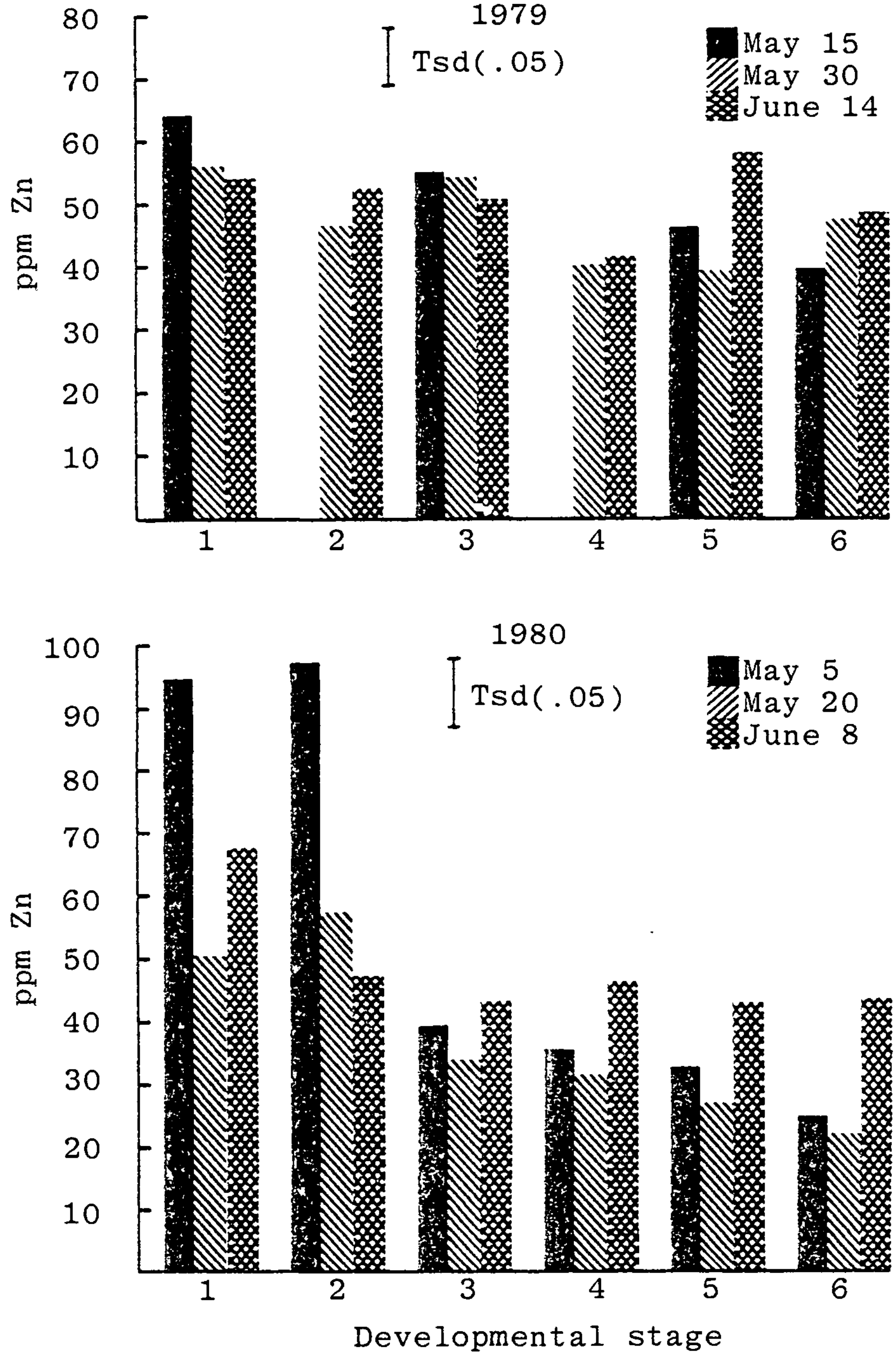


FIG. 10

Effect of planting date on Zn concentration at six developmental stages for two years.
Tsd: Tukey's significant difference.

sampled. Differences in N concentration (figure 1) among the three planting dates became less during the later stages of growth. Concentrations of P and Zn (figures 2 and 10) in the late-planted corn tended to be greater than in the two earlier plantings during the later stages of development. The effect of planting date on K, Ca, Mg, Fe, Cu, and B levels (figures 3, 4, 5, 7, 8, 9) in the ear leaf varied from one developmental stage to the next. Planting date influenced all mineral concentrations at most of the developmental stages studied.

