SWEET CORN PRODUCTION WITH DIFFERENT MULCHES, VARIETIES, AND PLANTING DATES IN NORTH DAKOTA

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ABSTRACT

Sweetcorn is a high value crop that can grow almost anywhere given the right temperature conditions. In North Dakota those conditions are not always met. Using mulch increases the soil temperature. Early planting will have a higher soil temperature increase, but also creates risk from frost damage. In this study, three varieties of sweetcorn was planted with different maturity days, on four covers (black, clear, biodegradable and no mulch), with four different planting dates (from April 15 to June 1). Emergence, growth stage, plant height, leaf area index, soil and near surface air temperature, yield and sugar content was measured. The germination rate was shortened for the clear mulch by 2.6 days. Through this one year study, we can say that mulch is effective in raising soil temperature, increases early growth for 84 day variety and increases fresh yield for all mulch covers when compared to the no mulch treatment.

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1. INTRODUCTION

1.1. Background

North Dakota is located in upper Midwest North America and is one of the coldest states in the continental United States. The state's northern border is shared with Canada, the west with Montana and the south and east with South Dakota and Minnesota, respectively.

Agriculture plays a very important role in North Dakota. In 2014, North Dakota had 9 crops ranked number one in production in the US, while corn for grain and silage was ranked numbers 12 and 13 in the country, respectively (USDA, 2015). Many factors can contribute to good crop production, such as soil water content, plant nutrients and temperature. Some factors such as soil water through irrigation/drainage and fertilizer content via fertilization can be easily managed/controlled, while other factors such as air and soil temperature are not easily managed. In North Dakota, cold temperature is the most limiting factor for crop production in a short growing season. It limits the types of crops that can be successfully grown in the state, specifically high value crops like sweet corn and vegetable crops.

For sweet corn production, certain growing factors need to be met in order to grow and thrive. One of the main factors that affect its growth is the low soil temperature. The soil temperature in North Dakota does not always reach the desired temperature until later in the spring, especially in the northern part of the state, close to the Canadian border. The soil needs to reach a certain temperature in order for seeds to germinate and grow and that temperature is set as 10 Celsius (NDAWN, 2016). With the unpredictable spring weather in North Dakota, early planting can become dangerous for the plants due to the cold soils or frost injury. This lower temperature and late planting date in North Dakota limit the sweet corn production with short season variety and late planting dates, thus low marketable value.

One way to manage the effects of the temperature is to use mulches, which covers the ground and modifies root zone temperature in order to improve the growth and yield of a crop (Ibarra, 2008). Mulches modify the soil temperature by changing the energy balance in the soil, and by altering the amount of solar radiation that is absorbed into the soil or reflected back into the atmosphere. Black and reflective mulches may actually reduce the soil temperature. In contrast, transparent mulches produce a relatively large net radiation at the soil surface (Liakatas, 1986). Mulches can also be used to conserve soil moisture, reduce evaporation, control weed growth and prevent diseases (Mahadeen, 2004, Green, 2003, Diaz-Perez, 2007).

There are different types of mulches depending on the producer's specific needs. Clear plastic mulches can increase the soil temperature, improve early yield and advance the crop maturity (Aguyoh, 1999). Black plastic mulches can control weed growth by limiting the amount of light reaching the soil. There are also different types of biodegradable mulches that act similar to plastic mulches but can be left in the field and will degrade over time.

The use of plastic mulches to improve the growing conditions for a crop has not been studied in North Dakota as we are aware of. Plastic mulch can possibly increase soil temperature and extend the growing season for sweet corn. An elongated growing season can then increase the quality and yield from the sweet corn. The longer growing season will also allow an earlier planting time, and longer maturity varieties as well as a better marketable value and economic return.

1.2. Research Objectives

The objective of this study was to evaluate sweet corn growth and response to four different types of mulches (black, clear, biodegradable, and no mulch) that were planted on four different dates (April 15th, May 1st, May 15th and June 1st) for three hybrids with different maturities of 65, 75, and 84 days.

2. LITERATURE REVIEW

2.1. Sweet Corn

Sweet corn is a naturally occurring recessive mutant form of regular field corn. It grows relatively in the same manner as field corn but with one major difference, sweet corn produces twice as much sugar than regular field corn and much less starch. As the plants reach the milk (R3) growth stage, they produce natural sugars that fill out the kernels. The kernels are also called the seeds which have an embryo and a food storage compartment. The kernels cannot store their food in a sugar format so the plant has to convert it to starches if given a longer time to grow. Harvesting the sweet corn is done during this milk stage with high sugar and moisture contents for a good marketable value.

Sweet corn is divided into three broad groups based on sweetness; normal sweet, sugary enhanced sweet and super sweet (Singh, 2014). All three of these groups have different genes that give them a certain level of sweetness. Normal sweet varieties have a mutated gene with a sugar increase but also have a rapid conversion rate for sugar into starch. Sugary enhanced sweet corn groups have a different gene where either 25% or 100% of the kernels will be sugary. This gene also increases the shelf life. The super sweet group is two to three times sweeter than that of the sugary enhanced versions and has the longest shelf life, but it is harder to grow and produces smaller ears than the other two groups (Singh, 2014).

2.1.1. Factors Affecting Sweet Corn

There are numerous factors affecting the growth of sweet corn: planting date, variety, planting density, soil conditions, etc. Corn, including sweet corn, is normally planted mid to late May in the Fargo, North Dakota area or when average air temperature conditions consistently stay in the 10^{o}C range (Fraisse, 2011). Also, during this time of the year, the air temperature can drop below $0^{o}C$ at night. Sometimes, spring weather is much colder and planting can be delayed anywhere from two weeks to a month from a normal planting date. This can cause lower corn yields because a variety with a shorter maturity has to be planted due to the shortened growing season.

2.1.1.1. Planting Date

The planting date has a large impact on the growth and development of sweet corn. As stated before, sweet corn is planted mid to late May in Fargo. The corn cannot be planted earlier in the season because the low soil temperature and air temperature conditions have an impact on the development of the plants. If the plants sustain damage due to frost or poor germination, the sweet corn may have to be replanted. The minimum temperature at which the sweet corn can survive and grow is $10\ ^{o}C$. Although this temperature can be different for each variety, this is the temperature most producers use for planting. The soil temperature in the spring can vary greatly from year to year, some years the spring season in North Dakota is warm enough to plant the sweet corn earlier than normal, but other years the conditions are cold and cause a delay in planting. A delay in planting can also cause a delay in the harvest of the sweet corn. If the harvest is delayed by too much, the sweet corn may not produce any yield, and faces the risk of frost damage in the fall.

A strategy that producers utilize is staggering the planting dates of the sweet corn at different intervals. The crops will be planted in 10 to 15 day intervals starting with the earliest planting date possible. This spreads out the amount of time the producer has mature sweet corn and reduces the risk of frost damage in spring and/or late fall. When mulches and staggered planting dates are used, producers can increase the amount of time fresh sweet corn is available.

2.1.1.2. Planting Density

Planting density plays an important role in the growth of sweet corn. If plant density is too high, they will not have enough room to grow properly. In a small scale operation, this is not a big concern as plants can be thinned to the correct density. Also, if the density is too low, the sweet corn will not have a good yield.

2.1.1.3. Corn Variety

The variety of sweet corn also affects the growth and yield of sweet corn. Different varieties or hybrids of sweet corn have differences in how sweet they taste, the overall length of time it takes for the corn to mature and Growing Degree Days (GDD) needed. A longer degree day variety of sweet corn will take longer time to mature but will have a higher yield than a shorter GDD variety which takes less time to grow.

If the growers do not wish to stagger the planting dates, they have the option of choosing varieties of sweet corn that take different amounts of time to mature. In this way, they only have to plant once, but with different varieties. This will also increase the amount of time fresh sweet corn is available for consumers.

2.1.2. Leaf Area Index

Leaf area index (LAI) is a dimensionless variable defined as the total one-sided area of photosynthetic tissue per unit ground surface area (Watson, 1947). This definition works well for broad leaves and leaves that have a flat surface. It is acceptable because both sides of the leaves have the same surface area. When a leaf is twisted, rolled or not flat, the one-sided area is not clearly defined. A new way to define LAI for non-flat leaves was developed and is defined as the maximum projected leaf area per unit ground surface area (Myneni et al., 1997). This new definition is based on the inclination angle of the leaves of the crop. LAI can be measured by instruments, such as LiCor-2200c (Li-COR, Lincoln, NB), which computes LAI from above and below canopy readings and determines light interception at 5 zenith angles (Li-Cor, 2015). This means that it considers the leaf angle of incidence automatically. Since the largest differences in canopy properties (height and canopy closure) occur at the silking stage (R1), LAI measurements were taken at this time. The changes in canopy structure, was mainly associated with changes in crop yield (Williams II, 2006), Changes in canopy structure can be caused by many factors including environmental stress, such as drought during the silking stage. For example, during a drought the water the plant receives from the soil is limited. Since the nutrients the plant needs is also carried in the soil water, the plants do not receive the proper amount and therefore may suffer nutrient deficiencies.

2.2. Mulches

Mulching is the process of covering the soil surface directly by a material (Takakura, 1989). Mulches are used to increase soil temperature, reduce weed growth and help to conserve moisture in the soil. The mulches that are used in larger scale productions are variations of plastic sheeting. Not all mulches are of the plastic variety. Nurseries, flower beds and personal gardens for example, may use organic mulches such as straw, grass clippings or wood chips. These organic mulches are not practical for large scale production. They are, however, cost efficient for small scale gardens or flower beds.

Plastic mulches have been used throughout the United States as well as worldwide. They are used to increase the growth and yield of crops, mainly high value crops such as sweet corn and other vegetable crops. Cucumbers were found to have a higher yield when grown on plastic mulches than on bare soil (Ibarra, 2008). With the cold growing conditions in North Dakota, mulches can be used to increase the soil temperature in the early spring which will allow the crop to be planted earlier and have a longer growing season.

