GROWTH, YIELD AND QUALITY OF TRANSPLANTED BABY CORN (*Zea mays* L.) UNDER VARYING AGRONOMIC CONDITIONS IN MERU COUNTY-KENYA

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Declaration

This thesis is my original work and has not been presented for a degree in any other institution.

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Table of Contents

List of Tables

List of Figures

Acronyms and Abbreviations

CRD	complete randomized block
GDD	growing degree day
SAS	Statistical Analysis Software
VS	vegetative stage
WUE	water use efficiency
RZT	Root zone temperature
pmoVml	PicomolesVolume per mililiter
IARI	Indian Agricultursl research Institute
FC	Field Condition
TH	Thai Gold
FYM	Farm yard manure
EAT	East Africa Time
TSP	Triple super phosphate
MAP	MonoAmmonium phosphate

Abstract

Corn (*Zea mays* L.) is one of the most significant cereal crops worldwide. Babycorn is currently farmed in Kenya mostly for export markets, with a very limited quantity being grown for local use, mostly in urban areas. Insufficient evidence-based research prevents baby corn, which is a relatively new crop, from being transplanted at a large scale. Two experimental studies were conducted to establish the performance of transplanted baby corn under varying growth conditions in Meru County. The first experiment was to determine the best baby corn transplanting stage under farmer conditions (Field and Greenhouse conditions). The experiment was setup in a split plot randomized complete block design (RCBD) with three replications. Two baby corn varieties (PAN 14 and Thai Gold) were grown under 4 transplanting stages (0,200, 300 and 400 Growing degree days (GDD)) under green house and field conditions. To determine interaction between different treatments (plastic mulch colours and phased transplanting stages) on the performance of baby corn plant varieties a field experiment was setup in a split-split plot RCBD design with three replications. PAN 14 and Thai Gold were transplanted at four transplanting stages (0,200, 300 and 400 GDD) under four different plastic mulch colour (yellow, clear, black and control). Data was collected on growth (maturity GDD and flowering height) and yield parameters (cob length, diameter and weight). Collected data were analyzed using SAS 2007, and means were separated by LSD test ($P \leq 0.05$). There were statistically significant interactions ($P \leq 0.05$) observed between the transplanting stage and baby corn varieties and mulch colour on maturity GDD, flowering height under various growing conditions. There were no significant interactions ($P > 0.05$) among plastic mulch colour, transplanting stages, and varieties on cob length, cob diameter, and cob weight. However, significant interactions were found between plastic mulch colour and baby corn varieties on cob length and cob weight. Transplanting baby corn at 200 GDD resulted in significantly($P \leq 0.05$) higher growth and yield performance. Additionally, PAN 14 variety exhibited greater resilience to dynamic growth conditions compared to Thai Gold, suggesting its suitability for field conditions. Black plastic mulches showed significantly ($P \leq 0.05$) higher soil temperatures, followed by transparent films, yellow films and non-mulched. Transparent plastic mulches showed the best yield and vegetative growth for both varieties but could not effectively control weeds. Black plastic mulches produced significantly ($P \leq 0.05$) higher yield and vegetative performance than non-mulched, but were lower than the transparent film performance. Additionally, black plastic mulches showed better performance. The temperature differences between the mulch treatments were attributed to variations in solar energy reflection, absorption, and transmission. The choice of plastic mulch colour, transplanting stages, and varieties had significant effects($P \leq 0.05$) on factors such as maturity height, maturity days, and soil GDD. Yellow plastic mulch had the longest maturity period, while the control had the longest maturity period in all transplanting stages. The study recommends that transplanting baby corn at 200 GDD under black mulch leads to the best growth performance, while transplanting PAN 14 baby corn variety at 200 GDD under transparent mulch was the best in cob yields in both green house and field conditions.

CHAPTER 1: INTRODUCTION

1.1 Study Background

Maize (*Zea mays* L.*)*, also commonly known as corn is a member of the Poaceae family. It is the third most important cereal crop in the world after wheat and rice (Awata et al., 2019). Maize was first domesticated more than 9,000 years ago in southern Mexico/Meso America (Awika, 2011; Kennett et al., 2020). Maize holds the top position as the world's most produced staple cereal, surpassing 1 billion metric tons annually (García-Lara & Serna-Saldivar, 2019). However, its success can be attributed to its status as a C4 plant, which gives it a high photosynthetic efficiency and allows it to thrive in diverse environments, ranging from tropical to temperate zones (Awika, 2011).

In terms of water usage, maize demonstrates favorable characteristics, requiring an estimated 1222 litres of water per kilogram of product, which compares well to other major cereal crops (Mekonnen & Gerbens-Leenes, 2020). Maize has the highest capacity when considering the overall production of locations of the different cereal facilities (Awata et al., 2019). In sub-Saharan Africa, corn is the most significant cereal crop. It is an essential staple food for the estimated 50% of the population (Seck et al., 2012). Maize is a crucial source of protein, iron, vitamin B, and minerals (including magnesium, phosphorus, and potassium) in terms of nutrition (Rouf et al., 2016; Saritha et al., 2020).

Maize offers a range of options due to its different types, which encompass a variety of colours such as yellow, white, and blue, as well as various attributes like dent/flint, sweet corn, baby corn, popcorn, waxy maize, high-amylose maize, high-oil maize, and quality protein maize (Serna-Saldivar & Perez Carrillo, 2019). It has been produced for hundreds of years as a grain crop and more recently as a vegetable crop, including baby corn and candy maize. An intriguing aspect in maize production has been the development of the crop for vegetable usage. This "baby corn" kind of maize has primarily been used in horticulture fields (Gayatonde, 2016).

Fresh baby corn has a flavor that is hardly sweet and a crisp texture. It is a native delicacy that may be eaten raw or utilized in many other dishes (Hooda & Kawatra, 2013). Asia is the region that produces the most baby corn, despite the fact that Europe and America consumes it the most while the bi-products are used as animal feeds (Singh et al., 2019).

Baby corn is a young, clean maize ear with a finger period that has been harvested within two or three days of the silk emergence but before fertilization (Singh et al., 2020; Hooda& Kawatra, 2013; Singh et al., 2010). A vegetable crop called Baby corn might undoubtedly help farmers' financial standing (Malhotra, 2017). It is used to prepare various traditional and intercontinental dishes, besides being canned. Baby corn is also referred by other authors as an immature, unfertilized ears which is widely used by horticultural farmers around the world (Gayatonde, 2016; Ranjan& Sow, 2021). After seeding, Baby corn plants begins the reproductive phase within 45–55 days and finishes the cycle in 60–70 days (Akinnuoye-Adelabu & Modi, 2017; Kumar & Bohra, 2014). The ears are ready for use when they attain 5–10 cm length and 0.8–1.6 cm in diameter at the base or butt-end (Akinnuoye-Adelabu & Modi, 2017).

Nutritionally, Baby corn is comparable to other greens like cauliflower, cabbage, and tomato and has a sweet, juicy, and delightful flavor (Sanjeet et al., 2001). It contains approximately 89.1% moisture, no fat, 1.9 g protein, 8.2 mg carbohydrate, 0.06 g ash, 28.0 mg calcium, 86.0 mg phosphorus, and 11.0 mg ascorbic acid (Raggio Aonso & Gámbaro, 2018). Similarly, Hooda and Kawatra (2013) reported that baby corn contains 90.03% moisture, 17.96% protein, 2.13% fat, 5.30% ash, 5.89% crude fibre, 23.43 g/100 gm total soluble sugars, 1.96 g/100 g reducing sugars, 8.10 g/100 g cellulose, 5.41 g/100 g lignin, 5.43 mg/100 g ascorbic acid 670 µg/100 g β- carotene, 95.00 mg/100 g calcium, 345.00 mg/100 g magnesium, 898.62 mg/100 g phosphorus as well as 0.05 methionine, 2.85 isoleucine and 0.675µg/g methionine, isoleucine and leucine respectively.

Baby corn has increased in popularity as a young vegetable all over the world due to growing housing expenses and a shift away from non-vegetarian diets toward vegetarian ones (Ranjan & Sow, 2021). However, there are just four nations with production processing facilities: Thailand, Indonesia, India, and Brazil. The highest-quality baby corn was produced in Thailand as of 2000 (Ellis et al., 2006). Apart from 13 to 20% of its clean ear weight being used for human use, the husk, silk, and stover of immature maize are also utilized as green feed for ruminants and swine (Bakshi et al., 2016).

The United States is the biggest importer of baby corn, mostly from Asian nations, particularly Thailand. According to Rosen et al.(2012), imports from the United States made up around 40% of all the baby corn shipped through those countries. Baby corn production is still in its infancy in Kenya, thus it is crucial that additional research be done to increase both output and quality.

In Africa, maize is consumed in many different forms, including porridge, paste, and beer. Fresh maize on the cob can be grilled, baked, or boiled before consumption (Ekpa et al., 2019). Thus each component of the maize plant has a monetary value. The grain, leaves, stem, tassel, and cob can all be used to make a variety of recipes and non-food products. In sub-Saharan Africa, baby corn is mostly grown by small-scale subsistence farmers in intricate agricultural structures. These farming setups, however, typically lack labor, irrigation, seed, fertilizer, and other agricultural inputs. The crop has mostly contributed to dietary variety, increased revenue, and the boom in the food processing business in the world (Rajendran et al., 2017).

Among the countries known to export baby corn include those in Asia (China, Thailand, Sri Lanka, Taiwan, and Indonesia), Africa (Kenya, Zimbabwe, Zambia, and South Africa), and Latin America (Nicaragua, Costa Rica, Guatemala, and Honduras) (Hussain, 2021). Among the top importer countries are Bahrain and Qatar, along with Denmark, the Netherlands, France, the United Kingdom, Germany, and the United States. Baby corn is specifically eaten as a vegetable. It has flavour and appeal in addition to salads, spaghetti, soups, and other favorite recipes (Ohlhorst et al., 2012).

Production of baby corn has proven to be a hugely successful project in countries like China, Thailand, and Taiwan. It has been successfully scaled up for horticulture exports in and is one of the foreign exchange earners together with other horticultural plants (Kaisrajan & Ngouajio, 2012). In Kenya, small scale farmers work together to produce baby corn exclusively for export. In 2014, baby corn was grown on an area of 567 hectares in Kenya, resulting in a harvest of 4,784 metric tons, with an approximate value of Ksh. 100 million. The biggest producing counties during the year were Makueni, Kirinyaga, Machakos, and Laikipia, which together accounted for 94% of the nation's total production (USAID, 2016). This also saw the production area increase by 12% from the previous year in 2014 (Kamau, 2017).

The level of production, however, mostly stayed the same as it was in 2015. This may be explained by the fact that a large portion of the crop was grown without irrigation. Overall, the price of baby corn in 2015 increased by 17% compared to 2014 (Karuma et al., 2015). As at 2021, the level of production was 73,681 metric tons valued at Ksh. 42 million, and121,810 metric tons valued at Ksh. 97,504,132(Thapa et al., 2021). With change in weather patterns brought about by Climate change, farmers around the world are adopting new production technologies like mulching.

Mulches are materials that are applied to the soil surface for a variety of functions (smoothening of weeds, preservation of soil moisture and moderation of soil temperature). The mulches used in farming systems come in a variety of types and qualities. Thus, different coloured plastic mulches have been made and used in various crop production methods (Ibrahim et al., 2021; Kefelegn & Desta, 2021). The main goals of using coloured plastic mulches are to change the radiation budget and reduce soil water loss (Kader et al., 2017). In addition, they aid in controlling weeds as well as soil temperature, water use efficiency, plant development, yield, and quality (Kader et al., 2019). The most popular mulches are made of gravel, pebbles, polyethylene film, organic materials like straw, hyacinth, wood, or leaves that can be used alone or in mixes, or living elements like turf grass, rye, and clover (Iqbal et al., 2020; Li et al., 2018).

In underdeveloped nations, organic mulches, primarily organic straws, are most frequently used. However, organic mulches decompose, are less efficient, require more work, and are weather dependent (Zribi et al., 2015).

The use of polyethylene (PE) as a plastic mulch for vegetable crop production started in the 1950s after its discovery as a plastic film in 1938. It has significantly improved commercial crop productivity (Li et al., 2020). In the year 2018, 360 million tonnes of plastic was produced worldwide and used as follows: Asia 51%, Europe 17%, North America (18%), Africa 7%, Commonwealth of Independent States 3%, and Latin America 4% (Filho et al., 2020; Kumar et al., 2021). However, nearly 4% of the plastics produced are used in agriculture for various tasks, including mulching (Filho et al., 2020).

The farming community has used a variety of polyethylene coloured plastic mulches with various formulas for various agricultural purposes. Numerous researchers have evaluated the effects of these coloured plastic mulches on various crops (Abdul-Baki et al., 1996; Gordon et al., 2010 and Shonte et al., 2012). Previously, vegetable cultivation employed black, clear, and white plastic mulches. Today's most popular plastic colours include black, white, green, brown, red, silver, and blue. These colours were developed taking into account how they affect plant physiology and light absorption. Plastic mulches come in a variety of colours which change the microclimate of both soil and plant levels. The spectral balance, quality, and quantity of light are all impacted by the colour of plastic mulch, and this has an impact on several aspects of plant growth and development, including plant yield (Torres-Olivar et al., 2016).