Planting date had greater effect on yield in 1979 (r=.73) than in 1980 (r=.37). Early planting increased yield in 1979; in 1980, planting date did not significantly affect the yield of plants receiving 125kg-N/ha, but did significantly affect the yield of plants receiving only 45 kg-N/ha (Table 1). It appears that the earlier plantings were better able to utilize the extra added nitrogen; therefore, response to additional nitrogen application might be expected to be less for later plantings.

To evaluate the nutrient status of sweet corn, the effects of planting date on the requirement for each nutrient must be determined. Also, consideration must be given to stage of plant development and plant part sampled. Using the standard values of the Ohio Plant Analysis Laboratory (29), nutrition did not appear to be a limiting

TABLE 1

Fresh weight of husked marketable ears (yield) as affected by planting date and applied nitrogen rate.

N rate kg/ha	Planting date 1	Planting date 2	Planting date 3
	kg/ha		
		1979	
45	19200b[z]	17510cd	16880cd
125	20970a	18110bc	16550d
		1980	
45	16280bc	15670c	18160ab
125	18670a	18760a	19950a

[z]Means with the same letter within each year are not significantly different at .05 level.

factor because all plant nutrients, except for N in plants receiving low N-rate, were present in sufficient amounts. It appears then, that planting date affected the N requirement for sweet corn.

In order for a plant analysis program for sweet corn to be beneficial during a current growing season, samples must be taken during early development so that corrective or routine fertilizer applications of some elements can be applied in time to insure optimum yield. Interpretative data and the effects of planting date, therefore, should be obtained during the early developmental stages. Results of this and other studies, suggest that either standard values must be determined for different planting dates, or that environmental conditions associated with different planting dates must be incorporated into the analytical program. Soil temperature (43, 51), air temperature (3, 25, 51), photoperiod (25, 52), solar radiation and water evaporation (51) were shown to influence leaf element concentration, dry matter production and yield.

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APPENDIX

(In this section additional data are presented which were not shown earlier.)

Fresh weight and dry weight of whole plants as affected by planting date, N and B treatments

In 1980, fresh weight of five whole plants (above ground portion) was taken at each sampling. The plants were then dried at 37°C and weighed. No dry weight was taken in 1979. Planting date affected both dry weight (table 1) and fresh weight (table 3) of whole plants. During the vegetative stages (stages 1 and 2), plants from the late planting had a greater dry weight and fresh weight than plants from the two earlier plantings. At later developmental stages, the late planted corn produced more dry weight than the other plantings, while the early planted corn produced the greatest fresh weight. Dry matter production has been shown to be directly proportional to soil and air temperature (25, 43, 51) and photoperiod (25); therefore, environmental conditions were more favorable for vegetative growth for the late planted corn as soil and air temperatures became warmer as the planting was delayed.

Nitrogen fertilizer application also affected fresh weight and dry weight of the whole plant (tables 2 and 4). Fresh weights and dry weights tended to be higher for the plants receiving 125 kg-N/ha, with the increase in both becoming greater as the plants approached harvest. Boron applicaton had no effect on dry weight or fresh weight.

TABLE 1. Effect of planting date on dry weight (g/plant) at six developmental stages for 1980.