2.2.1. Benefits

2.2.1.1. Increase Soil Temperature

Mulches increase the soil temperature by altering the energy balance of the soil. When plastic mulch is installed in the spring, there is a small layer of air trapped between the soil and the mulch. In transparent mulches, this layer of air acts as an insulator for the soil. At night, when the temperature drops, the heat from both the water and the soil on the ground will normally radiate out of the soil into the atmosphere. If a mulch is in place, heat loss will be slowed by the insulating layer, although it will not trap all of the heat as it still has a chance of escaping through places where there is no mulch in place or where the mulch is touching the soil. For opaque mulches, the temperature of the soil under the mulch is dependent upon the reflectivity of the material and the thickness of the air layer between the mulch and the soil. An opaque mulch is most effective when it has contact with the soil (Liakatas, 1986).

By increasing the soil temperature, these mulches will extend the growing season, thus allowing crops like sweet corn to be planted earlier. A variety of sweet corn that has a longer maturity rate could be planted, which will have a higher yield than a variety that has a shorter maturity rate. The earlier planting date can also have an effect on the amount of time it takes for the sweet corn to mature. This means that producers in North Dakota will be able to get their better quality product to market earlier.

2.2.1.2. Reduce Weed Growth

Mulches can reduce weed growth, reducing the amount of time and money spent on weed management (Green, 2003). On large scale production, this implies less herbicide application to the field, reducing the amount of money spent on the herbicides as well as reducing the amount of vehicle traffic through the field. With weed control, and no herbicide application mulches can also have an important role in organic farming.

2.2.1.3. Conserve Soil Moisture

Mulches help to conserve soil moisture by providing a restrictive layer over the soil. This restricted layer will reduce the amount of water that evaporates to the atmosphere. In Jordan, black plastic mulch was shown to reduce soil water evaporation and improve retention of the water in the soil in rain fed conditions when compared to a no mulch field (Mahadeen, 2014).

2.2.2. Types of Mulches

There are several different types of mulches available such as organic, plastic, and biodegradable. Each type of mulch has its own advantages and disadvantages.

Organic mulches such as leaves, grass clippings, wood chips and straw are temporary and can decay over time. This type of mulch can be inexpensive (grass clippings, leaves). The rate at which organic mulch decays is influenced by soil and environmental conditions. In general, organic matter increases soil mobile nitrogen through leaching and decomposition (Lambers et al. 1998).

The most popular types of mulch is plastic sheeting, in different variations of color, thickness and transparency. Black and clear plastic mulch can increase the soil temperature faster than the bare soil. White plastic and plastic sheeting with reflective properties (similar to tinfoil) have a slower rise in soil temperature (Tarara, 2000). Plastic mulch is made from polyethylene polymers; the most common type of plastic. The mulch can be applied by hand or machine. It can reduce the amount of work in the field, such as weed control. At the end of the growing season, this mulch needs to be removed from the soil because it can pollute the soil and affect the seed germination for the next season.

While clear plastic mulch can raise the soil temperature quicker, it can also cause heat damage to the plants by overheating the soil when exposed to long periods of extreme heat. In the southern states, white or reflective biodegradable mulch is layered over the black plastic, to prevent heat damage to plants. This top layer will degrade and expose the black plastic underneath. This provides a slower temperature rise in the beginning of the season when plants are young. The black mulch on the bottom also provides weed control for the crop.

Another popular type of mulch is biodegradable. It is designed to act like a plastic mulch when first installed. After harvest, it can be plowed into the soil and will degrade over time, usually in one to two years. These types of mulches can be made from a wide variety of products. Some are from plant starches mixed with different polymers to create a plastic-looking and feeling degradable mulch. Mulches can also be made from different types of paper, coated with plant starches (Zhang, 2008). These mulch films may be more permeable, allowing more water into the soil while still providing similar benefits as the plastic mulch.

There are two processes by which biodegradable mulches degrade. Photo degradation is where the mulch degrades when exposed to visible sunlight, it becomes brittle and starts to tear. The limitation with this process is any mulch buried under the ground and not exposed to sunlight will not degrade until it is exposed to sunlight. The second process is biodegradation. This is the process by which mulches degrade when exposed to the microorganisms in the soil

(Kijchavengkul, 2008). Plastic biodegradable mulch comes in a variety of different colors. Clear, white and black are some of the most common colors available. The black mulch will take about eight weeks to start degrading while the white mulch takes approximately two weeks (Kijchavengkul, 2008). These mulches can take different amounts of time to degrade depending on the type of polymers that the plant starches were mixed with. Since the black mulch will take more time to degrade, it will likely have similar effect as black plastic mulch. It will also manage the weeds better than the clear and white biodegradable mulches because weeds under the black mulch have no photosynthesis and minimal growth.

2.3. Growing Degree Days

Growing degree days (GDD) are used to measure the accumulation of heat. They are also called Growing Degree Units (GDU) or Heat Units (HU) and are used to relate the growth and development of a plant to air temperature (Fraisse, 2011). It is found by calculating the average daily air temperature, which is calculated from the daily maximum air temperature and the daily minimum air temperature then subtracting a base temperature for the specific crop. For corn, the base temperature is 10 ˚C (NDAWN, 2014). An upper limit temperature of 30 ˚C is used to limit the GDDs.

The GDD's are accumulated over the course of the season. If the average daily air temperature is below the base temperature, the GDD is zero. In Fargo, North Dakota, the typical GDD is around 1300 degree Celsius (2372 Fahrenheit), while close to the Canadian border in Langdon, the GDDs are lower.

2.4. Soil Temperature

Many factors affect soil temperature. Some of the major ones include soil moisture, solar radiation, and soil surface albedo. Other factors are the texture and color of the soil, ground cover and organic matter content in the soil. Factors such as solar radiation and soil surface albedo are part of the energy balance.

2.4.1. Energy Balance

The energy in and out of the soil is a basic mass balance equation. The energy going in is equal to the energy absorbed into the ground, plus the energy that is released back into the atmosphere. This equation is:

$$J_n=S+A+LE \tag{1}$$

where J_n is the net radiation, S is the soil heat flux, A is the sensible heat and LE is the evaporative heat flux or latent heat flux (Hillel, 1998). The units are in W/m^2.

2.4.2. Net Radiation

Net radiation is the sum of all incoming solar radiation minus the reflected radiation. Approximately 45% of the incoming solar radiation arrives at the soil surface. The rest is either absorbed into the ozone layer, reflected back into space or is dissipated. The equation for net radiation is:

$$J_n=(J_s+J_a)(1-\alpha)+J_{li}-J_{lo} \tag{2}$$

where J_s is the incoming shortwave radiation, from the sun, J_a is shortwave radiation diffused in the atmosphere. J_{li} is the incoming long wave radiation from the atmosphere and J_{lo} is the outgoing long wave radiation from the soil. The longwave radiation contains more energy than the shortwave radiation.

The soil surface albedo, α, is also called the reflectivity coefficient. It is the fraction of incoming radiation (shortwave) that is reflected from the soil surface and not absorbed into the soil. A darker colored soil will have a smaller albedo, meaning more energy is absorbed into it than a lighter colored soil. Mulches affect the albedo of the energy balance by either allowing more energy to absorb into the soil or reflecting that energy back into the atmosphere.

2.4.3. Sensible Heat

Sensible heat is a measure of the energy required to change the temperature of an object without a phase change. This would be the heat that is transferred from the ground to the air because of the temperature difference between them. This type of heat is driven by conduction. An example of sensible heat is the heat that can be seen rising off a parking lot in the summer.

2.4.4. Heat Absorbed into the Ground

This term refers to the amount of heat that is absorbed into the soil. Approximately ten percent of the energy from the net radiation that makes it to the ground is absorbed into the soil. The temperature in the ground depends upon many factors including soil moisture, ground cover and heat in the soil. Ground cover is an important factor because with no cover, the soil will heat up faster. If there is vegetation covering the ground, the soil will likely warm up slower.

2.4.5. Latent Heat Flux

This is a product of the evaporation and the latent heat of water. Latent heat flux is the heat from the surface to the atmosphere that is associated with evaporation of water at the surface and subsequent condensation of water vapor. It is the amount of energy that is absorbed by the water when the water changes phases, specifically from liquid to gas (Tarara, 2000). The process of evaporation cools the surface and the process of condensation warms the surface.

2.4.6. Soil Moisture and Evaporation

Soil moisture is a major factor affecting soil temperature. High moisture in the soil will produce high evaporation rates. This is especially true if the air temperatures warm significantly during the day. High moisture content means the soil will not warm up fast because the evaporation of the water will remove most of the energy before the soil has the chance to warm up.

Water evaporation removes most of the energy since it has a higher heat holding capacity than the soil. Less soil moisture means it takes more time for the soil to absorb the heat. Soils with high moisture content also cool down more slowly at night compared to soils with a lower moisture content, which warm up faster during the day and cool down faster at night, if there is no crop cover on the soil.

3. METHODS AND MATERIALS

3.1. Experimental Location

The experiment site was located on the research plots west of the North Dakota State University campus in Fargo, North Dakota 46°52′38″N 96°47′22″W). Fargo is located along the Eastern edge of North Dakota.

Figure 1: Experimental location (Google maps, 2016).

3.2. Experimental Design

The research plots assigned for this study totaled about half an acre. They were located in two separate side by side plots (east and west) with a strip of grass in between. The experiment was a complete randomized design with sub-sampling, with three replications, in a split-split plot arrangement. The east and west plots consisted of four split plots separated by planting dates on April 15th (PD1), May 1st (PD2), May 15th (PD3) and June 1st (PD4). PD1 and PD2 were located in the west plot and PD3 and PD4 were located in the east plot. The split-split plots consisted of three different varieties of sweet corn with different maturity dates of 65, 75 and 84 days, respectively.

