Effect of clear plastic mulch and rowcovers on maturity and yield of direct seeded and transplanted fresh market sweet corn (*Zea mays* L.)

by

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This is to certify that the Master's thesis of

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has met the thesis requirements of Iowa State University

I would like to dedicate this thesis to my father Pitalis Aguyoh, and mother Paulina. Both of whom made it possible for me to get higher education.

They have shaped my life through good advice and encouragements.

Thank you.

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Iowa growers of sweet corn, have used clear plastic mulch and rowcovers to improve early yield and advance the maturity of the crop. Results have been inconsistent due to early temperature variability and inadequate information on the choice of the cultivar to grow. Our objective was to improve performance consistency of sweet corn by investigating production techniques with the early cultivar, 'Temptation', se at two sites, a silt loam in central Iowa in 1996 and 1997, and a loamy sand along the Mississippi river in eastern Iowa in 1997. Treatments consisted of bare soil or clear plastic mulch, rowcovers or none, direct seeded or transplanted. The transplants were raised in the greenhouse in either jiffy strips or 50-cell plastic trays. For the springs of 1996 and 1997, the plastic mulch harvest advantage for the direct seeded was +1 or 10 days for silt loam soil but no advantage for the loamy sand site. Use of rowcovers resulted in no yield advantage compared to clear plastic mulch. Transplants did not show a consistent advantage over direct seeding. The 50-cell tray transplants matured earlier than the jiffy strip transplants in both locations in 1997. Four week old transplants in both jiffy strips and 50-cell trays were not able to withstand the field stress and had very poor performance. Ear qualities such as row number, ear diameter, ear length, and tipfill were lowest with transplants.

GENERAL INTRODUCTION

Introduction

Sweet corn (*Zea mays* L.) is a warm season crop that has been adapted to a temperate climate. It is one of the most important cash crops in Midwestern United States. It is produced for either fresh market or processing. Sweet corn growth and development is inhibited by low soil and air temperature in early spring. Cool climate conditions in the upper Midwest followed by a short growing season are major factors that limit the length of the harvest season. To allow for early planting, it is important to raise the soil temperature to an optimum level for root growth and nutrient absorption.

Increased yields, better quality, and hastened maturity have been reported where plastic mulch and/or rowcovers are used to raise the soil temperature (Taber, 1983). Planting sweet corn under clear plastic mulch advanced maturity by 5 to 14 days (Hopen, 1964; Bible, 1972; Kretschmer, 1979). The high sugar types recently developed, such as se's and sh_2, are poorly adapted to low soil temperature. Plant stand and maturity of sweet corn under rowcovers are enhanced compared to conventional bare-ground direct-planting. Knowledge of the performance of directly seeded or transplanted sweet corn planted under clear plastic mulch, rowcovers, or a combination of clear plastic mulch and rowcovers, will be important for growers to benefit from premium market prices early in the season.

The overall goal of this study was to investigate how maturity, yield, and ear quality of sweet corn are affected by the use of clear plastic mulch, rowcovers and/or a combination of clear plastic mulch and rowcovers. The first objective was to compare the soil temperature changes, yield, growth and ear qualities of sweet corn grown under row covers and/or clear plastic mulch to those produced under conventional direct seeding on bare ground. The second objective was to investigate if there was any advantage of using transplants compared to direct seeding.

Thesis organization

This thesis consists of a review of relevant literature and one research manuscript prepared in partial fulfillment of the requirement of the graduate school for Master of Science. After the general introduction, the literature review is included describing related research work which has been done on sweet corn. The emphasis of literature review is low soil temperatures, clear plastic mulch, row covers, and transplants. The manuscript will be submitted to HortTechnology Journal. Following the manuscript are the conclusion, literature cited, and appendix.

LITERATURE REVIEW

Temperature effects

Low soil temperatures are associated with late winter and early spring when most crop production practices are started. Although first planting dates for sweet corn can be earlier than the dates for the last freeze in the spring, Brown et al. (1979) reported that cultivars with good germinating abilities will require at least one week to emerge and such seedlings will only recover from a light frost when they have developed at least three leaves, and before the growing point has emerged. Temperature is a major factor in determining the adaptation of many plant species grown in various localities. The occurrence of sub-optimal temperatures at the time of seeding is a major constraint in the commercial production of corn (Menkir and Larter, 1987).

Temperature will influence plant growth directly through seed germination and seedling emergence, and indirectly through its effect on nutrient absorption and availability, as well as on soil residue decomposition. A number of physiological mechanisms are temperature dependent. All root functions are temperature dependent (Miller, 1986). Kramer (1949) numerated several factors responsible for reduction in the absorption of water by roots at low temperatures, including retardation in root elongation, decreased permeability of root cells, increased viscosity of protoplasm of the cells and increased viscosity of water. Menkir and Larter (1987) reported that root zone temperatures in the range of 10 to 14 °C were detrimental to emergence and seedling growth of corn plants.

Production of hormones such as cytokinin and gibberellin in the roots is reduced at low temperature. For example, Ali et al. (1996) observed a significant increase in cytokinin concentration in tomato seedlings from 12.8 pmol/ml at 12 °C to 17.6 pmol/ml at 20 °C. Concentration of gibberellins was increased from 0.09 pmol/ml to 0.26 pmol/ml when soil temperature was raised by 8 to 20 °C. The transport of these hormones from the roots to the stem is affected more by the actual day and night temperatures than the average temperature. Ali et al. (1996) stated that the main effect of low temperatures on shoot growth is to slow transport of plant hormones and nitrates to the foliage, rather than reduce the rate of their biosynthesis. Menkir and Larter (1987) reported a reduction of root dry weights of seedlings at root zone temperature of 10 °C. Sub-optimal temperatures also restrict root extension and reduce overall root mass. Neilsen (1974) related the slow response of plants to the low soil temperatures to changes in root metabolic activities.

Miller (1989) indicated that the root growth of most plant species is lowest at 5 °C and increases progressively up to 25 °C. Above this temperature, a decline in the development of roots will be observed. Miller (1989) also reported an optimum growth temperature of 28°C for beans *(Phaseolus vulgaris)*, 25 to 30 °C for corn (*Z. mays* L.), 23 °C for potato (*Solarium tuberose*), 18 to 22 °C for pea (*Prism vulgarize*), 26 to 34 °C for tomato (*Lycopersicum esculentum* L), and for onions (*Allium cepa*) 18 to 22 °C. In their work with tomato, Hureweitz and Janes (1983) reported a sharp increase in the growth of tomato seedlings when the root temperature was increased from 12.8 to 15.6 °C. Wilcox and Pfeiffer (1990) indicated that corn growth was restricted when soil temperature was lower than 12.3 ° C, while the growth of other crops such as peas, radish and spinach was only reduced by soil temperature lower than 10 °C. Anatomically, corn plants are susceptible to sub-optimal soil temperatures because the growing point of the shoot remains below the soil surface for nearly 5 weeks, post-germination (Cooper and Law, 1977).