Planting date	Developmental Stage[z]					
	DS1	DS2	DS3	DS4	DS5	DS6
May 5	1.92b[y]	11.76b	462.5b	568.8b	840b	1094b
May 20	1.70b	11.85b	604.6a	590.1b	934b	1275a
June 8	2.58a	53.62a	409.4b	739.2a	1273a	1345a

[z]DS1 = plants 15 cm tall; DS2 = estimated midpoint between DS1 and tasseling; DS3 = tasseling; DS4 = silking; DS5 = midpoint between silking and harvest; DS6 = harvest.

[y]Mean separation in columns for each year by Tukey's method of multiple comparison, 5% level.

TABLE 2. Effect of applied nitrogen and planting date on dry weight (g/plant) at six developmental stages for 1980.

Planting date	N-rate kg/ha	Developmental Stage[z]					
		DS1	DS2	DS3	DS4	DS5	DS6
May 5	45	1.80b[y]	10.26b	462.1b	520.0b	797c	1005c
	125	2.05ab	13.27b	462.8b	617.6b	889bc	1184bc
May 20	45	1.75b	11.34b	608.6a	577.6b	881bc	1176bc
	125	1.65b	12.36b	600.5a	602.6b	986bc	1375ab
June 8	45	2.53a	52.05a	391.3b	742.5a	1182ab	1192bc
	125	2.62a	55.19a	427.4b	735.9a	1364a	1499a

[z]DS1 = plants 15 cm tall; DS2 = estimated midpoint between DS1 and tasseling; DS3 = tasseling; DS4 = silking; DS5 = midpoint between silking and harvest; DS6 = harvest.

[y]Mean separation in columns for each year by Tukey's method of multiple comparison, 5% level.

TABLE 3. Effect of planting date on fresh weight (g/plant) at six developmental stages for 1980.

Planting date	Developmental Stage[z]					
	DS1	DS2	DS3	DS4	DS5	DS6
May 5	13.26a[y]	121.1b	3739b	4373a	5817a	5938a
May 20	13.23a	120.0b	4405a	4772a	3238c	3188c
June 8	15.94a	548.8a	2831c	3197b	3857b	3906b

[z]DS1 = plants 15 cm tall; DS2 = estimated midpoint between DS1 and tasseling; DS3 = tasseling; DS4 = silking; DS5 = midpoint between silking and harvest; DS6 = harvest.

[y]Mean separation in columns for each year by Tukey's method of multiple comparison, 5% level.

TABLE 4. Effect of applied nitrogen and planting date on fresh weight (g/plant) at six developmental stages for 1980.

Planting date	N-rate kg/ha	Developmental Stage[z]					
		DS1	DS2	DS3	DS4	DS5	DS6
May 5	45	12.29a[y]	103.6b	3759b	4099b	5350b	5296b
	125	14.23a	138.4b	3719b	4647ab	6285a	6581a
May 20	45	13.66a	115.0b	4306a	4523ab	2973d	2921d
	125	12.80a	124.9b	4503a	5022a	3502d	3454d
June 8	45	15.80a	527.4a	2694c	3156c	3560cd	3431d
	125	16.08a	570.1a	2968c	3237c	4154c	4381c

[z]DS1 = plants 15 cm tall; DS2 = estimated midpoint between DS1 and tasseling; DS3 = tasseling; DS4 = silking; DS5 = midpoint between silking and harvest; DS6 = harvest.

[y]Mean separation in columns for each year by Tukey's method of multiple comparison, 5% level.

Effect of boron application on mineral concentration

The application of 2.0 kg/ha boron significantly increased B concentration only at the first developmental stage sampled, with only the midseason planting in 1979, and the early and late planted corn in 1980 showing this effect (table 5). The other mineral concentrations were unaffected by the boron application. If the critical value for boron in sweet corn is 7-9ppm in the ear leaf at silking, all ear leaves sampled were above this level. The lack of response to applied boron could have been due to several factors: (1) the low rate of boron applied, (2) Chehelis silty clay loam's great ability to adsorb B (66), (3) the method of application because broadcasting was shown to be the least effective method (49, 65), and (4) because there was sufficient available B as indicated by the soil test results of .63ppm B.