The most widely used and available plastic mulch is black. This is because it effectively absorbs solar radiation from the sun's ultraviolet, visible, and infrared wavelengths (Torres-Olivar et al., 2016). By absorbing a significant amount of radiation, it significantly increases soil heat. The black plastic mulch is the opposite of the white variety hence reduces soil heating requirements for crops by cooling the soil (Maughan & Drost, 2016a:Kaisrajan & Ngouajio, 2012;). Plastic mulches alter the radiation budget and reduce soil water loss, which have a direct impact on the microclimate in the area around the plant. This results in raising fruit quality, yield, and shortens the production period (Basnet, 2022; Bonachela et al., 2011). Additionally, coloured plastic mulches significantly affect soil water loss, soil temperature, plant morphology, and weed growth (Basnet, 2022). Colour variation influences FR: R (far-red to red) ratios, which regulate phytochrome absorption and reflection. Thus increased plant height and above-ground biomass are a result of plants receiving high FR: R light (Kusuma & Bugbee, 2020).

Black, white, and transparent plastic mulches are the three primary coloured plastic mulches used around the world for various crops. Black plastic mulch is utilized to absorb more light and heat, white mulch to reflect, and transparent mulch to generate intense heat (Awata et al., 2019; Gordon et al., 2020a; Kefelegn & Desta, 2021; Olesen et al., 2012). Different coloured plastic mulches have different effects on crop yield, according to research studies (Basnet, 2022; Maughan & Drost, 2016a; Palma & Laurance, 2015). Their level of impact extends to crop output and quality, as well as the soil and water.

One of the primary characteristics of soil that influences crop production is soil temperature. According to many authors, the temperature of the soil affects a variety of systems and activities, including nutrient uptake, water absorption, root growth, and the existence of soil microbes (Onwuka, 2016; Pregitzer & King, 2005).The temperature of the soil is significantly changed by coloured plastic mulch. According to Ibarra-Jiménez et al. (2011); Kefelegn & Desta (2021), coloured plastic mulches raised the soil's temperature above that of bare soil.

The effect that coloured plastic mulches have been observed to have on soil temperature by various researchers varies from region to region and from crop to crop. According to a research report by Jahan et al. (2018) and Kefelegn & Desta (2021), black plastic mulches resulted in greater temperatures of 25.1^{o}C, than olive, silver, white, and blue mulches which led to soil temperature of 22.3, 22.9 and 23.6^{o}C respectively. However, according to Ibarra-Jiménez et al. (2008), the soil temperature was higher under brown and blue plastic mulches than it was under black and other mulches. This variation resulted from differences in the soil types and local climates. Reports confirming this found that black plastic mulch was more effective than white/black or aluminum/black plastic mulching systems in raising the mean soil temperature (Machanoff et al., 2022; Moore & Wszelaki, 2019; Rylander et al., 2020; Svotwa et al., 2014).

In order to grow baby corn, either direct seeding or transplanting is possible. In horticulture transplanting has emerged as a superior technique to direct planting. It provides a controlled environment, ensuring ideal conditions for seedling growth (Owen & LeBlanc, 2015), reduces vulnerability to pests and diseases (Yang et al., 2023), and facilitates optimal spacing for higher yields (Nafchi & Mirabbasi, 2022). Transplanting shortens the growing season (Owen & LeBlanc, 2015), increases seedling survival rates and enables precise planting for improved germination (Fanadzo et al., 2009).

For plants to complete their growth cycles, they need a particular amount of heat, measured in “growing degree-days” (GDD) (Zhran et al., 2013). Plant flowering dates, harvest ripeness, and the interval between two developmental stages are all estimated using GDD (Akinnuoye-Adelabu & Modi, 2017; Olesen et al., 2012). Additionally, temperature affects how quickly successive new leaves appear at the stem’s apex (Babatunde et al., 2020; Devaux et al., 2021).

Transplanting stage influences the crop plant performance (Gautam et al., 2016). The quantity of fruits, fruit weight, and the length of the harvest per plant for capsicum plants were found to be influenced by the age of the transplants (Olesen et al., 2012). Greater plant establishment, grain yield per cob, grain yield per unit area, plant height, and straw production were found in maize seedlings that were three weeks old (Zhou et al., 2015). El-Hamed et al. (2011) reported that maize seedlings transferred after 14 and 21 days reached maturity 6 and 12 days earlier than those planted directly.

According to Singh (2019), baby corn is majorly grown for the export market in Kenya. However, poor germination, scanty rainfall and soil temperature are some of the major limiting factors that affect the quality and production of baby corn for the premium market., Mulching is one of the cultural techniques used to control soil temperature and conserve soil moisture (Ajay

& Shashi, 2012; Amare & Desta, 2021). Thus there is a need to develop a more precise transplanting stage suitable for optimal production using the GDD. As a result, the goal of this study was to establish the performance of transplanted baby corn under varying growth conditions in Meru County.

The effect of plastic mulches on the temperature of the soil and crop canopy microclimate relies on their thermal properties. These involve reflectivity, absorptivity, or transmittance depending on incoming solar radiation (Chia et al., 2021; Gordon et al., 2010). Black plastic mulch accelerated canopy establishment and grain yield due to increased root zone soil temperature and conservation of soil water (Mahadeen, 2015).

The changes in root zone soil temperature influences root physiological processes like absorption of water and soil nutrients and translocation of essential nutrients, which influences shoot and root growth(Amare & Desta, 2021b). Elevated soil temperatures quicken crop emergence and growth, making the plants achieve the desired population structures at early growth stages (Gordon et al., 2010b; Licht & Al-Kaisi, 2005). As a result, it enhances the absorption of solar energy, thus enhancing crop yield (Iqbalet al., 2020). For instance, cucumber crops grown under plastic mulch films matured 7 to 14 days earlier and increased yields by 2 to 3 times compared to those grown on bare soil (Torres-Olivar et al., 2016).

The colour of the plastic mulch film used for mulching the soil determines the performance of the radiant energy, thus impacting the microclimate around the cultivated plants (Chia et al., 2021; Franquera, 2015; Torres-Olivar et al., 2016). The interaction between the quality of the light reflected by the surface of the plastic mulch film, the capacity for transmission of solar energy and the increase in soil temperature determines the response of plants to the coloured film. The different types and colours of plastic mulch have characteristic optical properties that change the levels of light radiation reaching the soil. Therefore, the soil temperature can be modified by changing the colour of plastic mulch films in regions of substantially high or low temperatures, thus encouraging faster plant development (Amare & Desta, 2021). Chia et al.

(2021) reported that depending on the crop variety, geographical location, and season, different colours of plastic mulches create high root zone-temperature conditions that might damage the growth, compromising vegetables' yield. Plastic mulch colour includes but is not limited to transparent, black, red, white and yellow, and the choice of colour depends on the intended purpose of the mulch.

Black-coloured plastic film is the most popular among growers worldwide (Maughan & Drost, 2016). Over an extended period, it has been the standard plastic mulch in vegetable production as it changes the plant's growing environment by increasing the root-zone soil temperature and holds more soil moisture compared to un-mulched soil (Ajay & Shashi, 2012; Amare & Desta, 2021; Mahadeen, 2015; Torres-Olivar et al., 2016). However, according to Gordon et al. (2010), black plastic mulch lowers the quality of reflected light compared to other coloured mulches, like red and blue mulches. The spectral distribution of the light reflected by these red and blue mulches is better utilised for photosynthesis and photomorphogenesis (Arakawa et al., 2016; Torres-Olivar et al., 2016). These colours (blue & red) change the quality of the light spectrum regarding the proportions of the red to far-red wavelengths and blue light which predominantly control the photomorphogenesis as dictated by the different photoreceptors like phytochrome (Mormile et al., 2017).

Using black and transparent plastic mulch films causes an average temperature increase compared to un-mulched soil (Liu et al., 2014). The significant increase in temperature leads to early germination and shorter growing seasons due to the increased GDD of the soil. The increased GDD at the beginning of a season increase the chances of success in production in several ways. For instance, it enables crops to be grown with lower risk and a higher likelihood of germination; increases the choices of crops that can be grown (for instance, those fetching a higher price and requiring longer, warmer growing seasons); provides crop produce when price and demand are high; and, provides the farmer with more choices as to when plants may be harvested (Ajay & Shashi, 2012; Bucki & Siwek, 2019; Gordon et al., 2010; Iqbal et al., 2020).

Using transparent plastic mulch may also enhance baby corn production and quality, boost plant tolerance to cool soil conditions, and enhance seed germination (Jan et al., 2022). Mulching reportedly reduces water evaporation by 10% to 50%, according to Akinnuoye-Adelabu & Modi, (2017). In cold climates, early growth temperatures have a significant impact on maize yield (Roy et al., 2018). Thus the yield and quality of baby corn was enhanced as a result of mulching's impact on early season soil temperature (Sadras et al., 2016).

White plastic mulch film generates cooler soil temperatures than black plastic (Haque et al., 2018). This colour is preferable during hot/summer growing seasons in warmer regions compared to black as it provides cooler soil temperatures. On the other hand, clear mulch provides more significant net radiation under the mulch and is thus more effective in increasing soil temperature than opaque mulches (Amare & Desta, 2021). It absorbs lower solar radiation but transmits 85% to 95% of this energy depending on the plastic mulch film's thickness and degree of opacity. In addition, the underside of the clear plastic mulch usually is covered with condensed water droplets. These water droplets are transparent to incoming short-wave radiation but opaque to outgoing long-wave infrared radiation. Therefore, much of the heat lost to the atmosphere from a bare soil by infrared radiation is conserved by clear plastic mulch (Snyder et al., 2015). The clear (transparent and translucent) mulches promote a relatively large net radiation at the soil surface, increase soil heat flux hence, increasing the minimum and maximum soil temperature (He et al., 2021; Qin et al., 2022).In vegetable farming, the preference has predominantly been for black, transparent, and white plastic mulches (Amare & Desta, 2021; Lamont, 2017).

A previous comparison of transplanting of maize seedlings (at five-week age) and direct seeding shows that transplanting is a technique used to produce the best plant densities, hence optimizing production (Owen & LeBlanc, 2022).In comparison to direct seeding, the transplanted seedlings had a lower mortality rate (by a factor of 5.8%), a higher output (6.71 tonnes/hectare), and a quicker adulthood rate (10-20 days) (Rychtecká et al., 2013).Additionally, transplanting is typically used to establish vegetation in conditions that are less favourable for direct seeding, such as when birds pose a risk to emerging seedlings (Palma & Laurance, 2015). According to previous study (Sharma & Banik 2016), the practice can be extended to the production of baby corn and is frequently utilized in the cultivation of rice and alongside the production of many vegetable crops (Grossnickle & Ivetic, 2017).

At some point during planting time, detrimental climatic conditions such low soil temperature and cold breezes can be addressed by transplanting (Dai et al., 2016). According Kwabiah (2004), in some climatic conditions, low soil temperatures cause direct-seeded maize to emerge later than expected and rising seedlings to grow more slowly. By allowing for the provision of a young maize harvest for the early market, transplanting increases farmer income (Ngongo et al., 2021). This is due to the fact that transplanting reduces the length of the field's boom, enabling the production of even late-maturing, high-yielding cultivars at some time throughout the growing season (defined by either rainfall or temperature) (Dai et al., 2016; Ngongo et al., 2021). The activity is typically used in the production of vegetable plants and in rice farming.

Maize does not perform well when transplanted because damaged roots do not grow, and root replacement is typically poor compared to crops like tomato and cabbage (Angelakis et al., 2020; El-Hamed et al., 2011). Even though post-transplant boom has received more attention in recent years, automatically impeded roots often have lower main root periods due to their usual morphological characteristics (Lu et al., 2020). Suberization and cutin synthesis at the endodermal layer after transplantation inhibited roots from emerging and decreased water absorption via the roots (Karuma et al., 2015; Reynolds et al., 2015). This is because there is a higher occurrence of suberization synthesis, which can significantly decrease due to the limited number of cells where the flora has developed during different stages of the plant nursery period.

The complexity of maize's response to transplanting shock can vary depending on the severity and duration of the shock, as well as the level of improvement the maize has undergone at the time of the shock. Various factors, such as early root extension mechanism, branching, and function, which are influenced by the temperature during maize establishment, can affect the impact of transplanting shock on maize yield (Shrestha et al., 2021).

Squash (*Cucurbita pepo* var. *melopepo*) and cucumber *(Cucumis sativus* L.) seedlings' root growth was observed to have diminished when exposed to temperatures of 2°C and 6°C for 48 hours, respectively. When the temperature was increased to 26°C, the seedlings suffered permanent harm since they were unable to grow again for 96 hours (Li et al., 2017).

Temperature also has an immediate impact on the nutritional status of seedlings by influencing nutrient absorption and transportation from the roots to the shoots. As compared to tomato transplants planted in bare soil, tomato transplants cultivated beneath clean polyethylene mulch showed improved early root explosion and nutrient uptake, notably phosphorus (Dukare et al., 2020).

Improvements are needed in the existing technology to ensure proper maize transplantation. Furthermore, it is important to build upon previous research and propose enhanced technology that suits the capabilities and resources of farmers, among other considerations. This will allow for easier adoption and scalability of the transplantation process, which has already been implemented successfully by farmers in various crops like commercial rice and vegetables. However, small-scale farmers in Meru County, Kenya, have not fully embraced the use of plastic mulching. The objective of this study was to investigate the impact of different-coloured plastic mulch films on soil temperature, growth, and yield of two baby corn varieties (PAN 14 and Thai Gold) in Meru County, Kenya.

1.2 Statement of the problem

In Kenya's agricultural landscape, a notable knowledge gap exists regarding alternative production systems for baby corn, which encompasses various critical aspects. Firstly, the optimal transplanting stage for baby corn remains inadequately established across different production systems, leaving farmers uncertain about the most opportune time to transplant their seedlings for optimal growth and yield. Additionally, the scarcity of information extends to the selection of appropriate mulching materials tailored specifically for baby corn production. Understanding the properties and suitability of various mulching materials is essential for regulating soil temperature, moisture retention, and weed suppression, factors critical to the success of baby corn cultivation. These knowledge deficiencies underscore the pressing need for targeted research, extension services, and knowledge dissemination efforts to empower Kenyan farmers with the information and techniques required to efficiently and sustainably cultivate baby corn, thereby diversifying agricultural practices and bolstering food security and economic prospects.