In the split-split plots, each variety had three randomly selected plots, for each mulch cover (no mulch, clear plastic, black plastic and biodegradable), equaling twelve individual treatment plots per variety across all planting dates. The individual treatment plots were 3 m by 3.2 m which was enough room for four rows of sweet corn to be planted with 76.2 cm row spacing. The two middle rows of each sweet corn plot were data rows that were installed with the mulch (Figure 2).

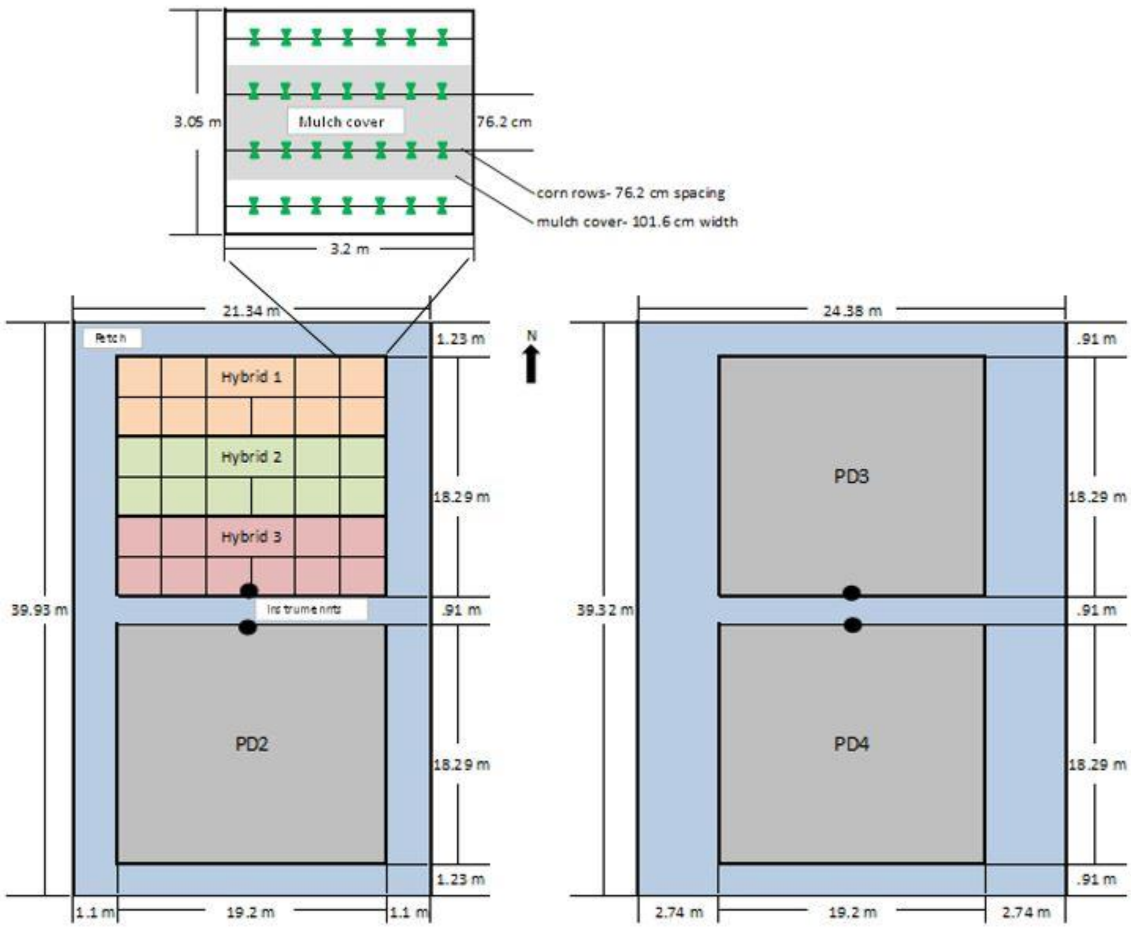

Figure 2: Plot layout and instrumentation location for the 2015 growing season.

3.3. Climate conditions

The experimental site is subjected to a typical semi-humid continental climate with cold winters and warm summers. The growing season in this region ranges from May to September with average monthly temperatures ranging from -13 ˚C in January to 22˚C in July. The highest air temperature usually happens towards the end of July and the lowest temperatures occur in late January. The weather conditions for the 2015 growing season are shown in Table 1 (NDAWN, 2016). The PET is calculated using a modified Penman equation. As shown in the table the total rainfall was 446 mm, of which 200 mm (45%) occurred in May.

Table 1: Monthly maximum (Tmax), minimum (Tmin), average (Tavg), and soil (Tsoil) temperatures, wind speed, solar radiation, total potential evapotranspiration (PET), and rainfall from April to September 2015 in Fargo, North Dakota.

Month	T_{max} (˚C)	T_{min} (˚C)	T_{avg} (˚C)	T_{soil} (˚C)	Wind (m/s)	Solar Radiation (MJ/m^2)	PET (mm)	Rainfall (mm)
April	15.7	0.7	8.2	8.5	4.1	18.2	181	16
May	18.7	6.7	12.7	13.7	3.7	17.7	148	200
June	25.4	13.8	19.6	20.1	2.9	21.1	174	64
July	27.9	16.7	22.3	24.0	3.2	22.8	199	71
Aug	26.6	14.1	20.3	22.3	2.9	19.1	161	54
Sep	24.8	11.8	18.3	19.1	3.0	14.3	137	41
Average /Sum	23.2	10.6	16.9	18.0	3.3	18.9	1001	446

3.4. Soils

According to Web Soil Survey (NRCS, 2016), soils at the experimental site are classified as Fargo Silty Clay with 5-7 percent organic matter. An initial nutrient analysis was performed prior to the 2015 growing season in fall 2014. Nutrient analysis was performed on soil samples from two different depths (0-15 and 15-46 cm). Ten separate samples were also taken from each of the two main plots. As shown in Table 2, a high nutrient difference, NO_3-N values of 115.2

and 77.5 Kg/ha, was found at a 15-46 cm depth between the west and east plots. Therefore, fertilizer applications were calculated differently for the two plots. The seedbed was prepared with a garden cultivator that was 1 to 1.2 m wide and 10 to 12.7 cm deep prior of planting in spring 2015.

Table 2: 2015 major soil nutrients in the experimental plots

	East		West	
	0-15 cm	15-46 cm	0-15 cm	15-46 cm
NO_3-N (kg/ha)	72.4	77.5	82.0	115.2
P (ppm)	45.6	15.4	49.2	34.2
K (ppm)	516	372	524	452
pH	6.72	6.54	6.82	6.7
EC (dS/m)	0.77	0.63	0.79	0.71

3.5. Instrumentation

3.5.1. Soil and Air Temperature Sensors

A total of 128 thermocouples were constructed from type T Duplex insulated thermocouple wire (Omega, Stamford, CT). For each subplot, 32 sensors were constructed, 16 for soil temperatures at 5 cm below the surface under the mulch and 16 for air temperatures at 10 cm in the air above the mulch. The air temperature sensor was housed in a radiation shield made from slotted PVC pipes to prevent direct heating (Figure 3). The shield was wire tight and fixed on a small wood pole. Each variety had one set of air and soil thermocouples randomly assigned to a mulch replicate. In each subplot, one randomly assigned variety had two sets of temperature sensors. The thermocouple wires were all buried and placed along the edges of the plots until they reached the desired plot.

Figure 3: Picture of the air temperature sensor with a radiation shield.

An accessory box containing one multiplexer and one data logger was placed along the edge of each PD (Figure 2). The 16/32 Channel Relay Multiplexer (Campbell Sci., Logan, UT) was used to increase the number of sensors that could be used with the CR1000 data logger (Campbell Sci., Logan, UT). Temperature data was measured and recorded from the time the sensors were installed, usually 1-2 days before planting, until the sweet corn was harvested. The temperature data was collected every 30 seconds but averaged for a 15 minute frequency so only one data point was recorded per 15 minutes.

3.5.2. Plant Canopy Analyzer

Leaf area index (LAI) measurements were taken with a Li-Cor LAI-2200C (LiCor, Lincoln, NE). The measurements were taken once a week at the same time (10 a.m.), under similar cloud conditions to get the most accurate readings. LAI was not taken in the first main plot because frost damage killed all but one or two plants in each data plot.

The sweet corn had a heterogeneous canopy so readings were taken following the manual recommendations. There was one “above canopy” reading taken before each plot followed by four “below canopy” readings. The pattern of the readings followed Figure 4. A 45 degree cap was used on the lenses of the sensor (Li-Cor, 2015).

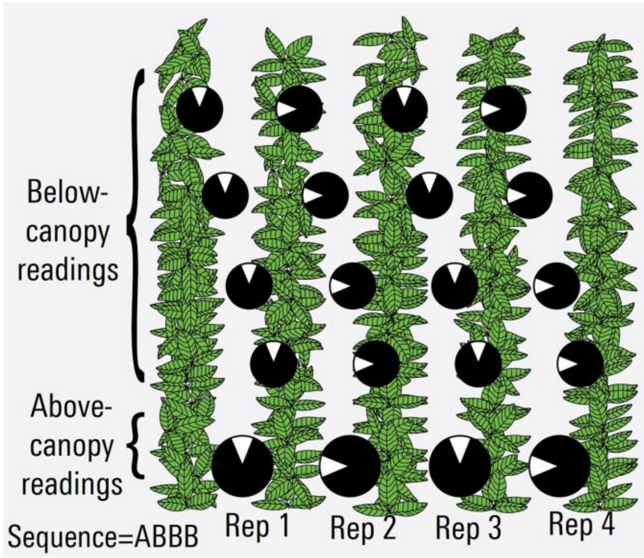

Figure 4: Sequence of leaf area index measurements.