TABLE 5. Effect of applied boron and planting date on boron concentration (ppm of dry weight) at six developmental stages for 1979 and 1980.

Planting date	B-rate kg/ha	Developmental Stage[z]					
		DS1	DS2	DS3	DS4	DS5	DS6
				1979			
May 15	0	11ab[y]	--	18b	--	13ab	9b
	2.0	12ab	--	17b	--	11bc	8b
May 30	0	8c	11b	20a	10a	8c	13a
	2.0	10b	13b	20a	10a	9c	14a
June 14	0	13ab	17a	12c	8a	16a	13a
	2.0	14a	20a	12c	9a	16a	12ab
				1980			
May 5	0	26b	13bc	21a	17b	17a	16a
	2.0	37a	17ab	19ab	16bc	16a	16a
May 20	0	22b	20a	15b	22ab	14a	16a
	2.0	23b	22a	17ab	24a	14a	15a
June 8	0	23b	9c	16ab	11c	15a	17a
	2.0	32a	12bc	17ab	13c	13a	17a

[z]DS1 = plants 15 cm tall; DS2 = estimated midpoint between DS1 and tasseling; DS3 = tasseling; DS4 = silking; DS5 = midpoint between silking and harvest; DS6 = harvest.

[y]Mean separation in columns for each year by Tukey's method of multiple comparison, 5% level.

Effect of nitrogen application on mineral concentration

The higher rate of nitrogen (125kg/ha) increased the concentrations of N (table 6), Mg (table 7), Mn (table 8), Cu (table 9), and Zn (table 10). From the second developmental stage to harvest, there was a consistent increase in these leaf elemental concentrations due to the higher rate of N applied, with the increases becoming significant at the later stages of development (from tasseling to harvest). Nitrogen treatment had more of an effect on N, Mg, Mn, Cu, and Zn in 1979 than in 1980. This may be due to the longer growing season in 1980 (average 18 days longer than 1979), or possibly the soil in the plot used in 1980 may have not been as fertile as the soil in 1979. Similar effects of N application on Cu and Mn (60) and Mg (64) have been reported.

TABLE 6. Effect of applied Nitrogen and planting date on nitrogen concentration (% of dry weight) at six developmental stages for 1979 and 1980.

Planting date	N-rate kg/ha	Developmental Stage[z] DS1	DS2	DS3	DS4	DS5	DS6
				1979			
May 15	45	5.44a[y]	--	2.64c	--	2.37c	2.06bc
	125	5.44a	--	3.33a	--	2.80a	2.63a
May 30	45	4.55b	3.42a	2.38c	2.64c	2.37c	2.14b
	125	4.56b	3.60a	2.62c	2.94a	2.79a	2.46a
June 14	45	4.22c	2.49c	2.98b	2.73bc	2.71ab	2.41a
	125	4.32bc	2.73b	3.21ab	2.92ab	2.47bc	1.83c
				1980			
May 5	45	5.44a	5.41ab	2.55bc	2.07bc	1.58b	1.53cd
	125	5.46a	5.62a	2.77ab	2.55a	2.15a	2.01ab
May 20	45	4.76b	4.89c	2.30c	1.82c	1.54b	1.43d
	125	4.74b	5.19bc	2.59bc	2.36ab	2.12a	1.96ab
June 8	45	5.28a	3.84a	2.52bc	2.12b	1.79b	1.82bc
	125	5.53a	4.07d	2.96a	2.62a	2.39a	2.17a

[z]DS1 = plants 15 cm tall; DS2 = estimated midpoint between DS1 and tasseling; DS3 = tasseling; DS4 = silking; DS5 = midpoint between silking and harvest; DS6 = harvest.

[y]Mean separation in columns for each year by Tukey's method of multiple comparison, 5% level.

TABLE 7. Effect of applied Nitrogen and planting date on magnesium concentration (% of dry weight) at six developmental stages for 1979 and 1980.