Soil is greatly affected by every method or technology (mulch) application designed to boost plant growth and development (Eltlbany et al., 2019). Physical, chemical, and biological properties of the soil are affected by these technological inputs (plastic mulch) applied. Soil temperature is one of the main aspects of soil that affects crop production. The temperature of the soil affects various systems and processes, such as nutrient uptake, water absorption, root growth, and the presence of soil microbes (Onwuka, 2016). Coloured plastic mulch drastically alters the soil's temperature. Coloured plastic mulches, according to (Ibarra-Jiménez et al., 2011; Kefelegn & Desta, 2021), increased soil temperature over that of bare soil.

Researchers have shown that coloured plastic mulches can affect soil temperature in different ways depending on the region and the crop(Gordon et al., 2010a; Rajablarijani et al., 2012; Torres-Olivar et al., 2016 and Jahan et al., 2018). However, the soil temperature was higher beneath the brown and blue plastic mulches than it was under the black and other mulches, according to (Kefelegn & Desta, 2021; Ranjan& Sow, 2021). This difference was brought on by various soil types and regional climates.

Black plastic mulch increases the minimum, maximum, and mean soil temperatures more effectively than white/black or aluminium/black plastic mulching systems (Basnet, 2022; Gheshm& Brown, 2020; Mahadeen, 2014; Rajablarijani et al., 2012).

Either direct seeding or transplanting can be used to grow baby corn. The use of transplants is a widespread practice in the cultivation of high-value vegetable crops, flowers, and fruits (Ahmad et al., 2018). It is a common approach employed by farmers to ensure successful growth and development of these valuable crops. Transplanting is particularly favored due to its effectiveness in achieving desired yields and quality in these plant varieties (Singh et al., 2020). Several growth factors, such as soil moisture, nutrients, temperature, light, and cultural practices, affect when it is optimal to transplant seedlings (Kader et al., 2017). Temperature has been shown to significantly affect how quickly plants grow, develop, and produce (Hatfield, 2015).

Seedlings from irrigated nurseries have been replanted in a range of habitats and crops throughout time to increase food security (Adonia, 2015). In areas with erratic rainfall or where rainfall might not support a crop, this has been achieved through reinforcing the crop stand as well as prolonging the growing season. The approach provides good yields by appropriately tying together proper sowing procedures and input application, avoiding risks and permitting the optimal use of water and other farm inputs (Roy et al., 2018).

When considering various aspects of crop performance such as cob parameters (length, base width, and number of cobs per plant), heat units needed for maturity, plant height, ear bearing height, and other agronomic characteristics, there is a lack of unanimous agreement on the optimal stage for transplanting. Different perspectives exist regarding the most suitable timing for transplanting, leading to uncertainty in determining the ideal stage for achieving desired outcomes in terms of crop yield and quality. This is mostly because the majority of studies have mainly looked at maize yield in terms of seeds, seriously under examining the cob parameters and baby corn's agronomic traits (Rahmani et al., 2015). Considering the wide range of 3-4 weeks transplanting age of maize seedlings, there is need to develop a more accurate transplanting stage using GDD which could be suitable for optimal production as compared to the conventional way of using time.

This research collected data on the correlations between the transplanting stage and plastic mulch colour based on the research objectives.

1.3 Research Objectives

1.3.1 General Objective

To establish the performance of transplanted baby corn under varying growth conditions in Meru County, Kenya.

1.3.2 Specific Objectives

The specific objectives of the study are:

1. To evaluate the impact of different GDD-related transplanting stages on the performance of baby corn varieties under farmer conditions in Meru County, Kenya.
2. To assess the effect of plastic mulch colour on the performance of baby corn varieties at different transplanting stages in Meru County, Kenya.
3. To determine interaction between different plastic mulch colours and phased transplanting stages on the performance of baby corn plant varieties in Meru County, Kenya.

1.4 Research Hypotheses

1. GDD-related transplanting stage has an effect on the performance of baby corn varieties under farmer conditions.
2. Plastic mulch colour has an effect on the performance of baby corn varieties transplanted at different stages.

3. There are no interactions between different plastic mulch colours and phased transplanting stages on the performance of baby corn plant varieties?

1.5 Justification of the Study

Production of baby corn in Kenya is a compelling venture. It offers the potential for expansion into horticultural exports, which could significantly contribute to foreign exchange earnings, aligning with other lucrative horticultural crops. The 2014 figures, indicate that cultivation of baby corn on 567 hectares resulted in a yield of 4,784 metric tons valued at around Ksh. 100 million, this underscores the economic viability of this crop (Kamau, 2017). This economic value has the potential for substantial growth through increased production, taking advantage of the global demand for baby corn as a high-value specialty vegetable. Embracing baby corn cultivation not only diversifies income sources but also enhances food security, generates employment, and bolsters foreign exchange earnings, establishing it as a strategically promising pursuit for Kenya's agricultural sector.

PAN 14 and Thai Gold are varieties commonly grown by local farmers and are well-adapted to the Kenyan climate and growing conditions. Understanding these commonly grown varieties in terms of their management is relevant not only for farmers but also for stakeholders along the baby corn supply chain, contributing to informed decisions and improved profitability in Kenyan agriculture and the broader food industry. In addition, the identification of the best-performing baby corn variety is of paramount importance for farmers in Meru County, as it has the potential to significantly enhance resource allocation and increase production. Choosing the most suitable variety, adapted to the local climate and soil conditions especially in Meru County, can lead to improved crop resilience and higher yields. By selecting varieties that demonstrate superior growth and crop uniformity, farmers can optimize the use of their resources, including land, water, and inputs like fertilizers and pesticides. This, in turn, can contribute to increased baby corn production, better economic returns for farmers, and overall food security and prosperity in Meru County.

Transplanting is frequently used to establish crops when there are less favorable conditions for direct sowing, such as when birds represent a hazard to growing seedlings or when seeds do not germinate (Fanadzo et al., 2009). Past research has shown that transplantation has advantages. Transplanting has been connected in one study to cost savings in replanting, depending on the severity of the damage to the emerging seedlings (Gautam et al., 2016). These savings include the costs of labor and seed for replanting. When marketing green maize, the number of cobs and the proper cob size are essential revenue-determining elements, thus each seedling that survives also boosts earnings.

Increasing the plant population by use of transplants will indeed lead to the production of more cobs in in a unit area, which, in turn, has the potential to boost farmer’s profits. Onwuka(2016)showed how transplanting can be used to avoid unfavorable planting-time conditions such as cool winds and low soil temperature. This practice reduces the amount of water plants requires to grow, particularly if they mature quickly. This makes straight seeded maize develop more slowly and reach flowering stage eleven to fifteen days later than transplanted maize, which depends on nitrogen fertilization (Hooda & Kawatra, 2013b; Saritha et al., 2020; Troyjack et al., 2018).

The shorter crop cycle in the field results in water savings for the production of baby corn as compared to the amounts of water necessary for the production of straight planted maize (Adamtey et al., 2016; Rani et al., 2019). Savings like these would increase farmers' profits in situations when they use energy or fuel to pump and buy water. Whether deciding when to transplant baby corn and what agronomic qualities to expect with various transplanting combinations, horticulture farmers may find the study's findings helpful.

Identifying the most suitable baby corn variety that performs well in the specific growing conditions is essential. This understanding will empower farmers to make well-informed choices regarding variety selection, leading to increased yields, enhanced quality, and improved overall profitability. In addition, the identification of the best variety will play a critical role as it will enable farmers to optimize resource allocation, streamline production methods, and attain consistent success in cultivating baby corn. The information might also be helpful to researchers, extension agents, planners, and Kenyan officials as they determine how to handle irrigated agriculture.

Investigating how plastic mulch colour affects the performance of baby corn varieties at various transplanting stages has practical implications for maximizing yield, improving resource efficiency, and promoting environmental sustainability. The findings of this study will have direct benefits for farmers and will contribute to the development of sustainable and productive baby corn cultivation methods. By carefully choosing the right combination of plastic mulch colour and transplanting stage, farmers can create ideal growing conditions that optimize baby corn production.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Zea mays L., also known as maize, is cultivated in Kenyaon a surface area of about 1.5 million hectares, with an annualyields 2 metric tonnes of grain per hectare(Sepat et al., 2019). According to its function and/or starch content, maize has been divided into numerous varieties, including baby corn (*Zea mays* var. *Tunicate*), waxy corn (*Zea mays* var. *Ceratina*), dent corn (*Zea mays* var. *Indentata*), flint corn (*Zea mays* var. *Indurata*), popcorn (*Zea mays* var. *Everta*) (Maddela, 2009; Torres-Olivar et al., 2016) among others.

In terms of grain yield, Maize holds the highest rank among cereal crops. It falls at 0.33 on the scale of overall production, following wheat and rice. Moreover, it exhibits the highest production capacity among all cereals. As a C4 plant, maize thrives best within temperature ranges of 20 to 30^{o}C, enabling optimal growth rates. The C4 plant life cycle facilitates the conversion of carbon dioxide into four-carbon sugar molecules for entry into the Calvin cycle (Larson & Fuller, 2014). Maize's C4 classification grants it the ability to adapt to adverse climatic conditions, including extreme heat, drought, and increased levels of carbon dioxide. Consequently, it efficiently converts absorbed nutrients into food, ensuring successful growth even in challenging environments (Hooda & Kawatra, 2013; Rosen et al., 2012).

Baby corn (also known as young corn, mini corn or candle corn) is the ear of maize plant harvested young, when the silks have either not emerged or just emerged and no fertilization has taken placeand preferably harvested within 1 – 3 days after silking (Bar-Zur and Saadi 1990). The cobs are harvested after attaining a length and diameter of 4 to 9 cm and nearly 1.0 to 1.5 cm (Singh et al., 2019). Thus it is harvested at immature stage. In the market, ears of baby corn of light-yellow colour, regular row arrangement, 10 to 12 cm length and a diameter of 1.0 to 1.5 cm are the most prepared for human consumption (Muthukumar et al., 2005). Since only immature cob is harvested as the economic produce, the crop meant as baby corn can be harvested within 50-55 days after planting. It has been used as a vegetable in China and other parts of Asia for generations and has recently gained popularity worldwide.

Baby corn is a newly developed commercial product made from maize that few people are familiar with. It is not because there are not any high yielding varieties or advanced production of generation options available, but rather because there is limited knowledge about how to use and profit from this promising crop. Baby corn is a term used to describe a young, gleaming maize cob that has been picked within two to three days of the silk emergence but before fertilization (Castro et al., 2013; Ranjan & Sow, 2021; Sepat et al., 2019).

Baby corn, renowned for its underdeveloped and unfertilized ears harvested shortly after silk emergence, undergoes a rapid growth process within 45-55 days from sowing as it enters the reproductive phase (Castro et al., 2013). This short-season crop matures within 60 to 70 days, allowing for three to four cultivation cycles per year (Ajaz et al., 2013). The production of baby corn not only proves to be financially rewarding but also offers farmers diversification opportunities, higher prices, and quicker returns (Pandey et al., 2000). The profitability of the baby corn market has been highlighted (Hardoim et al., 2002), emphasizing the benefits of diversification, value addition, and increased income for farmers (Pandey et al., 2014).

2.2 Origin of baby corn

The origin of maize can be traced back to the Mexican highlands, from where it rapidly spread throughout the region, with its most likely place of origin being the Mesoamerican region (Jabran & Farooq, 2007; Rouf et al., 2016). Based on archaeological evidence and the analysis of phylogenetic variables, the process of domestication is estimated to have commenced around 6,000 years ago (Vigne, 2015). Baby corn, a variety of maize belonging to the Poaceae family's Andropogoneae tribe, is characterized by having twenty chromosomes and being a diploid plant with a chromosomal count of $2n = 20$ (Revilla et al., 2021).

In recent years, there has been a cultivation shift towards baby corn (*Zea mays* var. *saccharata*) derived from maize (Adamczewska-Sowińska & Sowiński, 2020). Baby corn production initially originated in Taiwan, significant advancements in its development occurred in Thailand (Chutkaewand Paroda, 1976). In 1976, Thailand initiated a baby corn breeding program aimed at evaluating and assembling germplasm with high potential for baby corn production (Ackatasanawan, 2001). This program utilized open-pollinated varieties, synthetics, and diverse composites, focusing on traits such as prolificacy, seedling vigor, hybrid yields, pest resistance, plant and ear morphology, robust root and silk strength, tolerance to plant density, responsiveness to nitrogen fertilizers, ear size, cob colour, and other desirable characteristics.

During the 1980s, efforts were undertaken to establish breeding programs specifically aimed at developing hybrid varieties of baby corn. These programs sought to take advantage of the enhanced uniformity in maturity and the expression of prolificacy traits found in hybrids (Ackatasanawan, 2001). The main objective was to create baby corn hybrids that exhibited consistent growth patterns and high productivity. By utilizing selective breeding techniques, these programs aimed to combine desirable characteristics from different parent plants to achieve improved hybrid varieties of baby corn. The focus was on enhancing the traits related to maturity and prolificacy, ensuring that the resulting hybrids would consistently produce uniform and abundant baby corn ears (Adamczewska-Sowińska & Sowiński, 2020). These initiatives marked an important step forward in the development of specialized baby corn hybrids, enabling more efficient and reliable production of this crop.