Plants have different rates of absorption of nutrients from the soil depending on their adaptation. Low soil temperatures do not appear to seriously reduce the rate of absorption of nitrogen, but do affect the capacity of the roots to reduce the absorbed nitrate and to assimilate it into organic nitrogen (Richards, 1952). Kafkafi (1990) observed a faster nitrate translocation to the roots, resulting into a higher concentration of nitrates at lower temperature than the shoots. Clarkson et al. (1992) found no evidence to relate the slow growth of rye grass (*Lolium perenne* L.) at temperature of 3 to 9 °C with restricted ammonium or nitrate absorption by the plants.

Huang and Grunes (1992) observed a substantial increase in the uptake of magnesium ions by 20-day old wheat seedlings, when the soil temperatures were increased from 10 to 15 ° C. This implies that at low soil temperature, as in early spring, a small increase in root temperature may significantly increase the rate of uptake of nutrients, such as magnesium, by young seedlings whose root system is still not well developed.

Clarkson and Deane-Drummond (1983) reported that low soil temperatures would influence root growth by affecting its metabolic activities, and capacity to act as a sink for photosynthates to keep its ability to absorb nutrients from the ground. Kafkafi (1990) related the effect of low temperatures on tomato growth to the influence of physical factors such as water viscosity and membrane permeability. Lal (1974) also cited decreases in the viscosity of water and permeability of root membranes as some of the factors responsible for overall reduction in water and nutrient uptake at sub-optimal root temperatures. The effects of low root-zone temperature has been linked to inhibition of leaf elongation resulting from a decrease in biochemical processes in the meristematic region, reducing both cell elongation and division (Kleinendorst and Brouwer, 1970).

Effect of clear plastic mulch

Plastic mulches have been used successfully on various vegetables to improve maturity and quality (Friend et al., 1990; Taber et al., 1986). Plastic mulches can be used where vegetable production is limited by early spring low temperatures. Their major effect is the increase of soil temperatures thus promoting germination and emergence of the seedlings (Splittstoesser and Brown, 1991).

Several crops have been successfully grown under plastic mulch. Muskmelons grown with plastic mulches have been reported to mature earlier than those raised on bare ground by 10 days to 2 weeks. Small seeded vegetables such as carrots and expensive hybrid seeds of cabbages and broccoli emerge better when grown under plastic mulch. When working with grain legumes, Adams (1962) found a more rapid accumulative plant development, earlier maturity and higher grain yields of the plants grown under plastic covers. Purser and Comeau (1989) listed advantages of using plastic mulches in vegetables such as earlier crop production, more efficient use of fertilizers and better quality of the produce.

Low soil and air temperature impede the germination and growth of sweet corn. However, it has been shown that clear plastic mulches can raise the soil temperature and advance germination of early sweet corn sufficiently enough to improve yield and number of marketable ears (Dinkel, 1966). Army and Hudspeth (1960), and Andrew et al. (1976) showed that the microclimate of the seed zone could be modified by covering the soil with plastic film. This zone develops into an area with higher soil temperature and moisture content than bare soil. Adams (1962) demonstrated that early season soil temperatures at 7.6 cm were 12 °C higher under clear plastic mulches than under bare soils. Friend et al. (1990) attributed the increase of the temperature around the plant to the 'greenhouse effect' as the plastic will allow the transmission of the radiant energy from the sun resulting in the accumulation of thermal radiation within the rowcover environment.

Andrew et al. (1976), Miller and Burger, (1963), and Purser and Comeau (1989) reported hastened germination, development and maturity of sweet corn cultivars planted under clear plastic mulches. Similarly, Hopen (1964) observed better percent germination of sweet corn seeds grown under clear plastic mulch. Eleven days after planting, an average of 10.3

seedlings had emerged as opposed to 5.7 seedlings on bare ground plots, while Kretschmer (1979) reported 86% emergence of sweet corn seedlings under plastic and 51.7% in the uncovered plots. Silk formation and harvesting were advanced on the average by 6 to 14 days with the use of plastic ground cover. The same results were found by Hopen (1964) who reported earlier harvesting of sweet corn by two weeks in plots under plastic covers. Bible (1972) observed increased yields and 5 days advancement in the maturity of sweet corn under plastic cover.

Effect of rowcovers

Rowcovers enhance the development of early spring crops, by modifying the plant's microclimate. Miller (1989), and Reed and Clough (1989) confirmed separately that rowcovers do influence plant growth by increasing the temperature around the plant and providing frost protection. The effectiveness of rowcovers in increasing both soil and ambient air temperature largely depends on the season.

Tomatoes grown under rowcovers in spring of 1986 had no significant yield increase despite an increase of air temperature by an average of 1.3% and soil temperature by 1.8% compared to uncovered plots (Wyatt and Mullins, 1987). Pollard et al. (1987) attributed the effectiveness of rowcovers in enhancing the harvest of vegetables to reduced radiant and convection heat loss. However, the effectiveness of rowcovers depend on the season and type of the crop. Wyatt and Mullins (1987) indicated in their study that increased earliness under rowcovers might not be realized unless the required adverse conditions are present.

Changes in the wavelength distribution of light reaching the plant throughout rowcover do affect plant growth and development (Friend and Decouteau, 1991). The authors studied plant response to wavelength selective mulches and rowcovers. They found clear polyethylene rowcovers to be the most transparent to the quantum of energy utilized by plants for photosynthesis. It allowed 93% of photosynthetically active radiation (PAR) to pass through, thus resulting in an increase in air and soil temperature.

Rowcovers have been used in conjunction with plastic mulches to act as mini greenhouses with the primary function of modifying the growing environment for the plant (Splittstoesser and Brown, 1991). Polyethylene rowcovers with perforated slits for ventilation have successfully been used in the intensive production of vegetables such as cucumbers and melons (Wilson et al. 1987). Mansour (1984), working on sweet corn, found that rowcovers increased earliness, growth, yield and gross returns ranging from $1,700 to $ 7,900 per hectare. Treatments under rowcovers also had improved plant stand, and silked 17 days earlier than bare ground treatments. In his work with sweet corn under rowcovers, planted on sandy loam soil in east central Kansas, Marr et al. (1991) reported earlier harvest by 7 days compared to bare ground treatments.

Transplants: Alternative to direct seeding

Transplanting is a common practice in agriculture used to improve dependability and earliness of vegetables. In Florida, transplanting of vegetables was found to be the largest factor responsible for the improvement of net returns for watermelons and muskmelons (Meline and Hochmuth, 1988). However, some vegetables including sweet corn, are regarded as 'difficult to transplant' because of greater top-to root ratio, a lower rate of root regeneration after transplanting, and lower intake of nutrients by the older roots (Loomis, 1924).