Planting date	N-rate kg/ha	Developmental Stage[z]					
		DS1	DS2	DS3	DS4	DS5	DS6
				1979			
May 15	45	.32a[y]	--	.38ab	--	.51ab	.60a
	125	.33a	--	.40ab	--	.54a	.60a
May 30	45	.30a	.28b	.42a	.37b	.45bc	.48b
	125	.31a	.31b	.43a	.40ab	.55a	.46b
June 14	45	.27a	.35a	.34b	.40ab	.38c	.46b
	125	.26a	.36a	.36ab	.44a	.50a	.46b
				1980			
May 5	45	.45a	.37ab	.35a	.33c	.39b	.46b
	125	.46a	.35ab	.39a	.41ab	.46b	.55a
May 20	45	.43a	.40a	.32a	.39bc	.46b	.48ab
	125	.44a	.40a	.38a	.47a	.54a	.54a
June 8	45	.42a	.32b	.36a	.36bc	.42b	.42b
	125	.41a	.33ab	.37a	.40abc	.44b	.44b

[z]DS1 = plants 15 cm tall; DS2 = estimated midpoint between DS1 and tasseling; DS3 = tasseling; DS4 = silking; DS5 = midpoint between silking and harvest; DS6 = harvest.

[y]Mean separation in columns for each year by Tukey's method of multiple comparison, 5% level.

TABLE 8. Effect of applied Nitrogen and planting date on manganese concentration (ppm of dry weight) at six developmental stages for 1979 and 1980.

Planting date	N-rate kg/ha	Developmental Stage[z]					
		DS1	DS2	DS3	DS4	DS5	DS6
				1979			
May 15	45	72a[y]	--	103a	--	65ab	56ab
	125	74a	--	97ab	--	71a	67a
May 30	45	58a	53b	78bc	47a	45b	43b
	125	61a	54b	84abc	52a	50ab	55ab
June 14	45	58a	59a	63c	55a	64ab	57ab
	125	57a	69a	68c	58a	67ab	63ab
				1980			
May 5	45	63a	70a	81ab	74ab	77a	72abc
	125	62a	83a	84a	81a	81a	82a
May 20	45	56a	67ab	65b	60b	57b	54d
	125	54a	78a	76ab	73ab	67ab	60cd
June 8	45	57a	53b	67b	64b	61b	65bcd
	125	57a	53b	77ab	77a	78a	79ab

[z]DS1 = plants 15 cm tall; DS2 = estimated midpoint between DS1 and tasseling; DS3 = tasseling; DS4 = silking; DS5 = midpoint between silking and harvest; DS6 = harvest.

[y]Mean separation in columns for each year by Tukey's method of multiple comparison, 5% level.

TABLE 9. Effect of applied Nitrogen and planting date on copper concentration (ppm of dry weight) at six developmental stages for 1979 and 1980.

Planting date	N-rate kg/ha	Developmental Stage[z] DS1	DS2	DS3	DS4	DS5	DS6
				1979			
May 15	45	14.3a[y]	--	10.4c	--	7.7b	2.5b
	125	14.2a	--	11.0c	--	9.5a	4.7a
May 30	45	13.5ab	11.2a	10.8c	8.6a	5.9c	3.2ab
	125	13.6ab	11.6a	13.0ab	9.7a	7.7b	4.9a
June 14	45	12.2b	10.9a	11.5abc	5.0b	5.5c	3.3ab
	125	12.5b	11.9a	12.7ab	5.9b	5.6c	4.6a
				1980			
May 5	45	8.1ab	7.2a	7.2bc	6.3bc	4.5bc	2.7b
	125	7.8ab	8.0a	8.0bc	7.1b	6.0ab	4.6a
May 20	45	7.6b	8.1a	6.5c	5.0c	3.5c	3.2b
	125	7.4b	8.7a	7.4bc	7.2b	5.2ab	5.2a
June 8	45	8.8ab	5.5b	8.6ab	7.2b	4.6bc	4.9a
	125	9.2a	5.0b	10.1a	9.0a	6.2a	5.9a

[z]DS1 = plants 15 cm tall; DS2 = estimated midpoint between DS1 and tasseling; DS3 = tasseling; DS4 = silking; DS5 = midpoint between silking and harvest; DS6 = harvest.