2.3 Baby Corn Varieties

Selection of appropriate varieties is crucial in achieving optimal and maximum crop yield. The choice of varieties also influences various plant characteristics and growth parameters such as plant dry weight, crop growth rate, tasseling and silking durations, number of cobs per plant, cob weight with and without husk, as well as maize and fodder yields (Sharma et al., 2013). To ensure successful baby corn production, it is essential to carefully evaluate and study the adaptability and performance of different varieties under specific local agro - climatic conditions. By considering the specific requirements of the region, including temperature, rainfall, soil type, and other environmental factors, the selection of suitable varieties should be tailored to maximize productivity and ensure successful outcomes. Additionally, the local agro - climatic conditions should be taken into account to identify the varieties that exhibit desirable traits and can thrive in the given environment, ultimately leading to improved baby corn production. Therefore, thorough research and analysis of suitable varieties in relation to the specific agro - climatic conditions are crucial for achieving successful and sustainable baby corn cultivation.

Kenya being a country endowed with abundant agricultural resources has been diversifying its crop production, particularly in the cultivation of specialty maize varieties. One such variety is baby corn, which has gained prominence in the agricultural sector. The country has seen an expansion in the production of different baby corn varieties, including Baby Asian, Early Sunglow, Extra Sweet, Kalahari, Kandy Corn, PAN 14, Panar, Silver Queen and Thai Gold among others (FarmLINK, 2018).

These varieties have garnered attention for their unique characteristics and market demand. Farmers in Kenya have recognized the potential of growing these specialized maize varieties, as they offer additional economic opportunities and contribute to agricultural diversification. The cultivation of baby corn allows farmers to tap into niche markets, cater to specific consumer preferences, and potentially generate higher profits. The adoption of these baby corn varieties showcases Kenya's commitment to innovation and meeting the evolving demands of the agricultural sector. Through the cultivation of specialty maize varieties like baby corn, the country aims to enhance its competitiveness in both domestic and international markets, thereby contributing to food security and economic growth.

Baby Asian, on the other hand, is a popular variety in Asia known for its tender and sweet corn kernels. It has a high yield potential and can be harvested within 60-70 days after sowing (FarmLINK, 2018). Early Sunglow, on the other hand, is an open-pollinated variety that matures early, making it ideal for areas with shorter growing seasons (FarmLINK, 2018). It produces cobs with yellow kernels that are sweet and tender. Extra Sweet is a variety that lives up to its name, with exceptionally sweet and tender kernels. It is a relatively new variety in Kenya but has shown promise in terms of yield potential.

Kalahari is a hybrid baby corn variety that produces uniform and attractive cobs, making it ideal for both fresh consumption and processing. Kandy Corn is a unique variety that produces multi-coloured cobs with kernels in shades of red, white, and blue. It is a popular variety for fresh consumption and has a high yield potential.

PAN 14, a hybrid baby corn variety, was meticulously developed by the Indian Agricultural Research Institute (IARI) through the crossbreeding of two inbred lines. Renowned for its remarkable traits, this variety exhibits a combination of high yield potential, early maturity, and robust resistance against prevalent diseases and pests (Bhattacharya et al., 2015). With its compact plant structure and relatively short height, PAN 14 is well-suited for high-density planting methods, enabling efficient land utilization. The ears of this variety possess a cylindrical shape and display a pale yellow colouration. Typically, they measure approximately 10-12 cm in length and have a diameter of 2-3 cm. The kernels, known for their tenderness, succulence, and sweetness, exhibit a desirable flavour and texture, making them ideal for fresh consumption and processing applications (Joshi et al., 2016).

One of the standout features of PAN 14 lies in its high yield potential, which can reach an impressive 30-35 tons per hectare under favourable growing conditions. Extensive studies have demonstrated the variety's exceptional adaptability to diverse agro-climatic conditions, making it suitable for cultivation in a wide range of soil types, including sandy loam, clay loam, and silt loam (Singh et al., 2015). The versatility and adaptability of PAN 14 contribute to its popularity among farmers, allowing them to achieve substantial yields across various geographical regions and soil compositions. Furthermore, PAN 14's resistance to common diseases and pests provides a valuable advantage to farmers, reducing the risk of crop loss and the need for excessive pesticide application. This not only ensures a more sustainable farming approach but also contributes to cost savings and environmental protection (Bhattacharya et al., 2015).

The development of PAN 14 has revolutionized baby corn cultivation by offering farmers a superior variety with enhanced productivity, disease resistance, and adaptability. Its combination of appealing visual attributes, delightful taste, and reliable performance positions PAN 14 as a preferred choice among growers, enabling them to meet the growing demand for baby corn while maximizing their yields and profitability (Joshi et al., 2016).

Panar is a high-yielding baby corn variety that matures early, allowing for multiple harvests in a single growing season. It is well-suited for production in Kenya due to its tolerance to drought and disease resistance (FarmLINK, 2018). Silver Queen, another hybrid variety, is known for its high yield potential and sweet flavor. It has a long growing season and requires adequate irrigation and fertilization to maximize its potential (FarmLINK, 2018).

Thai Gold, a hybrid baby corn variety, exhibits excellent performance and adaptability across various agro-ecological zones in Kenya. Developed through selective breeding methods, this variety has undergone rigorous testing in multiple trials to assess its capabilities. According to a study conducted by Lertrat and Pulam (2007), Thai Gold outperformed other baby corn varieties by producing the highest number of ears per hectare, with an impressive yield of 13,100 kg/ha. Notably, Thai Gold stands out with its vibrant yellow colour and remarkable uniformity, rendering it visually appealing to both local consumers and export markets. In addition to its attractive appearance, Thai Gold baby corn boasts a delightful sweetness, crisp texture, and tender kernels, making it an ideal choice for various applications, including fresh consumption, processing, and canning (Starkearyes, 2020). The combination of high yield potential, appealing visual attributes, and exceptional taste positions Thai Gold as a sought-after baby corn variety in the Kenyan agricultural landscape. Its market desirability and versatile uses contribute to its popularity among farmers and consumers alike.

Thai Gold baby corn variety has also shown good resistance to pests and diseases such as maize streak virus and common rust, making it a preferred choice for farmers in areas with high disease pressure. In a study by Wanlayaporn et al. (2013), Thai Gold baby corn variety showed moderate resistance to maize streak virus, indicating its potential to withstand the disease. In order to achieve the desired results in marginal conditions, farmers usually plant 60,000 to 80,000 plants per hectare. However, under optimal conditions with good management and sufficient watering, a plant population of 55,000 is considered ideal. The plants have a uniform height of 2.10m, and their ears are positioned 140cm above the ground (Starkearyes. 2020).

2.4 Nutritional Uses

Baby corn is one of the most important dual purpose crops grown round the year (Singh et al., 2015). This is because cobs are used as human food while the residue is used as livestock feeds. It can be effectively used as both a nutritious vegetable and as an export crop to earn valuable foreign exchange. Besides the main product, it also provides a considerable amount of quality green fodder by-product which is a valuable feed for cattle (Singhet al., 2009). Hence, the cultivation of baby corn provides an opportunity to maintain a dairy farm.

Maize holds immense global significance due to its diverse applications in human food, livestock feed, and the production of food and industrial products, as well as its use as a seed crop (Awika, 2011). Baby corn is delicious, decorative, and highly nutritious vegetable that is free from cholesterol. With its high fibre content, baby corn is considered a low-calorie vegetable (Das& Singh, 2016). In terms of mineral composition, the nutritional value of 100 grams of baby corn is comparable to that of an egg. It typically contains around 89.1% moisture, 8.2% carbohydrates, 1.9% protein, 28.0 mg calcium, 86.0 mg phosphorus, 0.1 mg iron, 0.5 g thiamine, 0.08 mg riboflavin, and 11.0 mg ascorbic acid (Jinjala et al., 2016). Overall, baby corn serves as both a nutritious fodder crop for dairy animals and a highly beneficial vegetable for human consumption. Its rich nutrient profile, digestibility, and palatability make it a valuable resource for supporting the health and well-being of both animals and humans.

The nutritive value of baby corn is similar to the non-legume vegetables like cauliflower, cucumber, cabbage and tomato. It has sweet taste, high digestibility and appealing colour, while both soft and crunchy nature makes it an exquisite ingredient for different traditional and continental dishes. The nutritional status of it is comparable to other common vegetables as shown in the Table 1.

Table 1: Nutritional value of baby corn from analysis of 100 g compared with other vegetables

Component	Baby con	Cabage	Tomato	French bean	Lady's finger	Raddish	Brinjal	Spinach
Moisture (%)	89.10	91.90	93.10	91.40	89.60	94.40	92.70	92.10
Fat (g)	0.20	0.20	0.20	-	0.20	-	0.20	0.70
Protein (g)	1.90	1.80	1.90	1.70	1.90	0.70	1.40	2.00
CHOs(g)	8.20	4.60	3.60	4.50	6.40	3.40	4.00	2.90
Ash (g)	0.06	0.70	1.60	-	-	-	0.60	-
Calcium (mg)	28.00	18.00	20.00	50.00	66.00	50.00	18.00	73.00
Phosphorous (mg)	86.00	47.00	36.00	28.00	56.00	22.00	47.00	21.00
Iron (mg)	0.10	0.90	1.80	1.70	1.50	0.40	0.90	10.90
Vitamin (iu)	64.00	75.00	735.00	-	-	-	130.00	-
Thiamine (mg)	0.50	0.04	0.07	0.80	0.70	0.06	0.04	0.03
Riboflavin(mg)	0.80	0.11	0.01	0.06	0.01	0.02	0.11	0.07
Ascorbicacid (mg)	11.00	12.00	31.00	11.00	13.00	15.00	12.00	28.00
Niacin (mg)	0.03	0.30	0.60	-	-	-	0.60	-

Source: (Zebong, 2009).

Baby corn cobs possess significant nutritional value, with each 100 grams containing 5.43 mg of ascorbic acid, 17.96% protein, 5.13% ash, 5.89% crude fiber, 90.03% moisture, and 2.13% fat, as indicated in Table 1 (Hooda et al., 2013). Furthermore, the cobs exhibit lower cholesterol levels and higher fiber content compared to other crops (Lau et al., 2022). The presence of folic acid makes baby corn beneficial for fetal development. Additionally, due to being enclosed within husks, the young cobs are well-protected from diseases, insects, fungicides, and pesticides, ensuring they remain free from residual effects (Das & Singh, 2016). These qualities have contributed to the crop's popularity among certain vegetable farmers and consumers.

Apart from canning in the affluent society, baby corn has become a distinctive demand for many traditional and continental meals due to its excellent nutritional value and crisp nature. 100 grams of baby corn were found to contain 89.1% moisture, 0.2 g lipids, 1.9 g protein, 8.2 mg carbohydrate, 0.06 g ash, 28.0 mg calcium, 86.0 mg phosphorus, and 11.0 mg ascorbic acid (Fang &Wakisaka, 2021;Araujo et al., 2017; Silva et al., 2009; Subaedah et al., 2021).

It can be eaten raw or preserved. Its nutritional cost is comparable to that of non-legume greens such cabbage, cauliflower, tomato, and cucumber. 100 grams of baby corn include 89.1 grams of water, 0.2 grams of fat, 1.9 grams of protein, 8.2 grams of carbohydrates, 0.06 grams of ash, 28.0 grams of calcium, 86.0 grams of phosphorus, and 11.0 grams of ascorbic acid (Palai et al., 2018).

In organic farming systems, livestock plays a vital role in nutrient recycling and maintaining the sustainability of low-input production methods. Thus young maize plants, after harvest, can serve as valuable fodder for cattle, making baby corn production an excellent complement to dairy farming. Interestingly, only a small portion of the fresh ear weight, approximately 13 to 20%, is utilized for human consumption, while the remaining components such as the husk and silk can be utilized as green forage for ruminants and pigs.

According to a study by Faungfupong and Tangadulratana (1987), baby corn production demonstrated the potential to yield 40 to 43 tonnes per hectare of fresh plant weight. Within this yield, the detasseling plant part accounted for 6 to 7%, the husk contributed 8 to 10%, and the remaining plant parts after ear harvesting represented 83 to 86%. These plant materials possess high nutritional value and can be utilized as roughage or silage for beef cattle and dairy cows, providing a valuable source of nutrients.

The integration of baby corn production with dairy farms allows for efficient resource utilization and the creation of a nutrient cycling system. By utilizing the different parts of the baby corn plant, farmers can maximize their yields and reduce waste. The nutritional value of the plant materials provides an excellent feed source for cattle, enhancing their diet and supporting their overall health and productivity. Through the integration of baby corn production with dairy farming, farmers can benefit from multiple revenue streams and a more sustainable production system. The utilization of maize plants as fodder for cattle ensures the efficient utilization of resources, reduces waste, and promotes a circular economy within the farming system. Additionally, the nutritional value of the baby corn plant parts contributes to the well-being and productivity of livestock, further enhancing the overall viability of this integrated approach (Faungfupong & Tangadulratana,1987).

Baby corn has emerged as a profitable crop, particularly among forward-thinking farmers who recognize its potential. Maize, being rich in vitamins, requires higher levels of nitrogen (N) compared to other mineral nutrients. In a study by Cheva-Isarakul and Paripattananont (1988), it was revealed that baby corn waste contained approximately 86.4% moisture, 94.4% organic matter (OM), 10.6% crude protein, 55.1% neutral detergent fibre (NDF), 26.8% acid-detergent fibre (ADF), and 2.0% acid-detergent lignin. The digestibility of dry matter (DM), OM, nitrogen-free extract, NDF, and ADF was found to be above 70%. Due to its succulence, digestibility, and palatability, baby corn green fodder is well-suited for dairy cattle. It also possesses lactogenic properties and offers significant nutritional value, with protein content ranging from 15% to 18%, sugar content from 0.016% to 0.02%, phosphorus content from 0.6% to 0.9%, potassium content from 2% to 3%, fibre content from 3% to 5%, calcium content from

0.3% to 0.5%, and ascorbic acid content ranging from 75 mg/100g to 80 mg/100g (Singh et al., 2006). This makes it an ideal fodder crop for dairy animals.