Use of transplants in the production of sweet corn has not been widely practiced. This is due to difficulty in establishing transplants beyond the critical age of two weeks and the unpredictable early spring soil temperature (Miller, 1972). Waters et al. (1990) reported a general low growth rate and lower yield of sweet corn transplants which were more than 3 weeks old. This could be due to greater damage to roots of the older seedlings with a subsequent increase in transplant shock.

Investigations on the use of transplants for early harvest has been done by various researchers, and with varied results. Miller (1972) reported an earlier harvest for sweet corn grown under plastic by 7 to 21 days over those grown on uncovered plots. The same trend was reported by Wyatt and Akridge (1993) in their work at a Tennesse farm. At Kanaville in the Atlantic province of Canada, Ricketson and Thorpe (1987), in their investigation on sweet corn, observed an early maturity of 7 to 12 days with transplants compared to direct seeded corn while Ledent et al. (1981) in France obtained an advancement of 10 to 15 days.

Reported yield and ear characteristics of transplanted sweet corn also vary depending on transplant age and time of transplanting (Waters et al; 1990). Lower yields were observed when transplanted sweet corn was compared to direct seeded corn, (Wyatt and Mullins, 1989; Ricketson, 1989; Wyatt and Akridge, 1993). Although the total yield of sweet corn was higher for direct seeded plants, Hochmuth et al. (1990) reported a 23-fold increase in early yield due to transplants. The lower yields and higher number of culls from transplants have been associated with pollination problems caused by low temperature or deficient pollen (Wyatt and Mullins, 1988). Ears from transplants also tended to be shorter, less attractive, with low percent marketability.

Ricketson (1989) found mature transplants to be shorter than direct seeded (120 cm vs 185 cm). Ears of mature sweet corn were 57 cm from the ground level for the direct seeded corn and 28 cm for the transplants. The same trend was reported by Mullins and Akridge (1993), Wyatt and Mullins (1989), and Wyatt and Akridge (1993), who reported a height of 116 cm for mature corn grown from transplants, and 141 cm for directly seeded plants. Reduction in the growth of transplants was attributed to cooler temperatures when plants were just initiating reproductive growth and loss of leaves of transplanted plants.

Wyatt and Akridge (1993) attributed the shortness of mature transplants to transplant shock, reduced root growth and loss of older leaves on transplanted sweet corn. Ears from such plants matured early by 12 to 20 days compared to direct seeded plants. Transplanting age is a major factor associated with the reduction in yield of many crops. Ibrahim and Gopalasamy (1989) reported 14.7% higher yield from maize seedlings transplanted at 5 days old compared to 10-day old seedlings.

Summary

Sub-optimal soil and air temperatures affect the germination and subsequent development of many horticultural crops. Low soil temperatures at seeding will adversely affect root growth, metabolic activities and its capacity as sink for photosynthates from the shoot. It will also affect the rate at which roots absorb both water and nutrients from the soil. Work done on the modification of temperature to enhance early germination and establishment has resulted in early maturity and better yields in a number of horticultural crops such melons, pepper and tomato. Use of plastic mulches, row covers and transplants as alternatives to conventional production methods has produced varied results. While these management techniques have resulted into early harvest of sweet corn, inconsistent results have been reported on their effects on marketable yields and ear quality.

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EFFECT OF CLEAR PLASTIC MULCH AND ROWCOVERS ON MATURITY AND YIELD OF DIRECT SEEDED AND TRANSPLANTED FRESH MARKET SWEET CORN (*Zea mays* L.)

A paper to be submitted to HortTechnology Journal

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Abstract: Iowa growers of sweet corn have used clear plastic mulch and rowcovers to improve early yield and advance the maturity of the crop. Results have been inconsistent due to early temperature variability and inadequate information on the choice of the cultivar to grow for early yields. Our objective was to improve performance consistency of sweet corn by investigating production techniques with the early cultivar, 'Temptation', se type at two sites, a silt loam in central Iowa in 1996 and 1997, and a loamy sand along the Mississippi river in eastern Iowa in 1997. Treatments consisted of bare soil or clear plastic mulch, rowcovers or none, direct seeded or transplanted. The transplants were raised in the greenhouse in either jiffy strips or 50-cell plastic trays. For the springs of 1996 and 1997, the plastic mulch harvest advantage for the direct seeded was +1 or 10 days for silt loam soil but no advantage for the loamy sand site. Use of rowcovers resulted in no yield advantage compared to clear plastic mulch. Transplants did not show a consistent advantage over direct seeding. The 50-cell tray transplants matured earlier than the jiffy strip transplants in both locations in 1997. Four-week-old transplants in both jiffy strips and 50-cell trays were not able to withstand the field stress and had very poor performance. Ear qualities such as row number, ear diameter, ear length, and tipfill were lowest with transplants.

Introduction

In a cool, northern climate where the growing season is short for warm season vegetable crops, the management techniques that will shorten the maturity period of a crop are of great interest to growers of fresh market vegetables. This is because consumers are generally willing to pay higher prices for commodities that are in limited supply. To increase early vegetable production, it is necessary to overcome unfavorable climatic conditions such as low soil temperatures. Sweet corn (*Zea mays* L.) is a popular warm season vegetable crop commercially produced for either the fresh market or processed (canning) throughout Iowa. Fresh market sweet corn harvested in Iowa by mid-July usually commands average prices of up to $4.00 per dozen. However, a month later when the crop is in full production the price may be as low as $1.75 per dozen. To obtain a premium price, good quality, early maturing cultivars should be planted two or more weeks before the average frost-free date in any given area (Taber, 1986). However, current production practices of planting on bare ground forces farmers to only plant when soil temperatures are conducive for seed germination, often resulting in late maturity of the ears. This is particularly so with the new hybrids of the genetic base sh_2.

The minimum soil temperature range for germination and emergence of sweet corn is 11 to 17.8 °C with the optimum temperature range of 21 to 30 °C (Richards, 1952). However, early spring soil temperatures normally averaging less than 10 °C may not allow proper seed germination. By the time soil temperatures become favorable for the seeding of sweet corn, the growers are at competitive disadvantage to each other and growers from other states.

To allow early production of the crop, it is necessary to try new crop management practices such as rowcovers, clear plastic mulches and use of transplants. It is well documented that clear plastic mulch and rowcovers have great soil warming capabilities (Miller, 1989; Dinkel, 1966). Use of these plastic ground covers in the early spring is expected to raise soil temperature to allow for more uniform, faster germination and subsequent growth of sweet corn. Of the many benefits of plastic mulch and rowcovers, the increase in soil temperature during a cool spring is probably the most important, as a higher minimum soil temperature favors continued root growth (Taber, 1993)

Among the cultural methods used by farmers in growing vegetables, transplanting has been the most adopted practice where early maturity and uniform yields are desired. By growing sweet corn from transplants, the seedlings are expected to develop a better fibrous root system for nutrient absorption and, therefore, should be able to stand the early spring cold temperatures. The overall objective of this study was to investigate how the maturity, yield and quality of an early maturing sweet corn can be improved by the use of plastic mulch, rowcovers and/or transplants.