3.5.3. Moisture Content Sensor

A Protimeter moisture meter (GE, Billerico, MA) was used to determine the moisture content of the sweet corn. The meter has two integrated pin electrodes that can measure the grain moisture content. This moisture meter is non-destructive, when used properly it only destroys the two kernels of corn that the pins are inserted. Moisture content was determined for all harvested sweet corn ears. It was also used to determine the correct time to harvest.

3.5.4. Sugar Content Sensor

A Westover hand held BRIX refractometer with automatic temperature compensation (Spectrum Technologies Inc., Plainfield, IL) was used in the lab to determine the sucrose content (sugar content) of the sweet corn on the Brix scale (˚Bx). Each ear of sweet corn that was harvested was rated on a brix scale of 0 to 32. It has been shown in corn that the brix content is an independent trait of the sweet corn variety (Salen, 2002) and an indicator of sweet corn quality.

3.5.5. Radiation Sensors

Two different types of radiometers, the Q7.1-L (Radiation and Energy Balance Systems Inc., Seattle, WA) and the CNR1-L (Campbell Scientific, Logan, UT), were used to measure the thermal properties of the mulches. The CNR1-L measures four components of the energy balance and the Q7.1-L the net radiation. The Q7.1-L measures the net radiation by measuring the voltage, which is proportional to the temperature difference between the top and bottom surfaces of the radiometer. The CNR1-L consists of a pyranometer and pyrgeometer pair that faces upward and a complementary pair that faces downward. The pyranometers and pyrgeometers measure short-wave and far infrared radiation, respectively. The CNR1 also includes a resistance temperature detector (RTD) to measure the radiometer's internal temperature and a heater that can be used to prevent condensation.

The radiometers were set up in PD4, in the 75 day variety, on June 29, 2016 at 10:30 a.m. in a no mulch plot. The goal was to leave them in a plot for one week with clear sky conditions. For the first week of testing, because the weather was cloudy and rainy, the radiometers were left in the plot for more than a week. The radiometers were moved to a biodegradable mulch plot on July 13th. The biodegradable mulch did start degrading during the time when the sensors were in the plot. The sensors were moved again on July 22nd to the clear plastic plot and July 30th to the black plastic plot. Therefore, each mulch cover treatment had at least seven days of radiation measurements.

3.6. Method

3.6.1. Fertilizer

The fertilizer application rate was calculated according to the nitrogen recommendations by the NDSU Extension Soil Service (Franzen, 2010) for sweet corn on a plot by plot basis. The amount of fertilizer needed was calculated separately for the east and west main plots. The fertilizer was calculated based on a yield potential of 22.4 metric tons per hectare. The soil test showed a NO_3N content of 115 kg/ha for the west plot and 77.6 kg/ha for the east plot. Each main plot was 0.051 hectare, which resulted in 4.4 kg of fertilizer for PD1 and PD2 and 6.3 kg of fertilizer for PD3 and PD4. The fertilizer was 32% nitrogen (NO_3-N), 10% available phosphate (P_2O_5) and 10% soluble potash (K_2O). The fertilizer was spread by hand before the mulch was installed in the field before each planting date.

3.6.2. Mulches

Four different mulch covers were used; a black plastic (BP), clear plastic (CP), a clear biodegradable (BM) and the bare soil (NM) as the control. The three mulches were purchased from Dubois Agrinovation (Simcoe, Ontario, Canada). The clear and black plastic mulches were both type Horti-240 with a one year lifespan. The clear and black plastic mulch dimensions were 1.35 X 1219 m (53’’X 4000’) and 1 mm thick. The biodegradable mulch was a Bio-360 brand from the same company. The mulch was made from corn starch and will degrade by biodegradation over time. The biodegradable mulch was a 1.22 X 1524 m (48’’ X 5000’) roll and 0.6 mm thick.

The mulches were installed by hand in the two middle rows of the plot. When the mulch was installed, the edges were covered with soil to prevent the mulch from blowing away by wind. The mulch was installed after the thermocouples were buried and the fertilizer was applied.

3.6.3. Planting

Since the thermocouple wires were buried under the soil, the sweet corn was planted by hand through the mulch with a hand jab planter (Seedburo Equipment Co., Des Plaines, IL). This planter is a simple device that allows the person to plant through the mulch while remaining standing. The device has a wedge shaped bottom that pierces through the mulch. The sweet corn was planted at 2.54 cm depth, 25.4 cm apart with a row spacing of 76.2 cm.

The PD3 and PD4 were not planted on time due to the large amount of rainfall received in May. They were to be planted on May 15th and June 1st, but ended up being planted on June 4th and June 19th, respectively. Fargo received 22 mm of rainfall on May 13-15th, and then an additional 61 mm of rain on May 17th which further delayed the planting. Due to the swelling nature of the clay soils at the experimental site, the team was not able to get into the field for six days, in which no rain was received, from May 19-24th. Fargo then received another 20 mm of rain on May 28th. The team was finally able to get into the field and prepare for planting on June 1st and planted on June 4th for PD3 that was originally supposed to be planted on May 15th. Since the time of planting is a variable, it was decided to wait two weeks to plant the PD4 on June 19th, 15 days after PD3.

3.6.4. Observations

Sweet corn emergence observations were recorded every day until the majority of the plants in the data rows had emerged. Thereafter, growth stage and plant height were recorded twice a week until harvest. Plant height was measured from the ground to the collar of the top leaf and then from the ground to the first leaf below tassel.

Frost damage occurred from May 18-20th, 2015, when temperatures dropped below 0 °C. Over those three days, Fargo also received 13.4 mm of precipitation (NDAWN, 2016). PD1 received the most frost damage because the plants were bigger and the growing point was higher above the ground and less protected by the soil. The sweet corn in PD2 had no lasting effects from the frost, because the plants were significantly smaller than those in PD1 and the growing point was lower near the ground and better protected.

The sweet corn plots experienced damage from jackrabbits and birds. In the PD1, jackrabbits damaged some plants in the border rows. A fence was immediately constructed around all the plots to limit the amount of damage that the jackrabbits could do. A significant amount of damage to the plots was also done by birds. They picked most of the plants in the border rows and some in the no mulch plots, in PD2 and PD3, causing the plots to have a poor plant stand.

3.6.5. Herbicides

Herbicide was sprayed on two separate dates. The first herbicide application was applied on June 11th on the PD1, PD3, and PD4 plots with 73.2 mL/ha of Laudis and 880 mL/ha of Destiny HC. The second herbicide application was applied on July 9th with 290 mL/ha of Status for PD1 and PD2 plots, and a combination of Laudis and Status for PD3 and PD4 plots. However, common mallow (malva neglecta) and Venice mallow (hibiscus trionum) were not killed by the herbicides and started to take over the plots by the middle of the growing season. They were hand pulled several times over the season.

3.6.6. Harvest

Sweet corn is ready to harvest when the moisture content (MC) in the kernels reaches 75%. Harvesting all sweet corn when it reached 75% moisture content is difficult, so it was harvested when in the range of 73-78% MC. Number of top and secondary ears and the height from ground to the base of the first ear was recorded. Six ears of sweet corn were harvested from each data plot. Three ears were harvested from both data rows. A random location was selected and three consecutive ears were harvested. The ears of sweet corn were put in sealable plastic bags and transported to the lab, where they were stored in a refrigerator until they were processed.

Processing in the lab started immediately. Weight (with and without husks), total length, edible length, diameter, number of columns, moisture content, and sugar content measurements were measured for each ear of sweet corn. With six ears harvested from each sub-plot, a total of 864 ears were measured.

3.6.7. Statistical Analysis

Using mulch cover, sweet corn variety and planting date as the main factors, multiple linear regression models were used to analyze the data using RStudio version 0.98.1028 (RStudio Inc., Boston, MA). The mean separation at the 95% family-wise confidence level among treatment means for mulch cover, variety, planting date and their interactions was obtained using the Tukey honest significant difference (HSD) test. The effects and differences are considered significant for p-values less than or equal to 0.05. For the Formed length, sugar content and weight without husks an ANOVA table was completed. The least significant difference (LSD) test was used to find the mean separation among the treatment means for variety, mulch cover and PD.

4. RESULTS AND DISCUSSION

4.1. Emergence

Sweet corn emergence is calculated as the time in days from planting to when the majority (80%) of the plants in the plots have emerged. The results showed that the emergence as days after planting (DAP) was shorter for PD2 (16.2 DAP), PD3 (6.7 DAP), PD4 (6.4 DAP) when compared to PD1 (17.5 DAP), with a very small time difference between the PD3 and PD4.

For the difference in emergence between the different mulch covers, the CP (10.6 DAP) had the shortest DAP, followed by BM (10.7 DAP), BP (12.3 DAP), and finally the NM (13.2 DAP). The measured emergence results were not surprising, the clear and biodegradable mulches increased the soil temperature the most, and therefore, shortened the time for the sweet corn to germinate. When comparing the three varieties, the DAP for the 75 day variety (10.6 DAP) is the shortest, followed by 65 (12.2 DAP) and then 84 day (12.3 DAP) varieties. The different DAPs for the three varieties were probably due to its genetic characteristics, but also showed that the 75 day variety responded better to the warm temperature of the mulches during the germination period, than the other two varieties. PD1 was planted on April 15 when the temperature was low, therefore, in general, a longer DAP was needed for the sweet corn to germinate, comparing to the rest of the PDs. When planted later, the temperature was warmer, so the cover had less effect on germination, as observed in this study. This leads us to conclude that increased emergence rates due to mulch cover will occur when a higher temperature increase occurs during the colder time period. A certain GDD needs to be reached in order for the sweet corn to germinate, while mulches alter the soil temperature and sequentially, the GDD for germination.