2.5 Yield Characteristics

2.5.1 Prolificacy

Prolificacy is the maize's natural property to develop more than one cob on the same plant. In maize, it is an adaptability character, with influence on production capacity and production stability. This is important as maize production is the result of six components: the number of plants per unit area, number of cobs per plant, the number of rows of kernels on the cob, number of grains per row, the percentage of embryos per maize cob and 1000 grain mass (Edwards 2015). This depends on both genotypic and environmental factors (Motto & Moll, 1983). However, subsequent ears can only develop once a threshold of the two factors has passed. Additionally, removal of the older ears normally induces the plant to produce new female inflorescences which gives rise to other ears (Silva et al., 2006). D'Andrea et al. (2022) recorded higher prolificacy and kernel number of the second ear values under low-restrictive environments (high N supply and low density) in maize crop.

Baby corn is a prolific cultivar, which means that it can produce more than one maize ear per plant, even though only one will eventually mature. Prolificacy depends on environmental and genotypic variables (Rani et al., 2019 and Adamczewska-Sowińska & Sowiński, 2020).

When the circumstances reach or exceed the threshold, extra power is instead employed for sub-apical production, making it possible to supply numerous young ears of maize (Uribelarrea et al., 2008). In spite of the cultivar's propensity for profusion, the removal of the primary ear prompts the plant to produce new lady inflorescences, which may also propel other ears skyward.

2.6 Baby Corn Production Globally

Baby corn production and markets are growing worldwide, especially in Asia, Africa, and South America (Wailare, 2014). Asian countries are the major consumers of baby corn. In Asia, Thailand, China, and Taiwan are the major baby corn producers (Singh et al., 2019). In India similar to other Asian countries, it is gaining attention among the growers owing to its high demand, promising market, value addition, and high-income opportunities. Baby corn is used either of the two ways; fresh or processed for consumption (Babu et al., 2020). Thus, it is becoming popular in domestic and foreign markets and has enormous processing and export potential. Recent development is of growing maize for vegetable purpose (Dass et al., 2008).

The United States is the largest producer of maize in the world, accounting for around 35 and 32% of worldwide production in the growing seasons of 2011 and 2012, respectively (USDA-FAS, 2013). Following the 1996 Federal Agriculture Improvement and Reform Act's adoption, which gave farmers more planting flexibility by lifting crop acreage restrictions, U.S. maize production increased (Ellis et al., 2006; Ginigaddara & Ranamukhaarachchi, 2011). Similarly, the creation and implementation of the Renewable Fuel Requirements under the Energy Policy Act of 2005, which forbids the use of ethanol as a fuel additive and mandates the use of maize grain as the primary feedstock at present, provided incentives to increase acreage and to maximize yields (Dukhnytskyi, 2019).

Currently, Thailand and China are the world leaders in baby corn production. It makes up roughly eight and 25 percent of the global production, respectively, in terms of place (Shrestha et al., 2021).Today, baby production is grown and consumed in many parts of the world including Asia, Europe, Africa and America. In the year 2022, baby corn production stood at about 1206.6 million metric tons grown on an area of 193.7 million hectares of land (Shahdandeh, 2022). By the year 2020 the major world producers included Thailand, China, India, Indonesia, Vietnam and Philipines with a production of 402,000, 80,000, 62,000, 35,000, 25,000 and 23,000 metric tons respectively (FAOSTAT, 2021).

In line with the financial recovery of maize production, which is a crucial prospective crop for Bangladesh and is grown virtually year-round, producing maize into baby corn could be the best option provided that modern agro-production methods are used (Zhou et al., 2015).

But it's possible that very little of this crop is grown in Bangladesh. Baby corn production has just recently begun in Bangladesh due to a lack of acceptable production of techniques for extensive sustainable industrial farming. There is a lack of statistics in agricultural technology, as well as adequate management techniques like water control; software for calculating fertilizer quantity, timing, and form hasn't yet been discovered.

Due to rising living costs and a shift in dietary preferences from non-vegetarian to vegetarian, baby corn has attracted an increasing number of consumers worldwide. Thailand produces the most baby corn, with an estimated $64 million (US) worth produced there in 2000 (Hussain, 2021; Swapna et al., 2020). Other benefits of baby corn include using the husk, silk, and stover as unseasoned herbage for feeding ruminants and swine; just 13 to 20% of the total ear weight is for human use.

Although there are no publicly available statistics on the production of baby corn in the United States, the US is the world's largest importer of this food, primarily from Thailand and Asian nations. According to reports from the US Department of Agriculture and the Foreign Agricultural Service, US imports made up around 40% of the total baby corn shipped by those countries (Iqbal et al., 2020; Thavaprakaash & Velayudham, 2016). In the USA, baby corn industry is still in its infancy, thus it's critical that additional research be done to increase productivity and quality.

Thailand is the world's most popular producer of baby corn and its top exporter. Production of baby corn has developed gradually over the course of the last approximately forty years and has become a successful business. According to (Adamczewska-Sowińska & Sowiński, 2020), Thailand only exported 90 tonnes of canned baby corn, for $31,000, in 1973. Twenty-five years later, the tons and price had increased to 54643 tonnes and $42,890 million, respectively. The rise obtained through Thailand was confirmed by Devaux et al. (2021) and Johnson et al. (2008). In terms of academic research, varietal trial comparisons of several infant maize cultivars for boom, yield, and agronomic features have received significant attention in Thailand. By employing eight unique young maize cultivars, Akinnuoye-Adelabu & Modi(2017); Dukare et al. (2020) and Rychtecká et al.(2013) investigated the ability of young maize to yield, the quality of the kernel, and other features. The two studies examined fundamental aspects of baby corn agronomy, including yield, first ear height, plant top and a wide range of harvested ears.

They concentrated on the cultivar that had the best all-around characteristics. Other cultivars were eliminated because they performed better overall on some features but less well on other trends. Given the limited prior research, it appeared that Thai academics were more interested in the concerns surrounding the field production and export of baby corn than in scholarly investigation. However, with more people switching to a vegetarian diet, rising living standards, and a sharp rise in the consumption of baby corn, people have become concerned about finding healthier, higher-quality baby corn. Das and Singh, (2016) emphasized the urgent need for Thai and other scientists to carry out additional research on effective production of structures for young maize.

India began producing young maize when agronomists and farmers realized that it was a crop with the potential to boost the country's agriculture's economic standing (Dass et al. 2008). The ability of newborn maize to generate foreign exchange and satisfy local need served as a catalyst for interest. Njoroge et al. (2019) and Silva et al.(2010) attempted to develop well-known baby corn production system that might enable Indian farmers to generate high yield and excellent products. Indian research on baby corn concentrated on the effects of fertilizer software and plant growth regulators on growth and production.

In response to Brazilian study on baby corn, the phrase "inexperienced corn," which refers to ears collected when the grain moisture is between 70 and 80%, was developed (Li et al., 2020).

Investigations in Brazil have typically concentrated on the effects of harvesting the first ear of maize while it is still a baby ear on grain maize yield and green ear yield. Additionally, the financial net sales were evaluated in order to determine the best techniques for harvesting baby corn and calculating the profit margin.

Baby corn has been developed as an export crop that can produce foreign currency while also providing more food for the locals, but it has been noted that the quality-restricted clinical research has resulted in insufficient data and a significant loss of time, which prevents the popularization of baby corn production of(Devaux et al., 2021; Kumar & Kalita, 2017 and Singh, 2019). A complete production strategy that includes planting, field management, harvesting, and marketing, is required for baby corn production to be successful. The demand for kid corn, which has become a familiar component of Americans' and Europeans' diets, is rising, yet Asia is the region where the majority of the crop is produced (Roy et al., 2018; Shiferaw et al., 2011, 2013).

Thailand is both the world's largest baby corn exporter and most successful producer. The production of baby corn has consistently changed over the past forty years and is now a lucrative industry. In the year 1973, Thailand exported 9000 cans of baby corn worth $3000, but 25 years later, the charge and quantity increased to 54,643 ton valued at $42.89 million (Warr et al., 2008; Warr & Kohpaiboon, 2007). However, specific baby corn cultivars have been the main focus of academic research in Thailand targeting yield, growth and various agronomic traits (Lavapaurya et al., 1990).

Eight specific baby corn cultivars were utilized by Castro et al.(2013); Dhasarathan et al.(2012) and Subaedah et al.(2021) to study the yield potential, kernel quality, and other traits of baby corn. The fundamental agronomic traits of baby corn have been studied, including first ear height, plant height, type of harvested ears covered in plant, husk weight, ear weights with and without husk, global dry weights, leaf dry weights, grades of harvested ears, leaf position index, and yield. They sought out the cultivar with the widest array of superior, comprehensive features (Dhasarathan et al., 2012)

Other cultivars have been eliminated because they demonstrated improved overall progress on favorable standards but performed poorly on other traits (Morrison-Smith & Ruiz, 2020). However, due to a change in dietary habits from non-vegetarian to vegetarian, rising living standards, and a significant increase in the consumption of baby corn, more people had been emphasizing healthier and better-quality baby corn.

In India, Baby corn production began when farmers and agronomists realized it could be a crop that would increase the financial viability of Indian agriculture (Gürel, 2017). Day et al. (2016) and Gürel (2017) worked to develop a baby corn production method that could be widely adopted and would enable Indian farmers to produce corn with a high yield and exceptional quality.

Additionally, the yield of baby corn increases when intercropped with amaranthus or young gram(Thavaprakaash & Velayudham, 2016), the yields are equivalent to or even higher than those of baby corn alone. Other studies on baby corn in India examined its foliar feeds, the effects of plastic mulch and weed control using bed planting and ridge planting (Kresnatita et al., 2020), the effects of using organic manure on baby corn, and additional studies on crop geometry (Iqbal et al., 2020).

Studies conducted in Brazil on younger maize gave rise to the phrase "Green Corn," which is used to describe ears of maize that have been harvested when the grain moisture is between 70 and 80% (Silva et al., 2006, 2009; Subaedah et al., 2021). The majority of the Brazilian studies focused on the impact of harvesting the first ear of maize when it was still a young ear on subsequent ear yield and grain output. Additionally, the financial net income is calculated in order to choose the best methods for harvesting younger maize and determining the profit margin (Silva et al., 2010).

Brazilian research has become promising, according to Jain et al. (2016), as a result of the country's almost nonexistent production of and rising need for baby corn. Additionally, they observed that removing the first ear of baby corn led to an increase in the production of baby corn, that inflorescences formed later in the season would delay fertilization since there was less pollen available, and that the extraordinary net became economically advantageous.

The United States' output of baby corn might be characterized as "infancy." The largest baby corn importer, is the USA, which spends alot of money each year importing baby corn to meet its needs. Even while little is known about the process, it's interesting to see that USA accounted for almost 20% of the space used for maize production of in the world (DeChristopher & Tucker, 2020;Wang, 2009 and Wang et al., 2010).

Researchers from Washington, Oregon, and Idaho published a paper on baby corn in which they briefly highlighted a few crucial statistics regarding the production of baby corn (Swapna et al., 2020). Wang et al. (2010) summaries proved useful for the current and future production of baby corn, showing that any variety of maize may be used to manufacture baby corn without losing flavor since baby corn is harvested before the reproductive stage, when the kernels start to increase sugar. According to Goyal et al.(2012), baby corn became favorable for its high nutritional value and lack of insecticides since the young ear was tightly enclosed in its husk when it was harvested.

Baby maize manufacture in the US can be characterized as “infancy.” As the largest baby corn importer, America spends hundreds of thousands of dollars per year importing baby corn to suit its needs. Curiously, according to Rouf et al. (2016) and Zhou et al. (2015), America accounted for over 20% of the sector's maize output hectarage. However, in Kenya there are scant records on baby corn production.

2.7 Management Practices

2.7.1 Nutrition Management

Nutrient management is an important aspect of baby corn cultivation, as it plays a crucial role in the growth and yield of the crop. The appropriate fertilizer application can lead to higher yields, better quality produce, and increased profits for farmers. Maize being a very exhaustive crop, fertilizer use plays a great role in increasing maize yield (Lucas et al., 2019) with the most crucial ingredient for crops of baby corn being nitrogen. According to a study done in India, nitrogen application at a rate of 120 kg/ha led to noticeably better yields than nitrogen treatment at lower rates (Roy et al., 2014).

Optimal phosphorus levels are also crucial for the early growth of baby corn crops, as highlighted by a study in Thailand, which indicated that higher yields were achieved with a phosphorus application rate of 60 kg/ha compared to lower rates (Kumar et al., 2021). Similarly, potassium plays a significant role in promoting successful baby corn harvests, as demonstrated by a Malaysian study that observed significantly higher yields when potassium was applied at a rate of 90 kg/ha compared to lower rates (Das et al., 2008). Furthermore, the timing of fertilizer application is an important consideration, with research in India showing that split fertilizer application at different growth stages resulted in higher yields compared to a single application (Srilatha et al., 2013)

The application of 105:70:70 kg/ha of N: P_2O_5:K_2O resulted in considerably greater baby corn plant height, according to Medhi & Dutta (2019). Singh et al. (2001) also noted that plants grow taller as fertilizer amounts are increased. Thus, higher fertilizer levels result in better metabolic processes carried out by the plant, which may be essential for photosynthesis translocation as well as protein synthesis, simulating root growth, activating plant enzymes, and many other processes that ultimately promote vigorous growth of the plant. Similary, the number of cobs per plant, length, and weight of the cob width and without husk responded well to increasing levels of fertilizer doses, the greatest values were seen in all cases.

Application of different nutrient levels and types greatly affects the yield and quality of young maize (Awika, 2011). Food insecurity, which is caused by insufficient output in relation to demand, can be overcome by increasing food production through application of nitrogen fertilizer. A crucial technique for increasing juvenile maize output is a nutrient like nitrogen. This is because every living cell in the flora body actively incorporates nitrogen, which also serves as a critical component of protoplast and chlorophyll.