Materials and Methods

Location: The trial on sweet corn cv Temptation, an early se type, was conducted in 1996 and 1997 at the Horticultural Research Station in central Iowa, and in 1997 in eastern Iowa. At both sites the previous crop was rye, and strips were left surrounding the plot area to serve as a windbreak. Soil in central Iowa was a moderately well-drained silt loam (Fine-loamy, mixed, mesic Typic Hapludolls) with an organic matter content of 4.6%. The site in eastern Iowa was an excessively, well-drained loamy sand soil (sandy, mixed, mesic Entic Hapludolls) with organic matter content less than 0.5%.

Treatments: Treatments consisted of bare ground or clear plastic mulch, rowcovers or none, direct-seeded or transplants. Rowcovers were used only with the bare ground treatment at the eastern Iowa site. Transplants were further evaluated according to their transplant age and cell size. Seedlings to be transplanted were raised in the greenhouse 2 and 4 weeks prior to the planting date. Seeds were planted in either shallow plastic 50-cell trays (4.8 by 5.9 cm) or deep jiffy strips (5.9 by 10.2 cm), filled with a peat-perlite-soil mixture. Greenhouse temperature was maintained at 21 °C. Prior to transplanting, six plants were removed from each plastic tray and jiffy strip for dry mass determination. The effect of rowcovers on sweet corn was not tested in 1996. Treatments were arranged in a factorial, randomized complete block design. There were four replications per treatment in central Iowa and three in the eastern location.

Field operations: At the central Iowa location, the trial was seeded both years on 1 May, about 8 days before the last 25% frost-free date and the eastern Iowa site was seeded on 29 April 1997. Compound fertilizer (14-14-14) was broadcasted one week before planting at the rate of 68 kg N per hectare. In central Iowa, nitrogen was incorporated into the soil as urea fertilizer at a rate of 70 kg N per hectare prior to seeding. To suppress weed growth, a combination of metolachlor and atrazine herbicides was incorporated lightly with a cultipacker just before laying the 1.2 m wide clear plastic film on 1.8 m row centers. Weeds between the rows were cleared by mechanical cultivation. Esfenvalerate pesticide was used for the control of corn borers and/or earworms. At both sites, overhead irrigation was used to supply 2.5 cm of water per week whenever there was insufficient rainfall.

Both transplanting and direct seeding were done on double rows to a bed at an in-row spacing of 46 cm by 30 cm (between plants in-row). Each plot bed measured 1.8 m by 7.6 m long. Transplanting was done when the seedlings were either two or four weeks old. Two seedlings were allowed to grow per hill to give a population of 88 plants per plot. Where needed, clear plastic mulch (a photodegradable type) was applied before seeding. Both the clear plastic mulch and rowcover materials were from thin (0.0025mm) linear, low density, material. Perforated rowcovers, as opposed to slitted type, were placed over wire hoopes which were spaced approximately 1.5 m apart during transplanting. Edges of the rowcovers were pulled tightly over the hoops and buried into the soil to prevent sagging. The perforated plastic material contained 2-cm holes every 10 cm for ventilation.

Data collection: When seedlings had attained 4 leaves, a stand count was made to determine the survival rate. Silk date on each plot was noted when 50% of plants in the treatment row had formed silk of about 2.5 cm in length. Just before harvesting, plant height was measured from the ground to the ear and to the extended tassel. Maturity date was determined when the ears were large enough to fill the husk tightly to the top, and the kernels were just beginning the milk stage. Silk at the end of the husk had then turned brown.

At harvesting, total number and weight of marketable and unmarketable ears were recorded. Any ear that was misshapen, less than 14 cm, or had any pest infestation was classified as unmarketable. Ear characteristics such as percent tipfill, ear length, ear diameter, and kernel row number were determined from the mean of six randomly selected ears per plot.

In central Iowa, soil and air temperatures were measured for all treatments in two blocks with copper-constantan thermocouples placed in the soil at 10 cm depth and air at 15 cm height. Three thermocouples were wired in parallel according to the procedure of Culick et al. (1982) to give one average output reading for each plot. Temperatures were monitored hourly with a CR-10 data logger (Campell Scientific, Logan, Utah) with a scan rate of 5 min and averaged hourly. At eastern Iowa, soil temperature was measured from 1 to 13 May by a hand probe, at 8 am (minimum temperature), and at 4 pm (maximum temperature)

Data analysis: Data were analyzed by general linear models procedure, and the Duncan Multiple Range Test (DMRT) was used to separate means of variables such as plant height, yield, days to maturity, and ear characteristics.

Results

Temperature effects: Clear plastic mulch did not influence either the minimum or maximum air temperature in 1996 and 1997 in central Iowa (Table 1). However, rowcovers significantly increased maximum air temperature in central Iowa by 16.4 °C in 1997 compared to no rowcover treatment (Table 1 and Figure 1), but had no effect on minimum air temperature (Table 1). May 1997 average air temperature was -4.6 °C below normal and there were 6 days of light frost.

Mean minimum and maximum soil temperatures were influenced by both plastic mulch and rowcovers in eastern and central Iowa (Table 2). Clear plastic mulch resulted in a marginal but insignificant minimum soil temperature gain of 1 °C in central Iowa in both years. At the eastern Iowa site, clear plastic mulch significantly raised the minimum soil temperature by 2 ° C, compared to bare ground treatments. The magnitude of the difference in minimum soil temperature among ground covers increased with a decrease in bare ground temperature (Figure 2). Minimum soil temperature was highest with the rowcover treatments at both sites.

Clear plastic mulch had no effect on maximum soil temperature in 1996 in central Iowa and in eastern Iowa in 1997, but increased the average soil temperature by 4.2 °C to 24.6 °C in central Iowa compared with the bare soil in 1997 (Table 2). Rowcovers enhanced the minimum soil temperature in central Iowa, but not eastern Iowa. Still these temperatures were below the root growth threshold temperature of 12 °C. Rowcovers greatly enhanced maximum soil temperature at both sites by 5 to 6 °C compared to bare ground treatments (Figure 3).

Growth, maturity, and yield in Central Iowa: In 1996, the plastic harvest advantage was 1 day, but the transplant advantage compared to direct seeded was 6 days (Table 3). The larger volume jiffy strip produced no harvest advantage over the shallow and less expensive, 50-cell tray. Transplant age was only effective with the 50-cell container, where the 4-week old transplants matured 3 days earlier than the 2-week transplant size (data not shown). This combination of clear plastic mulch and 4-week old transplants produced in 50-cell trays resulted in a 9-day harvest advantage compared with direct seeded-bare ground. However, this 4-week old transplant treatment had less than 50% survival because of harsh, cold conditions and was eliminated from further study.