4.2. Plant Height

Plant height was analyzed separately by mulch cover and planting date. Figure 5 shows the sweet corn height for the four PDs under different covers averaged for each variety. In PD1, there was no statistical difference in height among the different mulch covers, though theoretically the higher difference was expected because sweet corn was planted the earliest or at the coldest time in the season. This result was likely caused by the frost damage on May 19-23, 2015 that stunted the growth of most of the plants in PD1. For the other three planting dates, the sweet corn height showed a similar increasing trend. Sweet corn with no mulch was significantly shorter than those with covers, with the BM sweet corn the second shortest, and the tallest sweet corn was under the BP and CP covers. Sweet corn in PD3 had the biggest difference between the mulches and NM plots. This could be due to a number of factors including better growing conditions under the mulch to facilitate faster growth.

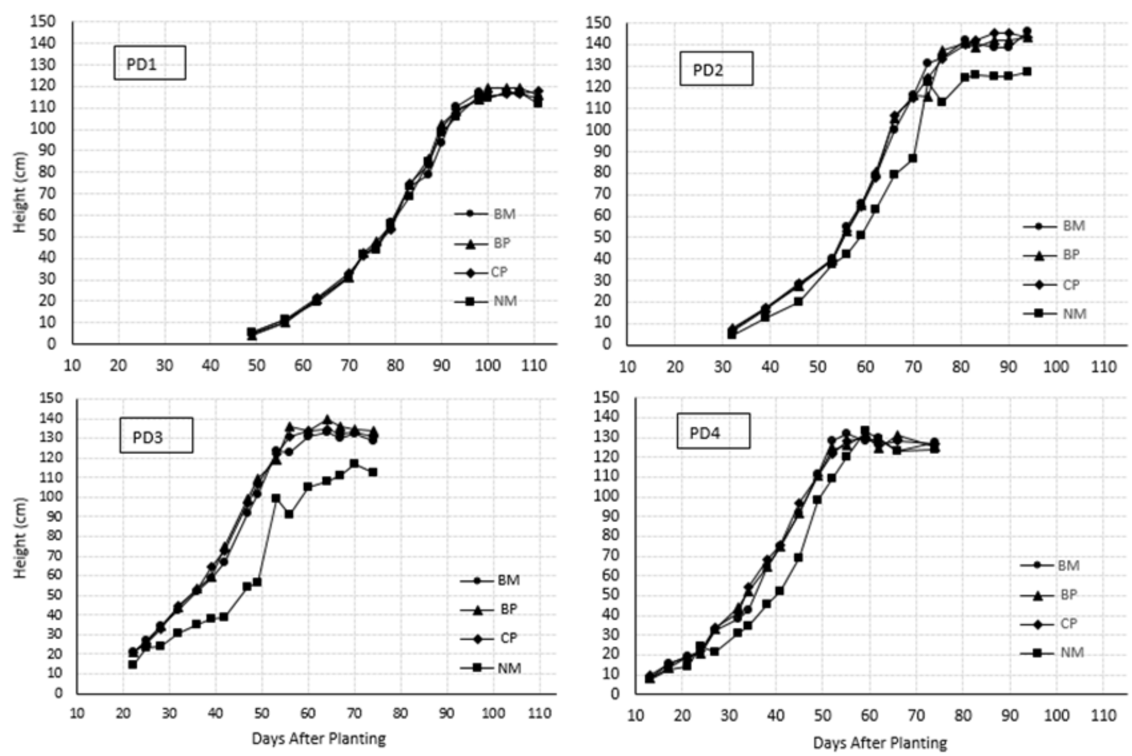

Figure 5: Sweet corn height under clear plastic mulch (CP), black plastic mulch (BP), biodegradable mulch (BM), and no mulch (NM) for four different planting dates.

Within each PD, the sweet corn height showed a significant difference among different varieties. For PD1 and PD2, the 65 day variety was statistically shorter than the 75 and 84 day varieties at P = 0.05 level. For PD3 and PD4, the 65 day variety is shorter than the other two varieties, but not statistically different at P=0.05 level. This implied that the 65 day variety grew shorter and has less vegetative growth during the early stages due to temperature differences than the other two varieties. The 75 and 84 day varieties, however, showed similar height for all PDs, which implied that the vegetative growth for the two varieties are about the same, and the difference in maturity would be in the late season between the two varieties. From here, we can conclude the mulch cover that induced a higher soil temperature would have a higher impact on the 65 day variety than that on the 75 and 84 day varieties.

4.3. Soil Temperature under Mulch Covers

The mean soil temperatures at 5 cm below the soil surface under different mulch covers over the four different planting dates are shown in Figure 6, in separate box plots. For PD1, PD2 and PD4, CP has the highest temperatures (20.7, 21.8, 25.3˚C, respectively) followed by the BP (19.7, 20.9, 24.3˚C), BM (19.3, 20.7, 23.9˚C) and finally NM (18.6, 20.1, 23.4˚C). For PD3, the order of the mean temperature is different, the temperature for BM (22.2 ˚C) is higher than BP (22.1 ˚C) and CP (22.0 ˚C), while NM (21.7 ˚C) has significantly lower temperatures than the mulch covers. The differences between the mulch covers in PD3 could be caused by human error when installing the temperature sensors. However, a higher standard deviation was seen for the first three PDs, probably because the soil temperature changed significantly throughout the growing season.

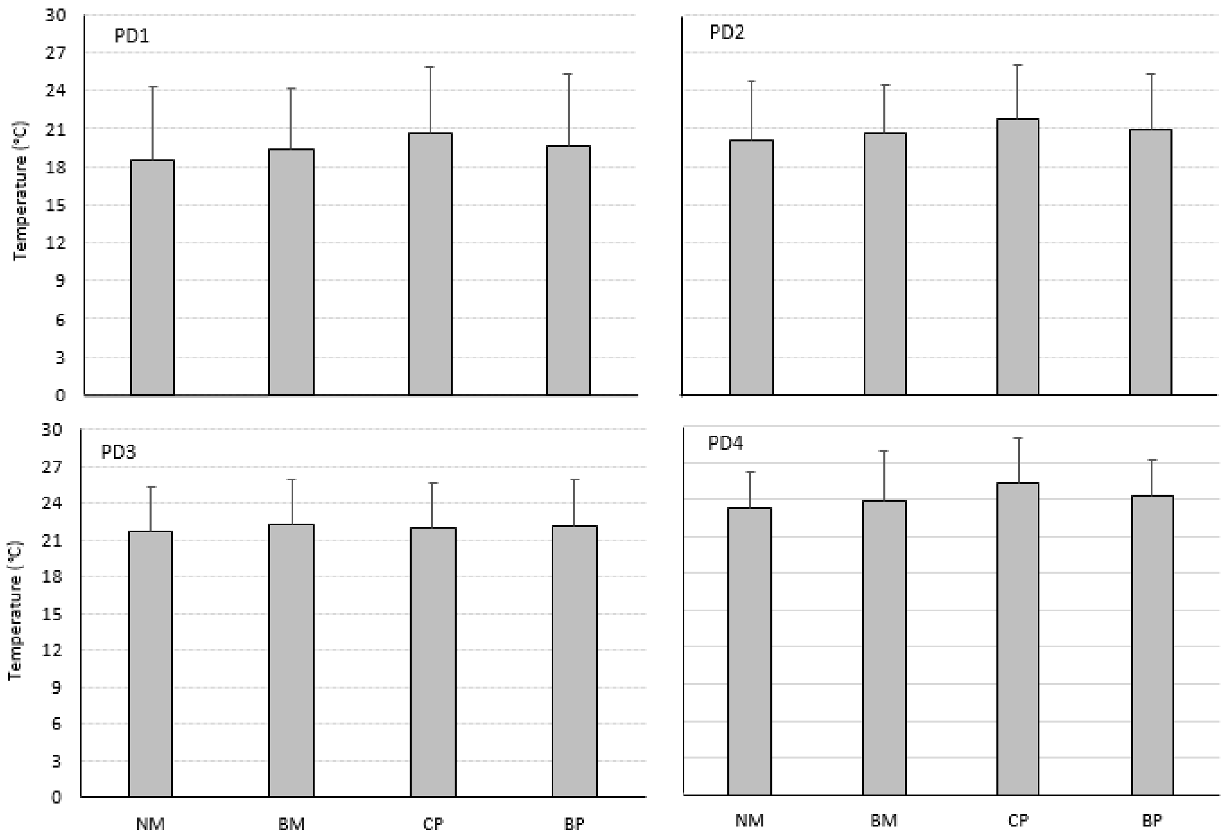

Figure 6: Mean daily soil temperature under clear plastic mulch (CP), black plastic mulch (BP), biodegradable mulch (BM), and no mulch (NM) for planting dates on April 15 (PD1), May 1 (PD2), June 4 (PD3) and June 19 (PD4).

Figure 7 shows the 30 minute soil temperature variations for the first two months of PD1 that was planted on April 15th, 2015. It was expected that the PD1 should have the greatest temperature difference between the mulches and NM due to its earlier planting date. Therefore, PD1 was chosen as an example to demonstrate the temperature difference due to mulches. As seen in the figure, CP had the greatest temperature difference compared to the NM: followed by BM and then BP. BP had the lowest soil temperature increase since the non-transparent black mulch blocked most of the incoming radiation and resulted in no direct heating and temperature increase. CP yielded the highest soil temperature because it allowed the energy to be absorbed into the ground and caused the soil temperature to increase. During the first two months, the soil temperature did not go below freezing and was always above 0˚C. However, the air temperature went below 0 ˚C from May 18 to 20th, 2015, and caused frost damage to the sweet corn plants planted on April 15th, 2015. This indicates that soil temperature increase led to better growth, but put the bigger plants into a more vulnerable situation for above ground freeze damage.