A group of researchers discovered that there has been a significant increase in interest in using nitrogen in baby corn (Angelakis et al., 2020). Maize is also a labour-intensive crop, thus managing its nutrient requirements requires a lot of care (Day et al., 2016). The amount of applied inorganic fertilizers like urea, TSP, and MAP as well as natural manures like cow dung and vermicompost have a substantial impact on the growth performance and yield of baby corn (Adamtey et al., 2016). According to Anandhi (2015), increasing the N utility charge caused the leaf area index, dry depend accumulation, and net assimilation price of maize to significantly increase at extraordinary increase degrees. It is possible for cover plants (leguminous or non-leguminous cover plants) or young manures (especially leguminous young manures) to completely or partially replace inorganic N fertilizer, particularly for high N-requiring cereal plants like maize, and sell as a result of using sustainable production of techniques.

Since inorganic fertilization is insufficient to maintain the current plant productivity ranges of high-yielding varieties, massive application of nitrogen with a suitable organic manure can be an efficient technique to increase nitrogen use efficiency, soil comfort, and crop yields in baby corn plants(Grote et al., 2021; Kresnatita et al., 2020) thus, integrating organic (FYM) and chemical fertilizers is a cost-effective way to maintain soil quality while also increasing the yield baby corn (Revilla et al., 2021).

The use of intensive cropping equipment necessitates reasonably fertilized soils, which should be maintained using an integrated plant nutrition management system (Olesen et al., 2012). Improved soil tilth, aeration, water retention, and stimulation of soil microorganisms that produce readily available plant vitamins are just a few benefits that organic manure provides (Roy et al., 2018; Singh, Deb, et al., 2020). The soil profile's enzymatic activity may be impacted by fertilizer (Abdul-Baki et al., 1996; Araujo et al., 2017). The amount of soil microbes and enzymes as well as the soil's accessible nutrient levels can be increased with the proper application of natural and inorganic fertilizers (Abrol et al., 2017; Jahan et al., 2018).

(Ibarra-Jiménez et al., 2011; Rychtecká et al., 2013) suggested that combining the use of organic and inorganic fertilizers could boost soil invertase activity and nutrient availability. Additionally, using natural manure in addition to chemical fertilizer can be a fantastic way to maintain and enhance the soil's fertility while boosting fertilizer use efficiency. Because of this, it would be useful to examine the results of applying natural manure combined with chemical fertilizer while also utilizing a nutrient management device, which has been the subject of widespread research (Ibrahim et al., 2021; Kaisrajan & Ngouajio, 2012).

Additionally, applying organic manure can improve soil quality and is more effective in protecting the environment than applying chemical fertilizer alone (Ellis et al., 2006). Typically applied natural manure resulted in soil with reduced bulk density, higher porosity values, and greater porosity and buffering capacities (Awika, 2011). The impact of various nutrients added to soil on the ecosystem of farming was extraordinary (Saritha et al., 2020)

The methods used to treat maize crops, notably the application of fertilizers, have an impact on the yield quality of baby corn (Dhasarathan et al., 2012; Rylander et al., 2020). The most crucial ingredient for maize growth and output is nitrogen (Swami, 2017). Chemical fertilizers enhance maize production, though they may have negative environmental and health implications as well as raise production costs. Thus, wiseutilization of fertilizers from a variety of sources to maintain a healthy and sustainable environment is recommended (Li et al., 2020).

Additionally, consumers who care about their health, the environment, and other factors are becoming more interested in organic agricultural products (Angelakis et al., 2020; Dai et al., 2016). Utilizing organic materials maintains the soil's physical, chemical, and biological characteristics (Ibrahim et al., 2021; Varga et al., 2004). However, the rate of nitrogen mineralization from organic sources is too slow to prevent maize from potentially absorbing too much nitrogen, especially early in the growing season, and to decrease yields (Troyjack et al., 2018).

Achieving sustainable agricultural production and maintaining soil health can be accomplished by adopting a comprehensive approach to nutrient management, as suggested by Castro et al. (2013), which goes beyond exclusively relying on either organic or inorganic nitrogen sources. Demand for maize and nitrogen mineralization are both influenced by the growing season. This is because microbes in the soil (bacteria, fungi, and actinomycetes) are involved in the mineralization process, and their activity is influenced by seasonal changes in soil temperature, water content, and aeration (Adamczewska-Sowińska & Sowiński, 2020).

2.7.2 Baby Corn Plant Spacing

The best crop spacing is one of the key elements for higher output, which results in inefficient use of resources, harvesting more solar radiation, and ultimately better photosynthesis. Although the spacing requirements for grain and fodder maize are clearly documented, similar figures are scant in baby corn. The grain or fodder crop of maize may also moreover be affected by the crop's short duration, the need for nutrient control, and a unique package of methods. Therefore, it's essential to standardize crop geometry and practice feeding young maize with the necessary nitrogen (El-Hamed et al., 2011; Machanoff et al., 2022).

Baby corn production is influenced by a variety of factors including the choice of variety, location, plant density, and management practices (Farid et al., 2014). The optimization of plant population per unit area is crucial in achieving high yields. Each baby corn plant typically produces between two to four cobs per plant. Sparse population can result in larger individual baby corn size, but the overall yield decreases due to a lower number of plants per unit area (BARI, 2008). Conversely, high plant density can lead to smaller baby corn size due to intense competition, but the total yield increases due to the increased plant population (BARI, 2008).

Maize is more sensitive to variations in plant density than other members of the grass family. High densities stimulate apical dominance (Cho et al., 2015). In dense stands, the amount of solar radiation reaching the apical meristems is smaller, and increases auxin accumulation which stimulates internode elongation, increasing plant height and ear insertion height (Zhang et al., 2019). Additionally, increase in plant population results in increased intraspecific competition for water, light, and nutrients, thus reducing the availability of photo assimilate for maintaining vegetative growth, resulting in weakened root and stalk tissues. These traits are affected by the increased plant density, making individuals more prone to stalk lodging and breakage (Sangoi, 2002).

In order to achieve higher ear yields, maintenance of stand density is the most important factor. This is because the spatial arrangement of plant governs the shape and size of the leaf area per plant, which in turn influences efficient interception of radiant energy and proliferation as well as the growth of shoots and their activity (Golada et al., 2013). Thus maximum yield can be expected only when plant population allows individual plant to achieve their maximum inherent potential in relation to other agronomic factors. Therefore, there is need to work out an optimum plant spacing by adjusting inter and intra row spacing in relation to other agronomic factors in order to exploit the full production potential of the baby corn plants.

Studies have shown that wider plant spacing of 60cm by 15 cm resulted in higher yields and improved growth and yield attributes (Prodhan et al., 2007 and Aravinth et al., 2011). Planting arrangement also significantly affects baby corn characteristics, such as plant and ear height, stalk diameter, total number of ears, number of marketable husked ears, fresh biomass, and dry biomass. One study found that a planting geometry of 45cm by 20cm was optimal for yield in four baby corn varieties, with an average yield of 1.5- 2.0 tonnes per hectare (Asaduzzaman et al., 2014).

Srikanth et al. (2009) found that a spacing of 60 cm by 20 cm resulted in taller plants, while wider spacing of 75x20 cm led to a higher number of leaves per plant, stem girth, leaf area index, dry matter production, and yield. Singh and Singh (2006) reported that the highest grain and stover yield were obtained with a plant density of 83,000 per hectare, which resulted in a higher number of harvestable cobs per unit area. However, the development of yield attributes at lower plant density could not compensate for the loss in grain yield due to fewer harvestable cobs. In another study, Kar et al. (2006) found that a spacing of 60 cm by 20 cm significantly increased the number of prime cobs, green-cob yield, net return, and benefit-cost ratio. The highest and lowest ear yield were observed with plant densities of 120,000 per hectare and 90,000 per hectare, respectively, resulting in ear productions of 9987 kg/ha and 8780 kg/ha (Kar et al., 2006).

Singh et al. (2015), reported that plant density affects several traits such as ear number, ear height, leaves number, leaves number above ear, ear leaf diameter, ear length, ear diameter, stalk fresh weight, and husked ear yield. The highest ear per plant (2.3 ear/plant) was observed at a density of 120,000 plants/ha, while the highest dehusked ear yield was at a density of 150,000 plants/ha which then resulted to a mean of 1969 kg/ha. Sarjamei et al. (2014 reported that ear yield was not significantly affected by the planting method. The interaction between plant density and planting method also influenced several traits such as leaves number above ear, ear leaf length and diameter, fresh stalk weight, and diameter (Bernhard et al., 2020).

Crop spacing was also found to significantly affect yield, with the best results observed at a spacing of 60 cm by 15 cm compared to 90 cm by 10 cm. Overall, the studies cited in the passage demonstrate the complex relationships between plant density, planting method, and crop yield in maize (Golada et al., 2013, Thavaprakaash et al., 2008). In contrast, Dar et al. (2014) found that a crop geometry of 50 cmby 15 cm resulted in higher plant height, leaf area index, baby corn, and green fodder yields compared to all other planting densities. Bairagi et al. (2015) observed that planting 2-3 baby corn plants in wider spacing of 45 cm by 30 cm resulted in higher plant height, maize yield, and fodder yield. These studies highlight the importance of crop spacing and planting density in optimizing maize crop yield and productivity. Overall, achieving optimal plant population density is critical in maximizing baby corn yield, and planting arrangements should be carefully considered to achieve desirable plant characteristics and yield.

According to Grote et al., (2021) and Zhou & Wang (2010), normal spacing of 60-20 cm was associated with taller vegetation, whereas wider spacing of 75-20 cm was associated with greater diversity of leaves/plants, stem girth, leaf area index, dry be counted production of, yield contributions, and yield. This is likely due to the higher density of harvestable cobs per unit area. The loss in grain production caused by the significantly reduced number of harvestable cobs in the vicinity of the unit could not be made up by the superior improvement of yield attributes at lower plant density (Awika, 2011).Araujo et al., (2017) reported crop geometry ranges under 60 by 19 had higher yields of green cobs and baby corn than ranges under 45 by 25.

According to Angelakis et al., (2020), the best ear per plant yield of 2.3 was recorded using a plant population of 120,000 plants per acre. The interaction between plant density and planting method results in a variety of leaves above the ear, ear leaf length and diameter, and brilliant stalk weight and diameter laying low. The highest dehusked ear yield was generated utilizing 150,000 plants per ha with an anticipated yield of 1969 kg per ha. The ear yield was unaffected by the current planting technique (Oughton & Ritson, 2007; Rani et al., 2019).

Crop spacing of 60 by 15 cm significantly boosts yield. Maximum baby corn production, young cob yield, and green fodder output were all recorded at 60 x 15cm spacing, which was superior to 90 cm x 10 cm (Angelakis et al., 2020; Hossain et al., 2011). The most important thing to maintain stand density for is improved ear yields. The shape and size of each plant's individual leaf determine its ability to intercept solar energy, as does the number of shoots that each plant produces and the rate at which they grow. Thus maximum production may be predicted most accurately when plant population permits each plant to reach its full intrinsic potential (Liang& Wang, 2020; Roy et al., 2018 and Vigne, 2015).

Sardar et al. (2020) adopted the term "crowding" to explain the spatial measurements of the geometric interactions among maize plants in a planted design. His theory on conflict between adjacent plants recommended maintaining a “minimum measurable distance”, at which time the spacing between any flora is exquisite enough to make any crowding implications insignificant. Modern hybrids often maximize their production under precise conditions at populations ranging from 81 500 to 108 700 plant life ha^{-1} dependent on maize grain and seed prices (Kader et al., 2017). Burrows et al. (1990) and Dukare et al. (2020) claimed that uniform spatial distribution of these vegetation in the stand might be expected to reduce plant-to-neighbour competition by enabling the most effective use of available light, water, and nutrients. Growing plant populations eventually cause a decrease in the amount of plant-to-be-had, inside-row area.

Mixed findings emerged from study on yield and how it responds to consistent, within-row plant spacing. Early investigations looking at spatially homogeneous stands discovered minor, subpar results on the last grain yield (Freedman & Keast, 2011; Grossnickle, 2012; Leskovar et al., 2001; Ngongo et al., 2021; Ohlhorst et al., 2012). Contrarily, other researchers have shown that uneven plant-to-plant spacing lowers grain output. Extra within-row spacing variability is typically connected with lower yields, according to research conducted in Kansas on a variety of plant varieties commonly seen in farmers' fields (El-Hamed et al., 2011; Onwuka, 2016). This earlier work was confirmed by (Rosen et al., 2012), who demonstrated that grain yield responded favourably as the character physical distance between subsequent inside-furrow seeds become progressively identical.

There are some historical principles that need to be taken into account in order to comprehend the impact character maize flora's placement in relation to their within-row companions has on the yield of the plant. The division of photosynthetic assimilates between the yield additives kernel amount and kernel weight is one of those principles. Others include crop stand established order, population, row spacing, inside-row spacing, inter-plant opposition, and row spacing. Some of those principles influence how much row space is allotted to each plant, while others are taken into account because of their potential to influence each plant's final production (Singh et al., 2020).

According to Kumar & Bohra (2014); Olesen et al. (2012) and Sardar et al., (2020), maize plants' ability to absorb nutrients depends on how much space they have between rows. Their experiment in Guelph used a single hybrid planted at densities of 50 000, 100 000, 150 000, and 200 000 plants ha^{-1}. The harvesting process involved weighing and measuring the entire plant, including the leaves, stems, silks, and many other components. They discovered that the coefficients of variation for grain yield consistent with plant, kernel number, and kernel weight significantly increased as inside-row area consistent with plant dropped, leading to high variability in plant-to-plant performance down the row (Ginigaddara & Ranamukhaarachchi, 2017).