Plant stand at harvest was similar (Table 3) because the plots were over seeded and thinned back to a final stand of two plants per hill at the fourth leaf stage of growth. Although treatments under clear plastic mulch produced greater number of marketable ears, this did not result into any significant increase in total ears (Table 3). Ear length was significantly greater for the longer maturity treatment, the direct-seeded bare ground compared with other treatments in 1996 (Table 4). Other measured ear characteristics such as ear weight, kernel row number, and tipfill were not affected by the treatments.

In 1997 in central Iowa, clear plastic mulch enhanced germination of direct seeded sweet corn by 3 days compared to bare ground treatment (Table 5). Seeds under rowcover + bare ground treatment germinated within 12 days, seven days earlier than those under bare ground alone. The fastest germination rate was obtained where a combination of row covers and plastic mulch was used. Seeds under this treatment germinated within 9 days. A significantly higher germination percentage (75%) was observed under clear plastic mulch compared to bare ground (55%) (data not shown).

Effect of clear plastic mulch and/or rowcovers on early germination of sweet corn seeds was not consistently observed on subsequent plant growth and development. In 1997, in central Iowa, clear plastic mulch had no major effect on the ear to ground height (Table 5). Plants under rowcovers had a 6-cm ear height advantage compared to direct seeded-bare ground plants. At maturity, plants grown under bare ground treatments were the tallest. Ear and tassel heights were lowest in the 2-week old jiffy strip transplants. Transplant size, as measured by plant height, was only 82% that of direct seeded treatment at harvest.

The number of days to 50% silk formation and ear maturity was affected by the ground cover treatments in 1997 in central Iowa. Treatments under rowcovers and/or combination of rowcovers and plastic mulch silked ealier than the bare ground treatments by 3 to 5 days (Table 3). Clear plastic mulch hastened maturity by 10 days compared with the bare ground soil. Although the maturity date for the direct seeded-bare ground was similar for both years, the treatments under clear plastic mulch in 1997 were 7 days earlier than in 1996. The use of rowcovers or transplants did not advance maturity compared to direct seeded with clear plastic mulch.

Unlike 1996, the longer maturing direct-seeded bare ground treatments produced the highest yield. As in 1996, 4-week old seedlings did not perform well in 1997 in central Iowa because frost and strong winds affected them more than the 2 week old transplants. More than 75% of the seedlings were killed by frost. The tall seedlings were already stressed when set in the field. They tasseled early before the plant was large enough to support an ear. Thus, this treatment was eliminated from the analysis. The 2-week old seedling stand was severely reduced by 40% compared to other treatments. Ear length, ear diameter, and ear weight were significantly greater for the direct seeded-bare ground treatments in 1997 (Table 4). The lowest ear qualities were associated with the transplants that were under severe stress (Table 4)

Eastern Iowa: The crop growing temperature in eastern Iowa was -3.6 °C below normal during May 1997. Although soil temperature was increased sufficiently by clear plastic mulch, there was no increase in harvest maturity (Table 6). Rowcovers with bare ground decreased harvest by one day. The 2-week old transplants raised in either plastic trays or jiffy strips showed a significantly reduced number of days to 50% silk formation, by 10 to 11 days, compared to direct-seeded bare ground treatments. But only the transplants grown in eastern

Iowa raised in 50-cell trays showed an enhanced maturity by 7 days. Direct seeded and 2-week old 50-cell tray transplants, both with clear plastic mulch, out-yielded the other treatments by 132 (doz./ha.) or 22 crates

Discussion

Previous research involving the use of clear plastic mulch with sweet corn reported an increase in soil temperature above the conventional bare ground treatments (Andrew et al., 1976). Our results show that both clear plastic mulch and rowcovers can raise soil temperature. This resulted in an early germination and enhanced maturity of 'Temptation' sweet corn. Results of this experiment confirm the reported modification of soil temperature by clear plastic film around the seed zone (Army and Hudspeth, 1960; Andrew et al., 1976). We also observed a greater increase in minimum soil temperature under rowcovers by about 2.7 °C compared to bare ground treatments. Our data show a higher increase when bare ground soil temperatures were extremely low (Figure 2).

Rowcovers and clear plastic mulch increase soil temperature by retaining net solar radiation thus creating 'greenhouse' like conditions (Splittstoesser and Brown, 1991; Friend et al., 1990). The effectiveness of rowcovers in retaining net radiation depends on the season and type of the crop (Pollard et al., 1987). Previous research reported hastened germination, development, and maturity of sweet corn cultivars planted under clear plastic mulch (Andrew et al., 1976; Miller and Burger, 1963; Purser and Comeau, 1989). We observed an earlier germination under plastic mulch and/or rowcovers by between 5 to 12 days compared to bare ground treatments. These results support Hopen (1964) and Krestscher (1979). Both reported over 30% faster germination of sweet corn seeds grown under clear plastic mulch compared to those of bare ground treatments. The faster rate of germination under ground covers could be due to an increase in minimum soil temperature enhancing physiological changes in the seeds.

Our data indicated a faster growth and maturity of plants grown under rowcovers and/or its combination with clear plastic mulch in central Iowa in 1997. Pollard et al. (1987) attributed the effectiveness of rowcovers in enhancing vegetable maturity to a reduced radiant and convection heat loss. It is possible that the enhanced soil temperature resulted in the plants developing a better root systerm early in the season to allow for sufficient nutrient absorption. Treatment effect on yield was inconsistent. For direct-seeded, the longer maturing bare ground treatments produced the highest yield in 1997 because perhaps the larger plants contained more biomas and/or leaf surface area for carbohydrate production. But at the eastern Iowa site, plant growth was similar and the clear plastic mulch increased yield by 625 doz./ha. Generally the longest maturity treatment, bare ground, resulted in a more attractive marketable ear as measured by ear length (Table 4). The expensive rowcover did not affect yield or ear quality at either location or year.

The reduction in yield by use of transplants was a direct result of stand loss. The lowest ear quality characteristic observed on transplants could be due to severe stress. Wyatt and Akridge (1993) associated reduced height of transplants to transplant shock, reduced root growth and direct loss of leaves at transplanting. The reduction in growth and vigor of the 4-week old transplants make them unsuitable for commercial production of sweet corn.