The diurnal soil and air temperature changes on May 2nd for PD1 are shown in Figure 8. The different mulches caused no difference on air temperatures, but a higher soil temperature difference. The CP cover resulted in the highest soil temperature, followed by BM, BP and finally NM. During the 24 hour period, the highest soil temperature was 25.1 ˚C in the CP plot at about 7:00 p.m., while at the same time; the soil temperature in the NM plot was only 20.5 ˚C. It was interesting to see that there was a five hour time difference between the highest air temperature and the highest soil temperature, while there was a 3 hour time lag between the lowest air temperature and the lowest soil temperature. This lag is caused by numerous things including the soil type, moisture and the type of soil cover. A minimal temperature difference of 1.0 °C happened at 8 a.m. between BP and NM, while the highest temperature difference 8.6 °C happened at 5 p.m. between CP and NM.

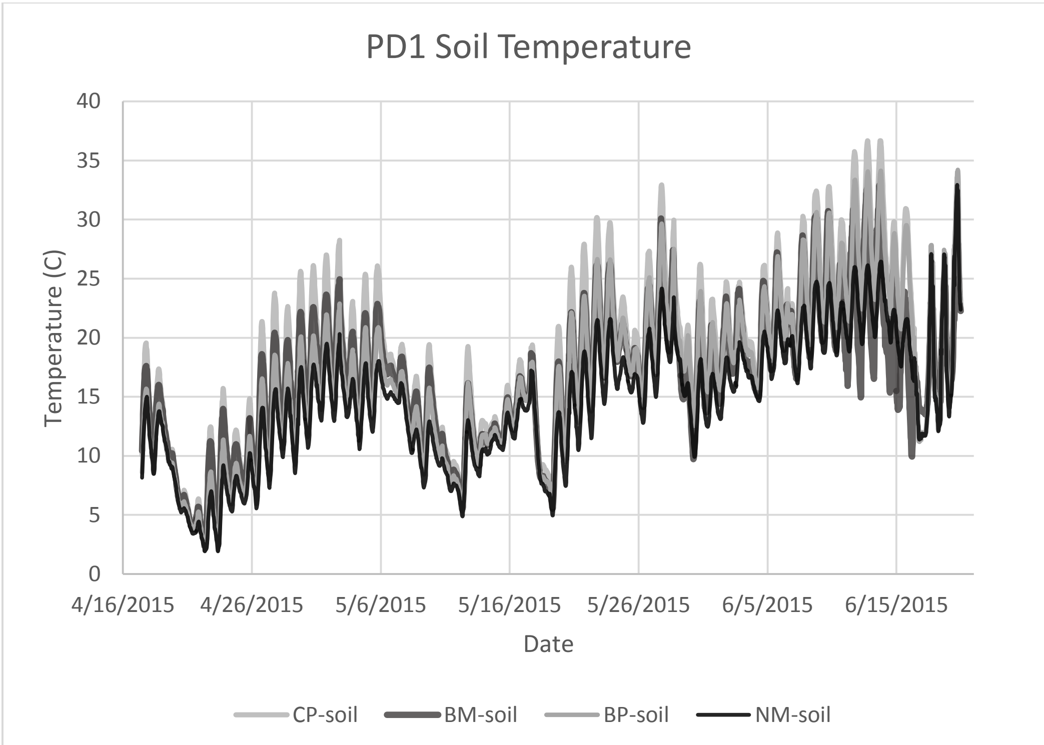

Figure 7: 30-minute soil temperature for PD1 for April 16 to June 15, 2015 for the four different mulch covers (CP = Clear Plastic, BM = Biodegradable, BP = Black Plastic and NM = No Mulch).

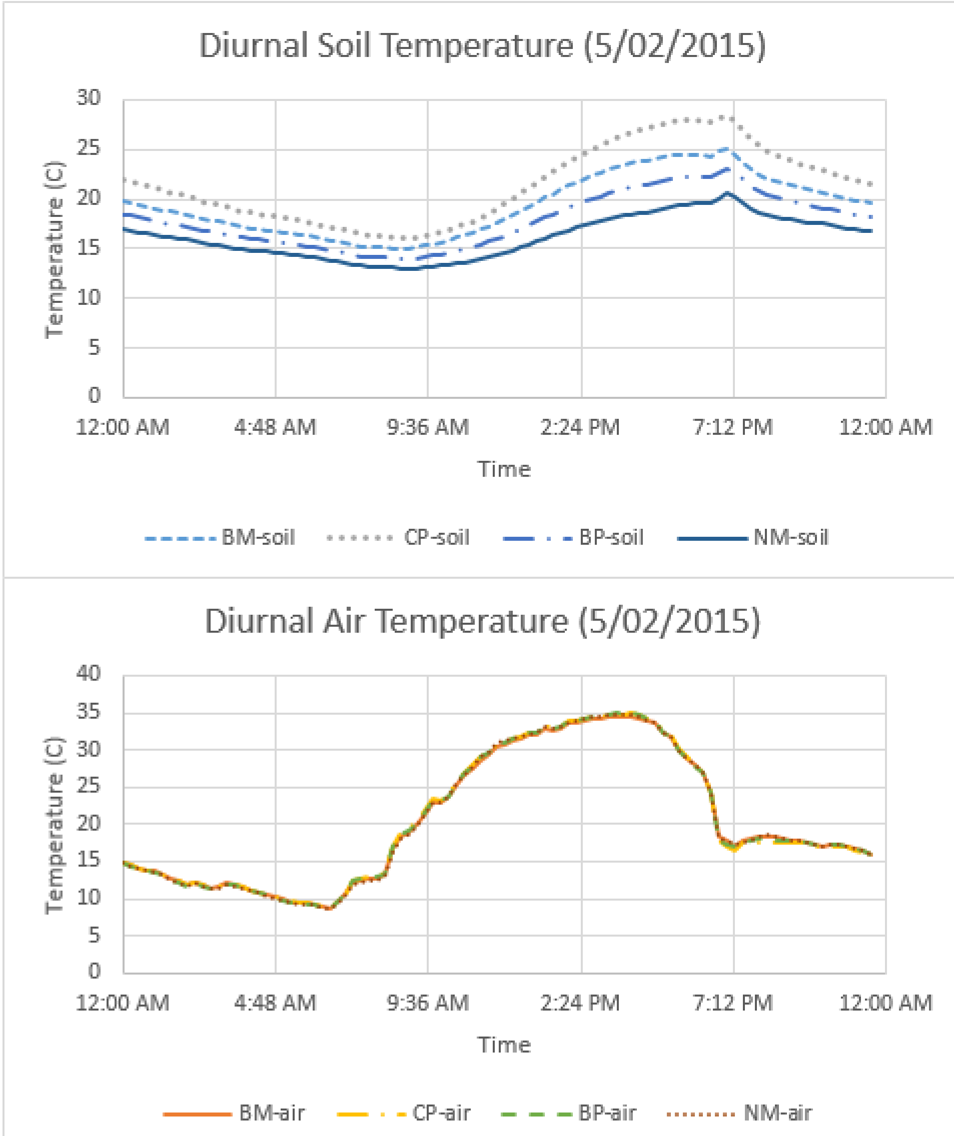

Figure 8: Diurnal soil (5 cm below surface) and air (10 cm above soil surface) temperature on May 2nd, 2015 for planting date 1 for the four different mulch covers (CP = Clear Plastic, BM = Biodegradable, BP = Black Plastic and NM = No Mulch).

4.4. Growing Degree Days

The GDDs were calculated using the soil temperature instead of air temperature in order to show the effects due to mulches. For PD1, the GDD's from germination on May 2nd to harvest on August 4-11th, 2015 are; NM = 1151 ˚C, BP = 1497 ˚C, CP = 1397 ˚C and BM = 1285 ˚C. The sweet corn planted in PD1 had frost damage that killed most of the plants with mulches. During the beginning of the growing season for PD1, CP had the higher GDD. But around June

13th, 2015, the GDD for the BP mulch was higher than the CP because of the minimum and maximum daily temperatures. The daily maximum temperature for the CP and BP mulch reached the upper limit (30°C) for corn growth from July 1st to harvest (August 25th), and the daily minimum temperature for BP was higher than the temperature for CP. This caused the daily average temperature for BP to be higher than the average temperature for CP, which resulted in a higher GDD for BP. As the summer progressed, the difference in the GDD's between the mulches and NM gets smaller, probably due to the canopy cover of the rows reduced the direct sunlight on the ground. For example, in PD3, the GDD's for the mulches are; NM = 1239 ˚C, BP = 1243 ˚C, CP = 1270 ˚C and BM = 1277 ˚C. This shows that mulches have a greater effect when they were installed earlier in the season. If they were installed later in the season, the GDD was affected minimally by the mulches since the temperature was higher, and an even higher temperature due to mulches would not yield more GDD's toward sweet corn growth.

As seen in Table 3 the GGD's for PD2 and PD3 are greater than the GGD's in PD1, but due to the short growing season in PD4 some of the mulch covers have shorter GGD's than the other PD's. The GGD's for air temperature is included as a reference. The GGD's for the air temperature was taken at 2 m height from the NDAWN station.

Table 3: The GGD's for PD's 1, 2, 3 and 4 for the four mulch covers (NM= no mulch, BP = black plastic, BM= biodegradable and CP= clear plastic) and for the air temperature.

˚C	PD1	PD2	PD3	PD4
NM	1151	1398	1239	1186
BP	1497	1331	1243	1262
BM	1285	1304	1277	1195
CP	1397	1424	1270	1313
Air	1012	1080	1131	979

4.5. Leaf Area Index

LAI measurements were taken in PD's 2, 3, and 4, while in PD1, no LAI measurement was taken because few plants in the mulched rows survived due to frost damage. The LAI results showed that although the LAI with different mulch covers were not significantly different from each other, they were significantly different from the NM covers. The average LAI for the mulch covers across all PD's is 2.7 for BM, 2.8 for BP, 2.9 for CP and 1.4 for NM, respectively. At the silking (R1) growth stage, the highest LAI (4.29) was found in PD2 in the BP plot. This means a higher yield for BP in PD2 should be expected.