Kernel boom slows from the top to the base of the ear as a result of a decrease in the delivered captured assimilate for ear boom. Boom which then comes to an end once the deliver level is reduced below their combined need for assimilates. Extra inside-row area in plants could mean more absorb nutrients, more kernels, and heavier kernels (Burrows et al., 1990; Mishra & Salokhe, 2008).

Liang & Wang(2020) defined opposition as the decreasing impacts on a single maize plant's yield brought on by elements such as the environment, the planting pattern, and how many and how close the neighbouring maize plants are. Therefore, in an evenly spaced hexagonal configuration, congestion might be at a minimum. According to his theory, competition among maize blossoms was characterized by "crowding" and the "impact of crowding," distance-derived additives that had a minimal impact on other plants while friends were separated by a minimum distance. Zhou et al.(2015) found an inverse link between the logarithm of common individual maize plant yield and plant population expansion, was supported by his theory. While this pattern of grain yield being consistent with plant was maintained even at high populations, Zhou & Wang (2018) also noted that grain yield values at the best populations had a tendency to diverge more from the regression line than at other populations.

Plant-to-neighbor crowding had no influence over assimilate partitioning, according to the harvest index measurements. According to their research, plant-to-plant conflict that occurs at V5 before anthesis and anthesis before grain filling had the worst effects on the final grain yield (8 to 21% and 6 to 22%, respectively) (Iqbal et al., 2020). According to Adamczewska-Sowińska & Sowiński, (2020; Singh, (2020) Lavlesh, et al. (2020), inside-row spacing variation affects the phenological and ontogenetic characteristics of each crop species and its cultivars, which in turn affects by-plant grain yield.

In Argentina, Babatunde et al.(2020) assessed the impact of population changes on within-row crowding on agricultural productivity. They sought to determine the significance of such reaction by examining how a hybrid's function, biomass plasticity, and assimilate partitioning to reproductive organs. Their investigations used hybrids with various adulthood instructions that were sown at several populations between 40,000 and 150,000 vegetation ha^{-1}. As a result of low biomass plasticity, which restricts their ability to intercept solar radiation at low populations, their findings showed that maize production responded to plant density, and that the degree of that reaction accelerated in shorter season hybrids.

Extended season hybrids have greater reproductive sink capabilities, enabling them to compensate for crowding within the range of densities by increasing kernel weights (Babatunde et al., 2020). This study offers preventative advice to manufacturers whose fields frequently exhibit high inside-row area well-known deviation. Longer season hybrids are encouraged for planting in order to reduce biomass and yield variability from plant to plant (Ginigaddara & Ranamukhaarachchi, 2011; Williams, 2008).

2.7.3 Detasseling

This consists of removing tassels before the pollen is released. Detasseling of baby corn is important as the product is rendered useless for the market once the kernels are formed.

However, the practice has either positive or negative effects on baby corn yields depending on both genotypic and environmental factors (Pereira et al., 2005). Thus it is an essential operation for baby corn production to ensure better quality cobs (Moreira et al., 2010). It is used in baby corn production to prevent pollination of silks, stimulate earlier harvests, increase prolificacy and increase ears yield (Ackatasawan 2001). This operation has to be done on daily basis until all the plants have been detasseled. Detasseling leads to an increase in ear total number, ear total weight, number of marketable unhusked ears and weight of marketable unhusked ears though there was no change in the number and weight of marketable husked ears (Moreila et al., 2010). Similarly, detasseled young maize plants significantly produced more cobs per plant (2.87), longer cobs (8.29) and heavier cob (16669.53 kg/Ha) than tasselled plants (Managaser, 2013). This was also confirmed by Moreira et al. (2010) who found that detasseling significantly increased the ear total number and ear total weight which contributed to higher final grain yield.

2.7.4 Harvesting

Baby corn is a high value crop which gives returns in 60 – 63 days. This should be done one to two days after silk emergence while the ears are still immature (Bairagi et al., 2015). Harvesting should be done after every 2 to 3 days as they grow too fast hence becoming unmarketable (Chutkaew and Paroda 1994). To achieve the preferred market, baby corn ears should be 10 to 12 cm long and 1.0 cm to 1.5 cm diameter and a weight of 7-8 g (Golada et al., 2013). The harvesting period lasts for 2 to 4 weeks resulting in 9 – 12 harvesting times resulting to a yield of 10 tonnes per hectare of unhusked baby corn ears (Milles and Shaffner 1999). Most varieties produce 2-3 ears per plant; however, the quality of the third ear may not be fully satisfactory.

2.8 Baby Corn Ecological Requirements

2.8.1 Soil temperature

Soil temperature is another important factor that can affect the growth and yield of baby corn. Soil temperature is a critical factor that can affect the germination of baby corn seeds. Optimal soil temperature conditions are essential for ensuring good seed germination and emergence, as well as for promoting healthy plant growth and development.

Amanullah et al. (2015) reported that baby corn seeds generally germinate best at soil temperatures between 25 and 30°C with an emergence rate of up to 87%. However, soil temperature conditions that are too low or too high can have negative effects on seed germination and emergence. Lower temperatures can lead to delayed germination and poor seedling emergence, while higher temperatures can lead to reduced seedling emergence and poor seedling growth. Baby corn seed germination rates have been found to significantly reduce when soil temperatures fell below 20°C (Azam et al., 2017). On the other hand, soil temperatures above 35°C led to reduced germination rates and poor seedling emergence in baby corn (Sarwar et al., 2015).

Soil temperature also significantly impacts the growth and development of baby corn plants. Different temperature regimes can influence the physiological and biochemical processes that occur during plant growth, including photosynthesis, respiration, and nutrient uptake. Baby corn plants generally grow and develop best at soil temperatures between 25 and 30°C (Amanullah et al., 2015). These conditions promote optimal photosynthesis, water uptake, and nutrient absorption, which are all important for healthy plant growth and development.

However, if soil temperatures exceed this range, they can have negative effects on baby corn growth and development, high soil temperatures (35°C or higher) can cause water stress and reduce photosynthetic activity, ultimately leading to decreased plant growth and yield (Sarwar et al., 2015). Conversely, if soil temperatures fall below the optimal range, they can also have negative effects on baby corn growth and development. Kolář et al. (2020) found low soil temperatures (below 20°C) reduced photosynthetic rates and slowed down the overall growth and development of baby corn plants.

Optimal soil temperature conditions promote good germination, plant growth and development, nutrient uptake, and ultimately, higher yield. A study conducted by Kaur et al. (2017), reported that the highest yield of baby corn was obtained when the soil temperature was maintained between 20-25°C, and the cob weight was positively correlated with soil temperature. Another study conducted by Debnath et al. (2015) showed that baby corn yield was significantly higher when the soil temperature was maintained at 20-25°C, and the cob weight was also positively correlated with soil temperature. The study reported that the highest yield of baby corn was obtained at 25°C, with a cob weight of 7.29 g, whereas the lowest yield was obtained at 30°C, with a cob weight of 4.33 g. The study also reported that the cob weight decreased significantly at temperatures above 25°C, indicating that there is an optimum range of soil temperature for achieving maximum cob weight. Sarwar et al. (2015), found that baby corn yield decreased significantly when grown in soil temperatures above 30°C, with yields dropping to as low as 1.3 t/ha at 35°C

Rahman et al. (2017) showed that the highest cob diameter was obtained when the soil temperature was maintained at 25°C. The study reported that the cob diameter increased significantly from 10.56 mm to 13.05 mm as the soil temperature was increased from 20°C to 25°C. However, the study also reported that cob diameter decreased significantly at lower and higher soil temperatures. The highest yield of baby corn was obtained at 25°C, with a cob length of 10.53 cm, whereas the lowest yield was obtained at 30°C, with a cob length of 8.15 cm (Debnath et al., 2015). The study also reported that the cob length increased significantly as the soil temperature was increased from 20°C to 25°C, beyond which it decreased significantly, indicating that there is an optimum range of soil temperature for achieving the maximum cob length.

2.8.2 Soil pH

The pH of the soil affects the availability of nutrients, mineral uptake, and overall plant health, which can have a significant impact on the yield and quality of baby corn production. The optimal pH range for the growth and development of baby corn is 6.5–7.5. This range provides a favorable environment for other crucial micronutrients needed for healthy baby corn plants while also guaranteeing the availability of vital minerals including nitrogen, phosphorus, and potassium.

A study by Raza et al. (2020) in Pakistan, found that the highest yield of baby corn was obtained in soils with a pH range of 6.5-7.5. Similarly, a study by Jain et al. (2016) in India showed that baby corn yield was significantly higher at a soil pH of 6.5-7.5 compared to lower or higher pH ranges. This optimal pH range was due to the availability of essential nutrients such as nitrogen, phosphorus, and potassium in the soil.

However, other studies have reported contrary results. Ramachandrappa et al. (2004) found that baby corn yield was highest in soil with a pH range of 5.5-6.5. He attributed this to improved availability of micronutrients such as iron, manganese, and zinc, which are essential for baby corn growth and development.

2.8.2.1 Soil moisture

Baby corn needs the right amount of soil moisture for optimum growth and development. The appropriate amount of soil moisture for the crop relies on a number of variables, including the kind of soil, the climate, and the growth stage. Thus, adequate soil water supply is essential for the crop to develop healthy roots and leaves, as well as to produce high-quality maize ears. Irrigation is a critical factor in the growth and development of baby corn. However, excessive water can lead to waterlogging and root damage, while insufficient water can cause stress and affect yield. However, the growth and development of baby corn can be considerably impacted by various soil moisture levels.

Rainfall is also a critical factor that influences the growth, development, and yield of baby corn. Adequate and timely rainfall is essential to ensure optimum plant growth, efficient nutrient uptake, and high-quality produce. On the other hand, insufficient or erratic rainfall can lead to water stress, reduced yields, and poor quality crops. Baby corn requires a moderate amount of rainfall during the growing season, which typically lasts for 60-70 days. The ideal rainfall range for baby corn cultivation is between 600-800 mm, with an even distribution throughout the season (Kumar et al., 2017). However, the rainfall requirement may vary depending on factors such as soil type, temperature, humidity, and crop management practices.

In regions with low rainfall or erratic distribution, supplemental irrigation may be necessary to meet the crop's water requirements. Studies have shown that the application of irrigation at critical growth stages can significantly enhance baby corn yield and quality (Mahajan et al., 2007). Drip irrigation is a popular method for supplying water to baby corn plants as it conserves water, reduces weed growth, and improves nutrient uptake efficiency (Bhowmik et al., 2008).

A crucial element in the growth and development of baby corn is the volume of irrigation water. For the crop to grow and yield at its best, the optimum soil moisture levels are necessary. This is because growth and development of the plants can be severely impacted by excessive or insufficient soil moisture levels, which can result in decreased maize production and quality.

Excessive soil moisture can lead to waterlogging, which can suffocate the roots of baby corn plants and reduce their growth and yield. Li et al. (2019), found that waterlogging significantly reduced the growth and yield of baby corn. The study suggests that avoiding waterlogging is essential for maximizing baby corn yield.

Eghball et al. (2018), reported that maintaining soil moisture at an optimal level (around 60% of field capacity) resulted in the highest yield of baby corn. The study suggests that farmers should strive to maintain soil moisture at this level to maximize baby corn yield. Under low water stress conditions, where baby corn is irrigated regularly with sufficient water, the crop exhibits optimal growth and development. This results in plants having a higher leaf area index, larger shoot biomass, and a higher yield compared to other irrigation regimes. Additionally, the quality of the maize ears is also better, with higher sugar and protein content. According to a study by Rashid et al. (2019), the growth and production of baby corn are greatly impacted by varying irrigation water levels. The study discovered that a water application rate of 80% of field capacity produced the maximum yield of baby corn. Additionally, waterlogging and root damage caused by high irrigation water levels lowered baby corn's performance.

Baby corn plants irrigated at 100% field capacity had higher plant height, leaf area, and yield compared to plants irrigated at 50% and 75% field capacity while water stress during the reproductive stage significantly affected the yield of baby corn (Choudhury and Singh 2022). In moderate water stress conditions, where the crop is irrigated less frequently with lower volumes of water, the growth and yield of the baby corn are reduced. The plants are smaller, with lower leaf area index, shoot biomass, and yield. The quality of the maize ears is also compromised, with lower sugar and protein content.

In severe water stress conditions, where the crop receives minimal or no irrigation, the growth and development of the baby corn are severely affected. The plants are stunted, with a lower leaf area index, shoot biomass, and yield. The quality of the maize ears is also poor, with reduced sugar and protein content. Hasanuzzaman et al. (2016) found that the highest yield and quality of the maize ears were obtained with moderate irrigation water levels, while excessive or insufficient irrigation water levels significantly reduced the yield and quality of the maize ears.

2.9 An Overview of Research Variables

Baby corn has developed into an exportable produce that increases locals' access to food while also bringing in foreign currency. Despite this, there are only a few limited experimental trials that have been referenced in the best possible performance scenarios for this crop. Due to this, the production of baby corn has become less common due to a lack of agronomic technology and limited knowledge (Rani et al., 2019; Ranjan & Sow, 2021).

Greater research is needed to increase baby corn's productivity through improved agronomic management since it has become a crucial crop for Kenya's horticultural export market. Although it is typically farmed for the export market, it has recently become a common ingredient in many of the regional dishes in Africa, especially in the urbanized areas. The size of production of in Kenya is still little since the production of baby corn isn't well connected. The crop is specifically grown for export with little to no consumption in the local area(Adamtey et al., 2016).