[y]Mean separation in columns for each year by Tukey's method of multiple comparison, 5% level.

TABLE 10. Effect of applied Nitrogen and planting date on zinc concentration (ppm of dry weight) at six developmental stages for 1979 and 1980.

Planting date	N-rate kg/ha	Developmental Stage[z]					
		DS1	DS2	DS3	DS4	DS5	DS6
				1979			
May 15	45	64a[y]	--	51ab	--	43bc	35c
	125	64a	--	59a	--	49b	44b
May 30	45	57ab	45b	51ab	35b	36c	41bc
	125	55b	48b	57a	45a	44bc	54a
June 14	45	55b	47b	48b	40ab	59a	49ab
	125	54b	57a	53ab	43a	57a	50ab
				1980			
May 5	45	97a	94a	33c	31bc	27cd	21cd
	125	91a	100a	44ab	41b	38b	29bc
May 20	45	52c	55b	29c	26c	21d	17d
	125	49c	59b	39bc	37b	33bc	27bcd
June 8	45	66b	44c	37bc	39b	36bc	37b
	125	69b	50bc	50a	53a	50a	51a

[z]DS1 = plants 15 cm tall; DS2 = estimated midpoint between DS1 and tasseling; DS3 = tasseling; DS4 = silking; DS5 = midpoint between silking and harvest; DS6 = harvest.

[y]Mean separation in columns for each year by Tukey's method of multiple comparison, 5% level.

TABLE 11. Effect of Planting Date on nitrogen concentration (% of Dry Weight) at six developmental stages for 1979 and 1980.

Planting date	Developmental Stage[z]					
	DS1	DS2	DS3	DS4	DS5	DS6
			1979			
May 15	5.44a[y]		2.98a		2.59a	2.34a
May 30	4.55b	3.51a	2.50b	2 80a	2.58a	2.30a
June 14	4.27c	2.61b	3.10a	2.83a	2.59a	2.12b
			1980			
May 5	5.45a	5.51a	2.66a	2.31a	1.87b	1.77b
May 20	4.75b	5.04b	2.44b	2 09b	1.83b	1.69b
June 8	5.41a	3.96c	2.74a	2.37a	2.09a	1.99a

[z]DS1 = plants 15 cm tall; DS2 = estimated midpoint between DS1 and tasseling; DS3 = tasseling; DS4 = silking; DS5 = midpoint between silking and harvest; DS6 = harvest.

[y]Mean separation in columns for each year by Tukey's method of multiple comparison, 5% level.

TABLE 12. Effect of Planting Date on potassium concentration (% of Dry Weight) at six developmental stages for 1979 and 1980.

Planting date	Developmental Stage[z] DS1	DS2	DS3	DS4	DS5	DS6
			1979			
May 15	4.06a[y]	--	3.01a	--	2.46a	1.80b
May 30	4.05a	3.11a	2.93a	2.53a	2.19b	1.89b
June 14	3.50b	2.77b	2.70b	2.27b	2.51a	2.23a
			1980			
May 5	3.39a	4.22a	2.73a	2.21a	2.22a	1.86a
May 20	2.88b	3.70b	2.07c	2.15a	1.99b	1.73a
June 8	3.21a	3.61b	2.50b	2.28a	2.09ab	1.85a

[z]DS1 = plants 15 cm tall; DS2 = estimated midpoint between DS1 and tasseling; DS3 = tasseling; DS4 = silking; DS5 = midpoint between silking and harvest; DS6 = harvest.

[y]Mean separation in columns for each year by Tukey's method of multiple comparison, 5% level.

TABLE 13. Effect of Planting Date on phosphorus concentration (% of Dry Weight) at six developmental stages for 1979 and 1980.