A reason the LAI measurements in the NM plots were low, was due to some of the plots having poor plant stands because of bird or frost damage. For the 68 DAP in PD4, measurements were only taken in one repetition for three mulch conditions (BP, CP and NM) because of wind damage from a storm that occurred on August 22, 2015.

Table 4: Average Leaf Area Index (LAI) for four different mulch conditions (Biodegradable= BM, Black Plastic = BP, Clear Plastic = CP, No Mulch = NM) on three planting dates (PD2 = May 1, PD3 = June 3, PD4 = June 1).

			PD2			
DAP	60	70	75	82	90	
BM	2.3	3.7	3.7	3.0	2.5	
BP	2.3	3.4	4.3	3.1	2.8	
CP	2.3	3.6	4.2	3.1	3.1	
NM	1.4	1.7	1.4	1.2	0.9	
			PD3			
DAP	35	40	47	55	61	67
BM	1.9	2.3	1.8	2.3	2.6	3.0
BP	1.2	1.3	2.2	2.4	2.8	4.1
CP	1.5	3.8	1.9	2.2	2.4	3.5
NM	0.9	0.0	0.8	1.1	1.3	1.8
			PD4			
DAP	40	46	52	61	68	
BM	1.8	2.2	3.6	3.0	3.3	
BP	1.4	2.3	2.4	3.9	3.9	
CP	1.7	2.2	3.3	3.0	3.9	
NM	0.5	1.0	1.6	1.9	3.9	

4.6. Albedo

The albedo of the soil can vary (0.1-0.4) depending on the soil's basic color, moisture content and smoothness. The dryer and smoother the soil, the higher its albedo will be (Hillel, 1998). The soil in Fargo, ND is a darker color. It was also impacted by rainy conditions throughout the period the sensors were in the NM plot, which is part of the reason the albedo is low. In this study, the albedo values were calculated from the seven day measurement in each plot by excluding values when the net radiation was below 0 W/m^2. The albedo for NM, BM, CP and BP was 0.086, 0.123, 0.101 and 0.136, respectively. The CP and NM values were found to be similar to what Ham (1993) found. However, the study did not use white biodegradable mulch and the BP mulch results were different. The average albedo for the black plastic should be lower than that of the clear plastic. The reason that the average albedo in the BP is higher could be due to the vigorous corn growth that may have affected the readings. When the sensors were moved to that plot, the sweet corn was 76.2 cm tall and grew 25.4 cm within the 12 days.

4.7. Harvest Data

Table 5: ANOVA table for the formed length and sugar content across all four planting dates (April 15th, May 1st, June 4th and June 19th).

Source	DF	Formed Length	Sugar Content
PD	3	*	**
Error a	6		
Mulch (M)	3	**	**
PD*M	9	NS	*
Error b	24		
Variety (V)	2	**	*
PD*V	6	**	**
M*V	6	NS	NS
PD*M*V	18	*	*
Error c	64		

* significant at $P<0.05$ ** significant at $P<0.01$

4.7.1. Formed Length

The final formed length for sweet corn is one of the most important factors for the evaluation of the sweet corn quality. A longer length is preferred, but a minimal length is expected for each sweet corn ear in order to have a marketable value.

When compared to the formed length of 15.9 cm for the NM cover, all other covers are significantly longer, with 18.2, 19.1, and 19.2 cm formed length for BM, BP, and CP, respectively. Varieties also have a significant impact on the formed length, comparing the formed length of 18.9 cm for the 84 day variety, the 75 day variety has a mean length of 16.3 cm, which is significantly shorter than the other two varieties, while the 65 day variety has a formed length 19.0 cm and is similar to the 84 day variety sweet corn.

The formed length for different PDs showed that a late PD resulted in a longer sweet corn, with 17.3, 18.3, 18.3, and 18.4 cm formed length for PD1, PD2, PD3 and PD4, respectively. Using the least significant difference (LSD) test there are no significant differences between planting dates (2, 3, 4), and no significant differences between the 65 and 84 day and no significant difference between CP and BP. Only the NM cover has significant differences with other covers. The longer formed length with any of the covers showed that mulch had a positive impact on sweet corn market value. A higher standard deviation is expected in PD1 because of the frost damage and in the NM cover because of damage from birds and rabbits.

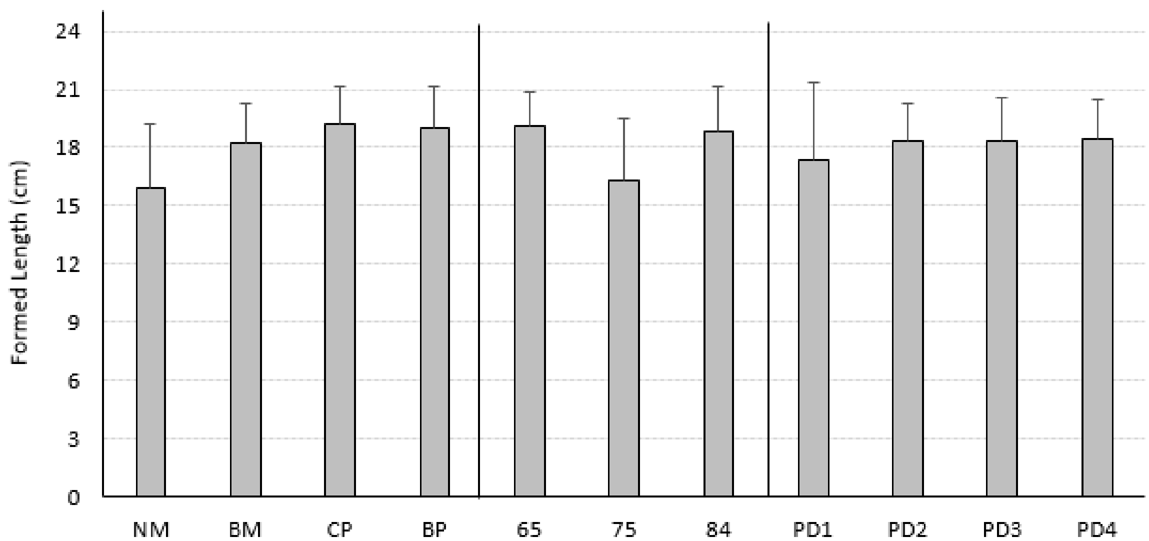

Figure 9: Sweet corn formed length for no mulch (NM), biodegradable mulch (BM), clear plastic (CP), black plastic (BP), the three sweet corn varieties (65, 75 and 84 day), and the four planting dates April 15 (PD1), May 1 (PD2), June 4 (PD3) and June 19 (PD4) in 2015.

4.7.2. Sugar Content

Sugar content is another important parameter that determines sweet corn quality. A sweet corn with proper sugar content will taste better than the one with too high or too low sugar content. Figure 10 shows the distribution of sugar content among varieties, planting dates, and mulch covers. The results showed that across all PD's, the variety had a significant effect on sugar content with the 65 day variety being the sweetest at 25.1 ˚Bx. During a Field Day held in August 2015, a taste test by attendees found the 65-day variety to be the least sweet of the three varieties, because the 65 day sweet corn was overripe on that day and passed the sweetest moment when harvested. All of the mulch covers had a significant effect when compared to the NM cover. When averaged across all PD's, CP was the sweetest with a 25.8 ˚Bx. The average sugar content of PD2 (24.5 ˚Bx), PD3 (25.7 ˚Bx) and PD4 (25.4 ˚Bx), all had a significant effect when compared to PD1 (23.2 ˚Bx). The frost event that occurred early in the growing season is what caused PD1 to have the lowest sugar content. That event also caused PD1 to have the largest variations in measurements.

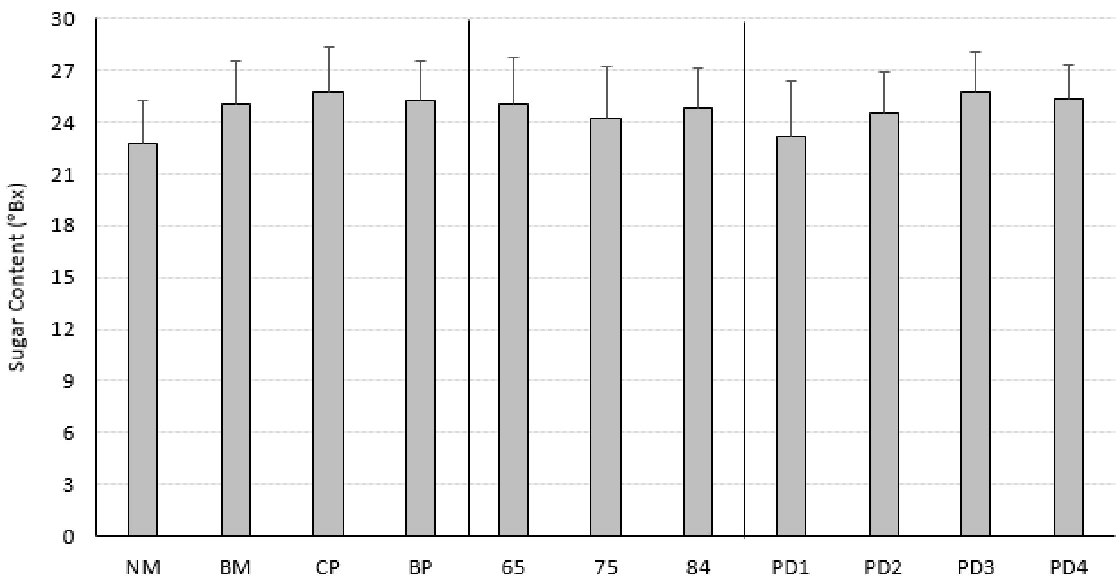

Figure 10: Sweet corn sugar content for no mulch (NM), biodegradable mulch (BM), clear plastic (CP), black plastic (BP), the three sweet corn varieties (65, 75 and 84 day), and the four planting dates April 15 (PD1), May 1 (PD2), June 4 (PD3) and June 19 (PD4) in 2015.