Conclusion

The effect of earliness techniques of high sugar sweet corn maturity date and marketable yield is dependent on the spring weather and location soil type. The most economical practice is the use of a high quality, vigorous variety tolerant to cold soils. Next, clear plastic mulch with direct-seeded may hasten maturity by 10 days (1996 on the silt loam site), but this practice was inconsistent from year to year. Years where benefit occurs may pay the costs where it does not. On the plains where high winds occur frequently in the spring, transplants at two weeks of age were superior to the 4-week old transplants. The benefit of transplant cell size was inconclusive.

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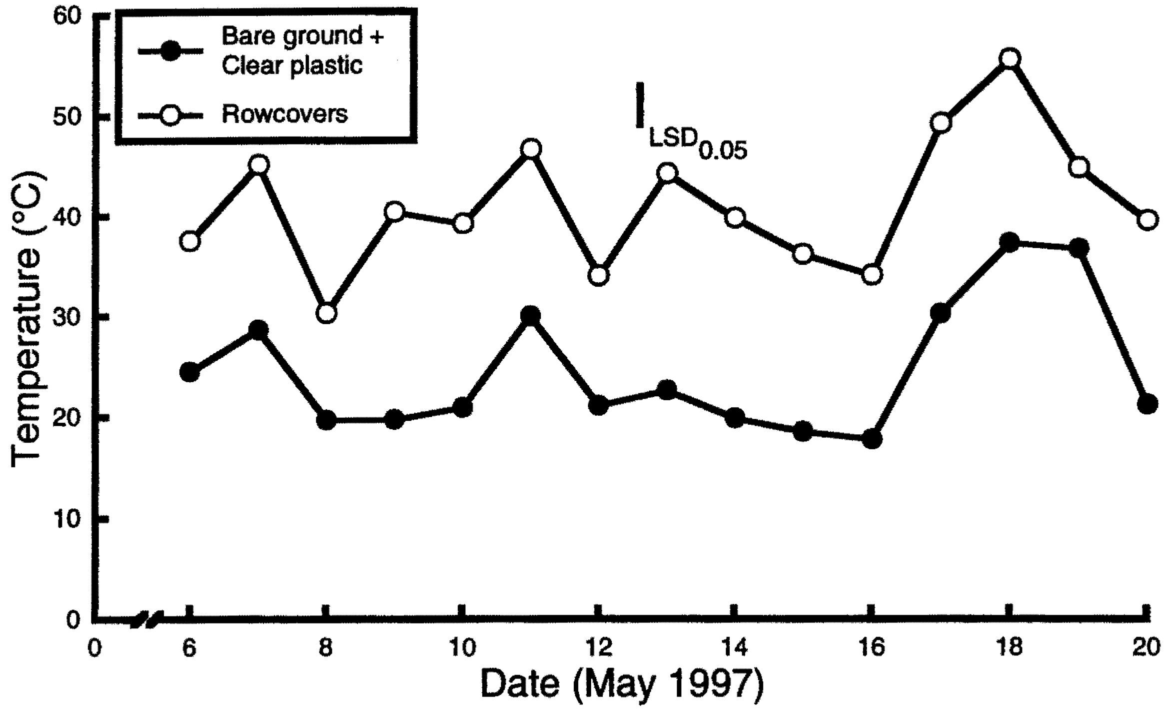

Figure 1. Maximum air temperature (°C) at 15-cm above the ground surface under bare ground, rowcovers, and clear plastic mulch in central Iowa in 1997. Data were means of two replications of a randomized complete block design with 4 replications.

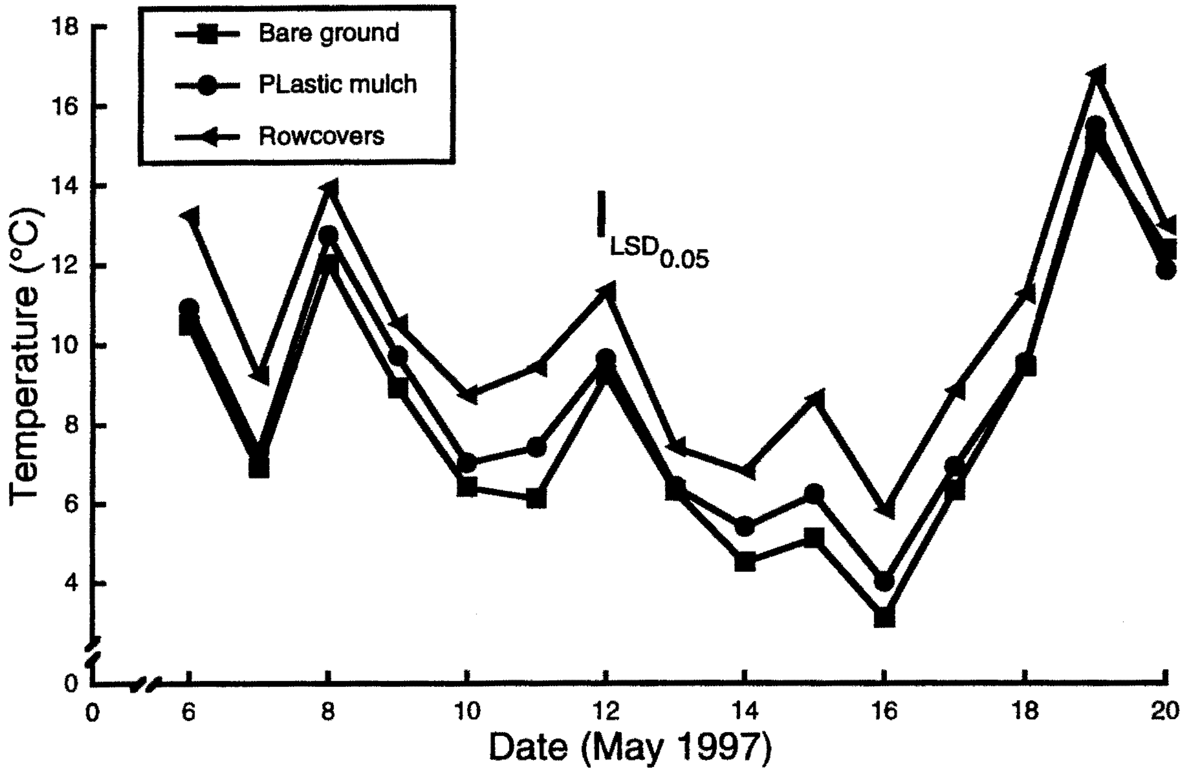

Figure 2. Minimum daily soil temperature (°C) at 10-cm depth under bare ground, clear plastic mulch or rowcovers from 6 to 20 May 1997 in central Iowa. Data were means of two replications of a randomized complete block design with 4 replications.