Planting date	Developmental Stage[z]					
	DS1	DS2	DS3	DS4	DS5	DS6
			1979			
May 15	.66a[y]	--	.56a	--	.31b	.28b
May 30	.52b	.48a	.45b	.34a	.32b	.31b
June 14	.47c	.43b	.25c	.36a	.42a	.34a
			1980			
May 5	.69a	.73a	.36a	.30b	.28b	.26b
May 20	.47b	.57b	.29b	.27b	.27b	.24b
June 8	.72a	.49c	.39a	.36a	.39a	.40a

[z]DS1 = plants 15 cm tall; DS2 = estimated midpoint between DS1 and tasseling; DS3 = tasseling; DS4 = silking; DS5 = midpoint between silking and harvest; DS6 = harvest.

[y]Mean separation in columns for each year by Tukey's method of multiple comparison, 5% level.

TABLE 14. Effect of Planting Date on calcium concentration (% of Dry Weight) at six developmental stages for 1979 and 1980.

Planting date	Developmental Stage[z]					
	DS1	DS2	DS3	DS4	DS5	DS6
			1979			
May 15	.50a[y]	--	.67ab	--	.80a	.87a
May 30	.48ab	.44b	.70a	.59b	.65b	.71b
June 14	.42b	.60a	.61b	.68a	.79a	.90a
			1980			
May 5	.73a	.54ab	.73a	.75a	.88a	.88ab
May 20	.65ab	.55a	.64b	.80a	.87a	.95a
June 8	.64b	.46b	.67ab	.76a	.82a	.86b

[z]DS1 = plants 15 cm tall; DS2 = estimated midpoint between DS1 and tasseling; DS3 = tasseling; DS4 = silking; DS5 = midpoint between silking and harvest; DS6 = harvest.

[y]Mean separation in columns for each year by Tukey's method of multiple comparison, 5% level.

TABLE 15. Effect of Planting Date on magnesium concentration (% of Dry Weight) at six developmental stages for 1979 and 1980.

Planting date	Developmental Stage[z] DS1	DS2	DS3	DS4	DS5	DS6
			1979			
May 15	.33a[y]	--	.39ab	--	.53a	.60a
May 30	.30ab	.29b	.43a	.39a	.50a	.47b
June 14	.27b	.36a	.35b	.42a	.44b	.46b
			1980			
May 5	.46a	.36ab	.37a	.37b	.43b	.51a
May 20	.43ab	.40a	.35a	.43a	.50a	.51a
June 8	.41b	.32b	.37a	.37b	.43b	.43b

[z]DS1 = plants 15 cm tall; DS2 = estimated midpoint between DS1 and tasseling; DS3 = tasseling; DS4 = silking; DS5 = midpoint between silking and harvest; DS6 = harvest.

[y]Mean separation in columns for each year by Tukey's method of multiple comparison, 5% level.

TABLE 16. Effect of Planting Date on manganese concentration (ppm of Dry Weight) at six developmental stages for 1979 and 1980.

Planting date	Developmental Stage[z]					
	DS1	DS2	DS3	DS4	DS5	DS6
			1979			
May 15	73. 0a[y]	--	100. 3a	--	67. 7a	61. 4a
May 30	59. 3b	53. 5b	81. 2b	49. 4b	47. 2b	49. 0b
June 14	57. 5b	63. 5a	65. 5c	56. 3a	65. 2a	59. 8a
			1980			
May 5	62. 4a	76. 7a	82. 0a	77. 6a	79. 5a	77. 4a
May 20	55. 0a	72. 5a	70. 2b	66. 5b	62. 3b	57. 0b
June 8	56. 9a	52. 7b	71. 8b	70. 6ab	69. 96	72. 0a

[z]DA1 = plants 15 cm tall; DS2 = estimated midpoint between DS1 and tasseling; DS3 = tasseling; DS4 = silking; DS5 = midpoint between silking and harvest; DS6 = harvest.

[y]Mean separation in columns for each year by Tukey's method of multiple comparison, 5% level.

TABLE 17. Effect of Planting Date on iron concentration (ppm of Dry Weight) at six developmental stages for 1979 and 1980.