4.7.3. Weight of the Cob Without Husks

Table 6: ANOVA table for the weight without husks for the four PD's (PD1 =April 15th, PD2 = May 1st, PD3 = June 4th and PD4 = June 19th).

	DF	PD1	PD2	PD3	PD4
Mulch(M)	3	**	**	**	*
Error a	6				
Variety(V)	2	**	**	NS	*
M*V	6	*	*	NS	NS
Error b	16				

* significant at P<0.05 ** significant at P<0.01

The larger and heavier an ear of sweet corn is, the more desirable it is to the consumer. By planting date, PD4 had the highest weight per ear (307.8 g) followed by PD3 (287.6 g), PD2 (273.5 g) and finally PD1 (252.4 g). Since the variation in the weight without husks is big, the four different PDs were analyzed separately. The order of the weight for the different mulches across all PD's is; CP is the highest, followed by BP, BM and NM. According to the LSD test, NM has significant difference with other three mulches, and BP and CP are similar. In early seasons, PD1 and PD2 and 84 day variety has the highest weight, followed by 65 and 75 day varieties. However, during PD3 and PD4, the 75 day variety has the highest weight, followed by 84 day variety and 65 day variety, and 75 and 85 varieties have no significant difference. The influence of PDs is also showed by these results.

The results are what were expected. The weight of the cob increases with a longer maturity variety, a later planting date and the CP mulch. The reason the CP mulch increases the weight is likely due to the fact that the mulch shortens the emergence time and increases the GDDs which gives the sweet corn plant more time to grow and develop than the other mulch covers.

4.7.4. Fresh Yield

For fresh yield, the total length of the cob had to be 20 cm with an edible/formed length of at least 10 cm (Kwabiah, 2004). Fresh sweet corn yield was determined by multiplying the number of harvestable ears in the plot by the ratio of ears harvested that met the criteria above. That number was then converted to dozens per hectare. As seen in Figure 11, for PD2, PD3, and PD4, the fresh yield was higher when the sweet corn was grown over a mulch cover than that over bare soil. In PD1, the results were reversed, the yield was higher for sweet corn grown over no mulch than that over a mulch cover. This result is soley due to the frost damage that affected PD1 early in the growing season. The frost killed most of the sweet corn planted over the mulch because they were at a higher growth stage than the plants in the NM plots.

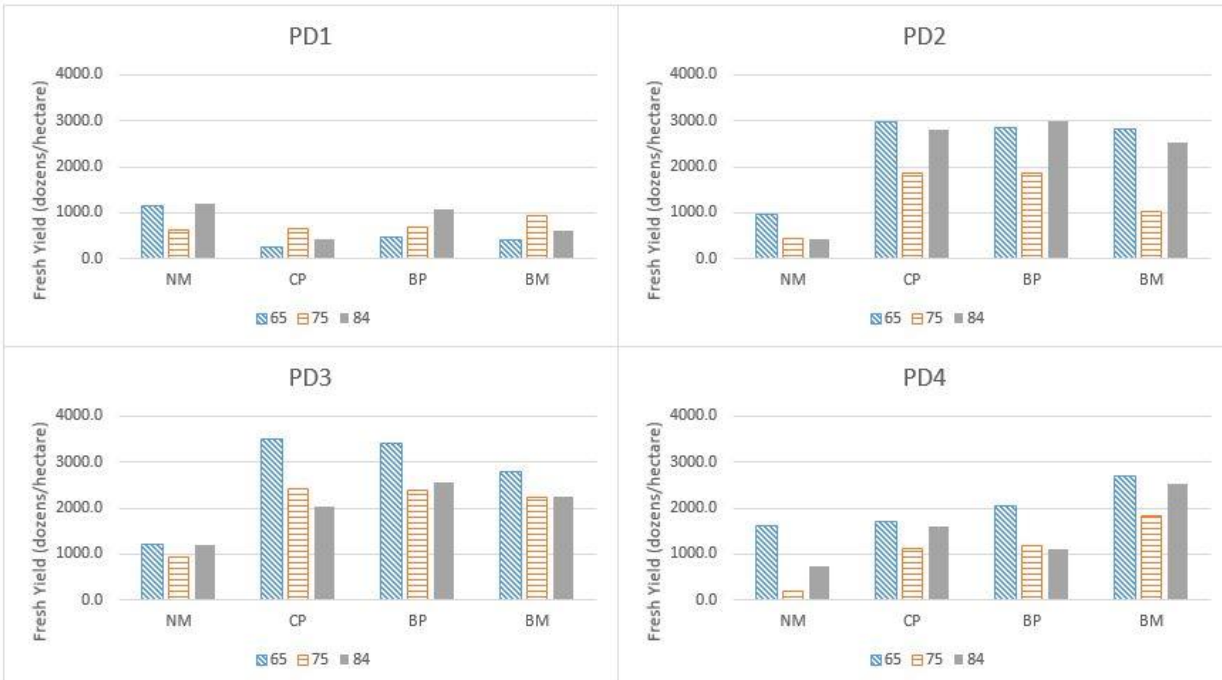

Figure 11: Sweet corn fresh yield for each planting date based on variety (65, 75, and 84 day maturity) and type of mulch covers.

There is almost a 100% difference between the 65 and 75 day varieties, which was caused by the bird damage that occurred to the NM plots as observed in the field. The birds picked most the seeds/seedlings out of the NM plots. When comparing the difference in the mulch covers, there was no difference in the 65 and 75 varieties. The 84 variety shows some difference between the BP and CP and the BM and CP. This suggests that given more time a bigger difference in the yield due to the mulch effect would occur.

The differences in yield between the mulch covers and varieties and the standard deviation for the yield can be seen in Table 7. The 65 day variety had the highest yield followed by the 84 day and then the 75 day variety. In theory, the 65 day variety should have the lowest yield because of its shorter maturity time. However, with the use of mulches, the shortest maturity variety had the highest yield compared to the other two later maturity varieties. This implies that a mulch cover has a larger impact to an early season variety than a later variety. This finding is similar to what Jia et al. (2014) reported that mulch has a higher impact on yield for a short season corn than that of a late season corn.

Table 7: Fresh sweet corn yield in dozens/hectare and standard deviation (STDEV) by planting dates for the three varieties (65, 75, and 84) and the four different mulch conditions (Biodegradable= BM, Black Plastic = BP, Clear Plastic = CP, No Mulch = NM).

Fresh Yield by planting date (doz/ha)						
		PD1			PD2	
variety	65	75	84	65	75	84
NM	1140.2	627.9	1196	956.8	448.5	428.6
CP	239.2	647.8	418.6	2990	1853.8	2810.6
BP	458.5	677.7	1056.5	2860.4	1853.8	2990
BM	418.6	926.9	598	2810.6	1016.6	2531.5
		PD3			PD4	
variety	65	75	84	65	75	84
NM	1196	936.9	1196	1604.6	179.4	737.5
CP	3508.3	2411.9	2043.2	1694.3	1116.3	1584.7
BP	3408.6	2382	2571.4	2053.1	1186	1096.3
BM	2800.6	2222.6	2242.5	2691	1833.9	2521.6
STDEV by planting date						
		PD1			PD2	
variety	65	75	84	65	75	84
NM	266.2	136.4	430.2	110.9	110.9	105.7
CP	41.9	144.4	83.8	160.1	297.4	182.7
BP	109.1	73.9	119.4	145.4	297.4	83.8
BM	83.8	151.1	110.9	83.8	182.7	60.9
		PD3			PD4	
variety	65	75	84	65	75	84
NM	211	261	48.4	290.5	41.9	85
CP	232.5	416.6	279.2	124.2	111.8	479.3
BP	217.8	174.6	233.4	171.7	366.3	139.7
BM	254.5	559.8	181.5	192.1	312.1	185.2

5. OBSERVATIONS

Soil temperatures early in the growing season are important for crop emergence and development. The sweet corn emergence time was shortened by about 2.6 days with clear plastic and biodegradable mulch compared to the no mulch plots. Using mulches in ND can increase the growing seasons mean soil temperature by 2.3 °C between the no mulch and clear plastic mulch. In the early spring, soil temperatures under the clear plastic mulch can increase by 5 °C, under the biodegradable mulch by 3.4 °C while the black plastic only increases the soil temperature by 1.1 °C. This occurred in PD1 on April 17, 2015, three days after planting. The temperature differences between the mulches and bare soil decreases as the days get warmer.

The 75-day variety and no mulch had the shortest sweet corn cob, while the 84 day variety had the sweetest sweet corn and no mulch resulted in the lowest sugar content than others. When comparing the fresh yield, sweet corn under all mulch covers showed a significant higher yield for all varieties, though the 75 and 84 day varieties had doubled the yield between the mulched and no mulched sweet corn. This is a promising result that mulches can significantly increase sweet corn yield regardless varieties and planting dates.

Using mulches to increase the growing season has many benefits but it can also face challenges. If a frost event occurs, as it did for PD1 (April 15), there is a possibility that the plants over the mulch cover will be killed, which has happened in PD1. The sweet corn planted over the mulch covers in PD1 was farther along than the sweet corn in the no mulch plots. As a result, the frost killed most of the plants planted over the mulch covers while most of the plants in the no mulch cover plots survived. Therefore, a proper planting date that is two weeks before a normal planting date is better than the April 15^{th} planting date; it is too early in the season.

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