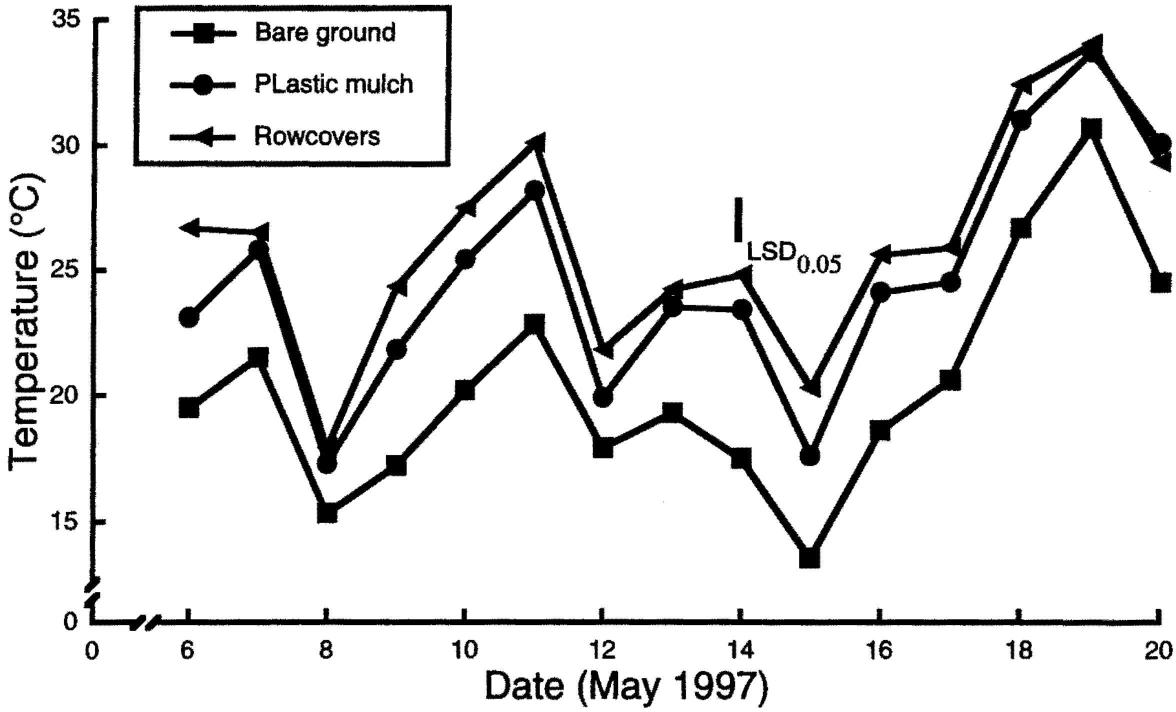

Figure 3. Effect of clear plastic mulch and rowcovers on maximum soil temperature (°C) at 10-cm depth in central Iowa from 6 to 20 May 1997. Values used were means of two replications of a randomized complete block design with 4 replications.

Table 1. Mean daily low and high air temperatures at 15-cm height above the ground surface in central Iowa in 1996 and 1997[z]. Means are from two replications.

	Minimum air temperature (°C)		Maximum air temperature (°C)	
Ground cover	1996	1997	1996	1997
Bare ground	8.1	2.0	26.8	24.2 b[y]
Rowcover + Bare ground[x]	--	1.9	--	41.0 a
Plastic mulch	8.4	1.7	27.7	24.9 b

[z]May average air temperature, compared with 40 years average, was -3.6 °C in 1996 and -4.6 °C in 1997.

[y]Mean separation within the column was achieved by DMRT, at 5% level of significance.

[x]Rowcover was not tested in 1996.

Table 2. Mean daily low and high soil temperature at 10-cm depth from 6 to 20 May 1997 in central Iowa and eastern Iowa. Data were from two replications.

Type of soil	Minimum soil temperature (°C)			Maximum soil temperature (°C)		
	Central Iowa		Eastern Iowa	Central Iowa		Eastern Iowa
cover	1996	1997	1997	1996	1997	1997
Bare ground	12.5	7.5 b[z]	9.5 b	19.6	20.4 b	26.1 b
Rowcover + Bare ground[y]	--	10.2 a	11.2 a	--	26.1 a	31.3 a
Plastic mulch	13.6	8.5 b	11.6 a	20.6	24.6 c	27.8 b

[z]Mean separation with the column was achieved by DMRT, at 5% level of significance.

[y]Rowcover was not tested in 1996.

Table 3. Effect of clear plastic mulch, rowcovers, transplants, and cell type on 'Temptation' (se) sweet corn establishment and yield in central Iowa, 1996 and 1997[z].

Treatment	Plant Stand%	Days to 50% Silk	Days to Harvest	Marketable (Ears/Plot)	Total yield (Crates/ha.)
Direct seeded		**1996**			
Bare ground	97.7	69 a[y]	85 a	54 ab	772
Clear plastic mulch	98.6	66 b	84 b	61 a	868
Transplants + Plastic mulch					
2 weeks + 50-cell tray	95.5	63 c	79 c	43 cb	685
2 weeks + jiffy strip	96.3	68 a	79 c	38 c	660
Direct seeded		**1997**			
Bare ground	100 a	63 a	87 a	76 a	924 a
Bare ground + Rowcovers	100 a	60 bc	83 b	62 ab	702b
Plastic mulch	100 a	62 ab	77 c	58 b	751 b
Plastic mulch + Rowcover	100 a	58 c	77 c	50 b	606 b
Transplants + Plastic mulch					
2 weeks + 50-cell tray	64 b	57 c	77 c	33 c	397 c
2 weeks + Jiffy strip	60 b	60 bc	83 b	34 c	412 c

[z]Sweet corn seeded and transplanted May 1 both years. May average air temperature compared with 40-year average was -3.6 °C in 1996 and -4.6 °C in 1997.

[y]Mean separation within years and within columns was by DMRT, 5% level of significance.

Table 4. Mean values of ear diameter, kernel row number, ear length, and percent tipfill of sweet corn (*Zea mays* L. 'Temptation') in central Iowa, 1997.

Treatment	Ear diameter (cm)	Kernel (rows/ear)	Ear length (cm)	Tipfill (%)
Direct seeded		**1996**		
bare ground	4.0	15.5	17.9 a[z]	98.7
Plastic mulch	4.3	15.6	15.5 b	98.4
Transplants + Plastic mulch				
2 weeks + 50-cell tray	4.3	16.0	16.3 b	99.4
2 weeks + jiffy trip.	4.1	16.1	15.9 b	98.0
Direct seeded		**1997**		
Bare ground	4.0	16.0 a	18.3 a	99.7
Bare ground + Rowcovers	3.8	15.5 ab	17.1b	99.6
Plastic mulch	3.8	15.3 ab	17.1b	99.4
Plastic mulch + Row covers	3.6	15.7 ab	16.4 cb	99.0
Transplants + Plastic mulch				
2 weeks + 50 cell tray	3.6	13.7 c	16.0 cb	97.4
2 weeks + jiffy strip	3.6	14.8 b	15.4 c	99.0

[z]Mean separation within columns and within years was by DMRT, 5% level of significance.