Planting date	Developmental Stage[z]					
	DS1	DS2	DS3	DS4	DS5	DS6
			1979			
May 15	213b[y]	--	184b	--	157a	161a
May 30	262a	157a	370a	223a	164a	159a
June 14	195b	124b	162b	159b	180a	222b
			1980			
May 5	226b	404a	130a	133a	152b	168b
May 20	215b	210b	119a	134a	178ab	166b
June 8	572a	151c	139a	161a	202a	226a

[z]DS1 = plants 15 cm tall; DS2 = estimated midpoint between DS1 and tasseling; DS3 = tasseling; DS4 = silking; DS5 = midpoint between silking and harvest; DS6 = harvest.

[y]Mean separation in columns for each year by Tukey's method of multiple comparison, 5% level.

TABLE 18. Effect of Planting Date on copper concentration (ppm of Dry Weight) at six developmental stages for 1979 and 1980.

Planting date	Developmental Stage[z]					
	DS1	DS2	DS3	DS4	DS5	DS6
			1979			
May 15	14.3a[7]	--	10.7b	--	8.6a	3.6a
May 30	13.6a	11.4a	11.9a	9.2a	6.8b	4.1a
June 14	12.4b	11.4a	12.1a	5.5b	5.6c	4.0a
			1980			
May 5	8.0b	7.6a	7.6b	6.7b	5.3a	3.7b
May 20	7.5b	8.4a	7.0b	6.1b	4.4b	4.2b
June 8	9.0a	5.3b	9.4a	8.1a	5.4a	5.4a

[z]DS1 = plants 15 cm tall; DS2 = estimated midpoint between DS1 and tasseling; DS3 = tasseling; DS4 = silking; DS5 = midpoint between silking and harvest; DS6 = harvest.

[y]Mean separation in columns for each year by Tukey's method of multiple comparison, 5% level.

TABLE 19. Effect of Planting Date on boron concentration (ppm of Dry Weight) at six developmental stages for 1979 and 1980.

Planting date	Developmental Stage[z] DS1	DS2	DS3	DS4	DS5	DS6
			1979			
May 15	11.5a[y]	--	17.3b	--	12.3b	8.3b
May 30	8.9b	12.1b	19.8a	10.2a	8.5c	13.9a
June 14	13.2a	18.3a	11.8c	8.7a	16.1a	12.7a
			1980			
May 5	31.6a	14.8b	20.0a	16.4b	16.8a	16.2a
May 20	22.7c	20.7a	15.8b	22.9a	14.3a	15.8a
June 8	27.3b	10.6c	16.5b	12.1c	14.2a	17.1a

[z]DS1 = plants 15 cm tall; DS2 = estimated midpoint between DS1 and tasseling; DS3 = tasseling; DS4 = silking; DS5 = midpoint between silking and harvest; DS6 = harvest.

[y]Mean separation in columns for each year by Tukey's method of multiple comparison, 5% level.

TABLE 20. Effect of Planting Date on zinc concentration (ppm of Dry Weight) at six developmental stages for 1979 and 1980.

Planting date	Developmental Stage[z]					
	DS1	DS2	DS3	DS4	DS5	DS6
			1979			
May 15	64.1a[y]	--	54.9a	--	45.9b	39.6b
May 30	56.0b	46.6b	54.2a	39.9a	39.6c	47.3a
June 14	54.1b	52.3a	50.5a	41.6a	57.9a	49.2a
			1980			
May 5	94.2a	97.1a	38.9ab	35.7b	32.6b	24.8b
May 20	50.5c	57.2b	34.0b	31.5b	27.0b	22.0b
June 8	67.8b	47.2c	43.1a	46.1a	42.8a	43.7a

[z]DS1 = plants 15 cm tall; DS2 = estimated midpoint between DS1 and tasseling; DS3 = tasseling; DS4 = silking; DS5 = midpoint between silking and harvest; DS6 = harvest.

[y]Mean separation in columns for each year by Tukey's method of multiple comparison, 5% level.