Table 5. Effect of clear plastic mulch, rowcovers, transplant, and cell type on germination and growth of sweet corn (*Zea mays* L. 'Temptation') in central Iowa 1997[z].

Treatment	Days to Germination	Plant height (cm) Ear	Tassel
Direct seeded			
Bare ground	19 a[y]	40 cd	180 a
Rowcover + Bare ground	12 c	46 a	171 b
Clear plastic mulch	16 b	43 bc	173 ab
Row cover + Clear plastic mulch	9 d	46 ab	169 b
Transplants + Plastic mulch			
2 weeks + 50-cell tray	--	27 e	148 d
2 weeks + jiffy strip	--	25 e	139 e

[z]Sweet corn seeded and transplanted May 1.

[y]Mean separation within the column was achieved by DMRT, at 5% level of significance.

Table 6. Effect of clear plastic mulch, rowcovers, transplants, and cell type on 'Temptation' (se) sweet corn establishment and yield in eastern Iowa, Fruitland, 1997[z].

	Days to		Marketable yield	Tassel	Ear
Treatment	50% silk	Harvest	(Crates/ha.)	Length	Length
Direct seeded					
Bare ground	64 a[y]	79 a	771 b	175 a	16.5 bc
Rowcover + bare ground	62 b	78 b	771 b	175 a	17.0 ab
Clear plastic mulch	62 b	79 a	897 a	175 a	17.5 a
Transplants + Plastic mulch					
2 weeks + 50-cell tray	53 c	72 c	957 a	140 b	16.0 c
2 weeks + jiffy strip	54 c	78 b	745 b	130 c	16.3 c

[z]Sweet corn seeded and transplanted April 29, 1997.

[y]Means in the column with the same letter are not different at 5% level of significance by DMRT.

GENERAL CONCLUSION

Use of rowcovers resulted in higher minimum soil temperature for bare ground soil in both eastern and central Iowa. Clear plastic mulch had no significant effect on minimum soil temperature in both years in central Iowa, but significantly ($P>0.05$) increased the minimum soil temperature in eastern Iowa in 1997.

Conventional direct-seeded bare ground treatments gave higher yields and better quality ears. Our results confirm earlier findings that transplants, clear plastic mulch, rowcovers or a combination of both rowcovers and clear plastic mulch can significantly raise soil temperature and enhance sweet corn maturity. However, these production techniques might not be economical in large scale sweet corn production. They produce low yields and inferior quality ears compared to direct-seeded bare ground treatments.

Clear plastic mulch and rowcovers can improve the plant stand, hasten germination, and maturity of sweet corn in cool springs. Modifications of soil temperature by the ground covers are more useful where the new high sugar sweet corn types like 'Temptation' are grown. Most of these cultivars have shallow root systems and do not germinate well in cold soils (Taber, 1993). Rowcovers resulted in earlier germination and maturity compared to all the treatments both in central and eastern Iowa. Rowcovers are more effective in creating 'greenhouse' like conditions to plant environment, increasing soil temperature for early germination and maturity of the crop.

Transplants raised in 50-cell plastic strip matured earlier than bare ground treatments by 7 days in eastern Iowa, and by 6 to 9 days in central Iowa. The 4-week old transplants raised in either jiffy strips or 50-cell plastic trays performed poorly in both sites. They were killed by late frost, silked early, and had the lowest number and quality of marketable ears. Transplant shock, and, loss of leaves and roots during transplanting, are some of the factors that might have affected the growth and yield of the 4-week old transplants.

APPENDIX

SUPPLEMENTARY TABLES OF ANALYSIS FOR EAR CHARACTERISTICS, GROWTH, AND MATURITY OF DIRECT SEEDED AND TRANSPLANTED SWEET CORN

Table 1. Analysis of variance of ear characteristics (tipfill, diameter, row number, and length) of sweet corn (*Zea mays* L. 'Temptation') in central Iowa in 1996.

		Ear tipfill			Ear diameter			Ear row number			Ear length		
Source	df	MS	F	P>F	MS	F	P>F	MS	F	P>F	MS	F	P>F
Replications	3	6.18	3.87	0.041	0.02	0.81	0.515	0.25	1.28	0.330	1.65	3.33	0.006
Treatment	4	1.21	0.76	0.572	0.03	1.16	0.390	0.28	1.41	0.294	3.65	7.34	0.0038
Rep.* Trt	12	1.6			0.03			0.2			0.5		

Table 2. Analysis of variance of ear characteristics (tipfill, diameter, row number, and length) of sweet corn (*Zea mays* L. 'Temptation') in central Iowa in 1997.

		Ear tipfill			Ear diameter			Ear row number			Ear length		
Source	df	MS	F	P>F	MS	F	P>F	MS	F	P>F	MS	F	P>F
Replications	3	4.09	0.79	0.519	0.18	0.40	0.756	2.00	0.66	0.591	0.30	1.08	0.389
Treatment	5	3.94	0.76	0.594	2.20	4.92	0.007	2.62	8.61	0.0005	3.94	14.26	0.0001
Rep.* Trt	15	5.19			0.45			0.31			0.27		

Table 3. Analysis of variance for days to harvest and yield of sweet corn (*Zea mays* L. 'Temptation') in central Iowa 1996.

		Days to harvest			Yield		
Source	df	MS	F	P>F	MS	F	P>F
Replication	3	0.077	175	0.0001	8.9	2.93	0.117
Treatment	5	41.3	102	0.0001	50.1	16.40	0.002
Comparisons							
Bare ground							
vs plastic mulch	1	2.0	1.69	0.214	3.4	0.95	0.352
vs others	1	96.3	143	0.0001	0.4	0.1	0.757
Transplants							
vs direct seeded	1	2.3	99	0.0001	17.6	4.97	0.049
50-cell trays							
vs jiffy strips	1	9.0	0.22	0.003	108	0.05	0.986

Table 4. Analysis of variance for days to harvest and yield of sweet corn (*Zea mays* L. 'Temptation') in central Iowa 1997.

		Days to harvest			Yield		
Source	df	MS	F	P>F	MS	F	P>F
Replication	3	352.8	1.17	0.358	138.1	1.74	0.205
Treatment	5	147.9	0.49	0.779	302.3	3.80	0.022
Comparisons							
Bare ground							
vs plastic mulch	1	512.0	1.69	0.214	513.6	6.46	0.024
vs rowcovers	1	77.1	0.25	0.622	356.0	4.48	0.053
vs others	1	390.7	1.29	0.275	807.7	10.16	0.007
Transplants							
vs direct seeded	1	10.7	0.04	0.850	144.1	1.81	0.199
50-cell trays							
vs jiffy strips	1	32.0	0.11	0.751	118.3	0.02	0.882