2.9.1 Transplanting

Baby corn can be planted through either direct seeding or transplanting methods. One of the main issues affecting productivity has been put up by horticulture farmers and agronomists as transplanting age (Jan et al., 2022). Transplanting involves carefully moving seedlings at the proper stage from the nursery to the planting site. This is because growth and development of baby corn are known to be influenced by multiple factors and amongst them being selection of cultivars for a given set of environment are the major aspects besides soil fertility, temperature regimes, solar radiations and irrigation. All of which play a very important role in exploiting good crop growth and development. Different hybrids and composites have different yield potentials, quality and varying maturity periods and have been developed and released on the basis for different agro climatic conditions (Ranjan & Sow, 2021).

It is currently accepted knowledge that growers of pure market sweet corn are motivated by obtaining the best prices at the youngest possible age. Anywhere, poor soil and air conditions limit the earliest practical planting season (Rylander et al., 2020). Many studies have focused on seed management techniques, but little is known about the use of transplanting practice to reduce the time between planting and harvest. The transplanting process is frequently used in the production of vegetable plants and rice. For filling up gaps following crop emergence or making up for short growth periods, transplanting is a common practice in some parts of Africa and Asia where sorghum and millet are grown.

Transplanting is a commonly employed technique for various valuable food crops (Kwabiah 2004). Transplants are utilized to establish plants under less favorable conditions, including protection against birds, soil-borne pests, and water scarcity (Kumar & Kalita, 2017). However, several factors, such as soil moisture, nutrient levels, temperature, light, and cultural practices, contribute to the preference for seedling transplantation (Bisgaard, 2015). Transplanting stage is determined by many factors including the type of crop, variety, intended use and the environmental factors. Thus, seedlings from the Solanaceae and Brassicaceae plant families are transplanted at an optimal age of 5-7 weeks, while those from the Poaceae and Cucurbitaceae families are transplanted at an optimal age of 3-4 weeks (Gavric and Omerbegovic, 2021).

Planting time is one of the key points in crop management for optimizing productivity whereby early planting of maize is preferable because of utilization of the entire growing season, achieving physiological maturity before frost, and proper drying, thereby increasing profit through reduced drying costs and allowing greater profit margin (Monicah et al., 2017).Thus transplanting date is probably the most subject of variation because of the very great differences in weather at planting time across seasons and within the range of climates but year to year variation in plant establishment, pest and disease incidence make it difficult to predict optimum transplanting dates for maize crops(Oktem, 2010). Accordingly planting date of sweet corn not only effects seed germination, but the whole phenological stages (Tsimba et al., 2013).

Monicah et al. (2017) found that Misthi variety of sweet corn registered its numerical superiority in all the phenological parameters like yield, uptake of nitrogen, phosphorus and potassium as well as significantly superior in days taken to 50 % tasseling, cob girth, number of grains/row, number of grains/cob row and phosphorus uptake in stover and potassium uptake in grains against other varieties due to changes in planting dates. Additionally, the cultivar Misthi took maximum days (60.71 days) followed by cultivar Sugar-75 (60.32 days) and Gold star (60.21 days) to attain 50 per cent silking in decreasing order of number of days, respectively. This variation in the number of days taken to tasseling and silking was due to genetic variation of the different sweet corn cultivars as well as the difference in planting dates (Khan et al., 2009).

Transplanting is a common agricultural procedure used to increase the reliability and earliest harvest of vegetables and cereals. In Florida, it was shown that transplanting vegetables was the main factor influencing the rise in returns for watermelons and muskmelons (Gayatonde, 2016; Ibarra-Jiménez et al., 2011; Wang, 2010). However, because to their larger top-to-root ratio, slower rate of root regeneration during transplantation, and decreased nutrient uptake using the older roots, some vegetables, such sweet com, are viewed as being "difficult to transplant" (Li et al., 2018).

In the cultivation of sweet corn, transplantation is no longer a typical practice. This is due to the challenge of establishing transplants after the critical two-week mark and the unpredictable nature of the early spring soil temperature (Ellis et al., 2016). Sweet corn transplants older than three weeks often had a poor boom rate and decreased yield, according to (Swapna et al., 2020). This might be because the roots of older seedlings sustain additional harm during a transplant shock's development.

The age of transplant is one of the factors which affect plant growth and grain yield; but it is ignored by the farmers during transplantation. The optimum seedling age to be used depends on the edaphic and climatic (temperature and moisture) factors, location and cultural practices (Weston, 1988). Hence, knowledge on the optimum age of transplant helps to understand the relationship between the physiological state, survival rates in the field and growth responses of the transplant under various cultural systems and environmental factors (Shukla et al., 2011). With variable degrees of success, various researchers have studied the use of transplants for early harvest. According to (Iqbal et al., 2020), maize grown on exposed plots was harvested 7 to 21 days later than sweet corn planted in plastic. Ibrahim et al.(2021) found an earlier maturity of 10 to 15 days in France, whereas Raggio Aonso & Gámbaro (2018) in Canada's Atlantic province revealed an earlier maturity of 7 to 12 days with transplants as compared to direct seeded maize.

With variable degrees of success, various researchers have studied the use of transplants for early harvest. According to (Bradford et al., 2019), maize grown on exposed plots was harvested 7 to 21 days later than sweet corn planted in plastic.

Compared to direct-sown plants, mature transplants are shorter, claims (Hooda & Kawatra, 2013; Kader et al., 2019). According to Castro et al. (2013); Kumar & Bohra (2014); Rani et al.(2019); Wang (2009) and Wang et al.(2010), mature maize produced from transplants can reach a maximum height of 116 cm, whereas plants that are directed seeded reached a height of 141 cm. The drop in transplant growth was attributed to cooler temperatures at a period when flowers were just beginning their reproductive cycle and the loss of leaves on transplanted plants.

Balliu et al. (2019) identified transplant shock, diminished root boom, and loss of older leaves on transplanted baby corn as the causes of the shortness of mature transplants. As compared to vegetation that was directly sown, the ear development of such plants took 12 to 20 days less time. Age at transplant is a major factor in the reduction in yield of many plants. According to Basnet, (2022), maize seedlings transplanted at five days old had a 14.7% higher yield than seedlings transplanted at 10 days old.

Transplanting is a common practice intended to improve vegetable reliability and decreasing cost of production (Balliu & Sallaku, 2017). However, some vegetables, like baby com, are perceived as "hard to transplant" because of their higher top-to-root ratio, lower rate of root regeneration during transplantation, and decreased uptake of nutrients through the older roots (Leskovar et al., 2021).

The use of transplants during the production of baby corn is not a common practice. This is a result of the difficulty in transplanting past the crucial age and the unpredictability of the soil temperature (Ferrari et al., 2018). According to Bradford et al. (2019), baby com transplants that were older than three weeks had a low growth rate and a lower yield. This was due to older seedlings' roots being damaged more severely with subsequent increases in transplant shock (Murphy et al., 2019).

Various researchers have conducted studies on the use of transplants for early harvest, with varying degrees of success. Araujo et al. (2017) and Kwabiah (2004) proposed that baby corn grown under plastic should be harvested 7 to 21 days earlier than candy maize produced on open plots. According to Luchsinger et al. (2019) transplanting age and time, affected yield and ear attributes of transplanted sweet corn. When compared to maize that was planted directly, transplanted baby corn has been proven to produce lower yields (Castro et al., 2013 and Shrestha et al., 2021). Additionally, ears from transplants tended to be shorter, less beautiful, and less marketable (Abrol et al., 2017).

According to Huang et al.(2020) and Mishra & Salokhe, (2008), mature transplants are shorter than direct sown plants (120 cm vs 185 cm). The same approach was recommended by Ranjan& Sow, (2021) and Rylander et al.(2020), recommended a maximum flowering height of 116 cm for mature maize grown from transplants and 141 cm for directly seeded. Gürel, (2017) and Went (2003) ascribed transplant shock, reduced root boom, and a lack of older leaves on transplanted baby corn to be the cause of shortness of mature transplants. According to Sardar et al.(2020), maize seedlings transplanted at five days produced a 14.7% higher yield than seedlings transplanted at ten days.

A study conducted by Yigermal et al. (2021) found that transplanting of polybag seedlings at four true leaf stages is economically feasible and can be recommended tentatively for maize production in the study area and similar agro ecologies. Thus the highest cob length was recorded from transplanting of four true leaf seedlings (25.47cm) followed by the control (23.53cm) and transplanting of five true leaf seedlings (23.47cm) which was also at parwith transplanting of one and three true leaf seedlings, while the lowest (21.67) cob length was observed from transplanting of two true leaf seedlings.

In maize, late-maturing and high-yielding cultivars can be accommodated within a short growing season depending on rainfall and temperature, as transplanted maize has been found to have a shorter duration of growth in the area (Babatunde et al., 2020). It is generally acknowledged that use of the optimum transplantation age, maximizes the production of potential (Vavrina, 1998). According to Adesina et al. (2014) and Singh et al. (2013), proper transplanting age can improve crop growth, production, and exceptional.

In maize, transplanting nine-day-old seedlings offers a superior plant height; leaf area, root period, and overall dry count yield (Adesina et al., 2014). The 4-leaf seedling stage has been demonstrated to be the best transplanting stage for maize, resulting in satisfactory seedling status quo and agronomic performance. Ginigaddara & Ranamukhaarachchi (2015) reported that seedlings that were more than 20 days old significantly reduced the amount of grain produced.

Similar to this, every other study found that transplanting 21-day-old maize seedlings had worse vegetative growth, earlier blooming, and later maturation than direct-seeded crop (Kwabiah, 2004). According to Rosen et al. (2016), compared todirect seeded maize, the maturity period of 14 and 21-day transplanted seedlings fell by 8-10 days and 13-15 days respectively. Sardar et al. (2020) claimed that transplanting 21-day seedlings produced an equal amount of grain compared to direct-sown crop that reached maturity 8–10 days early.

Time to harvest of maize was shortened by one to three weeks within the USA and by 10 to 12 days in France, depending on the age of transplants (Rosen et al., 2016). In long and short wet seasons, respectively, transplanted maize produced grain yields that were 14.7% and 11.5% higher than direct seeding respectively (Burrows et al., 1990). At the same time, a study on the effects of transplanting and seedling age on grain yield and its additives of a few maize cultivars revealed that grain yield from transplanted crops was around 15.44% higher than that from direct sowing, while grain yield decreased as seedling age increased. He also noted that under circumstances of delayed planting, maize transplantation could present a chance for directed sowing. It is clear that transplantation now-rather than directly seeded maize-has higher agronomic effects (El-Hamed et al., 2011).

Greater uniformity of the fields, better control of crop density, and improved yield are all advantages of transplanting practice (Swami, 2017). In his classic paintings on transplanting, Loomis, (2015) put up three transplantation guidelines: one that is easy to transplant and does so successfully; a middle-of-the-road institution; and a difficult-to-transplant category. Cabbage, tomatoes, lettuce, cauliflower, and beets all made it through the transplanting process with flying colours. There are peppers, onions, celery, and eggplant at the intermediate institution. It is challenging to transplant beans, maize, cucumbers, and melons. Survival after transplantation is highly correlated with the simplicity of the root alternative (Ranjan& Sow, 2021).

Especially in commercial plantings of high-value vegetable plants, transplanting is a reliable way to guarantee adequate crop status quo. For commercial vegetable farmers, the production of transplants is a highly competitive industry where the ability to deliver the requisite quantity and quality of transplants at a specific time is crucial to maintaining customer satisfaction. Baby corn transplantation is still not a common practice because it drives up production of costs (which includes labor) and impedes plant development due to poor regeneration (Araujo et al., 2017).

In an effort to increase stands and speed maturation, sweet corn has been transplanted. According to research, there are noticeable differences in the likelihood that different vegetable species will survive after being transplanted, particularly if the roots have been damaged or the weather is unfavorable. However, it was noted in India that maize may be successfully transplanted throughout the country's winter (Zribi et al., 2015). Through the use of transplanting, maize crops can also be established considerably earlier and may even offer better results (Kaisrajan & Ngouajio, 2012).

Setting up the best baby corn transplanting age beneath successful farmer settings in Meru County is one of the goals of this study.

2.9.2 Growing Degree Days

Tropical maize is more sensitive to temperature than cool-season vegetation like baby corns because it has adapted for being produced in temperate regions for a long time. Heat affect growth and development and is used to forecast phenological events for plants across the study period (Pregitzer & King, 2005). Depending on how much heat is captured by the plant, it affects maize development throughout the entirety of its life cycle, from emergence through tasseling, silking, and grain filling to physiological stage (Bradford et al., 2019).

Temperature controls the development of many organisms that do not have complex thermoregulatory systems. This allows scientists to predict the development of different organisms by accurately using development or phenology models that are based on the accumulation of heat units (growing degree days) during a growing season. These sorts of models have been developed for many plants. This is because temperature significantly affects phenology, leaf expansion, internodes elongation, biomass production, and the partitioning of assimilates to different plant parts (Kaushal et al., 2016). Thus in many plants, phenological transitions happen when enough warmth has accumulated. For that matter, crop development can be estimated using the accumulated degree days throughout the season as each phenological stage of the crop is achieved due to the attainment of a certain heat sum (Pallavi, 2018). Temperature being the most important factor throughout the growing season, then different types of maize can be expected to reach adulthood after accumulating different amounts of thermal units, also known as growing degree days (GDD). GDD is the number of degrees the average daily temperature exceeds a base temperature of a certain plant. It is a type of temperature summation used in numerous studies to forecast phenological events for horticultural and agronomic vegetation across the study period (Pregitzer & King, 2005).

Thus the growing degree days GDD are a measurement of the total number of days needed for a plant to grow by thermal means alone. Hence the influence of temperature on phenology and yield of crop plants can be studied under field condition through accumulated heat units system (Nishad et al., 2018) In comparison to other environmental parameters (photoperiod, water, sun radiation, and soil fertility), temperature typically has the greatest impact on the phenological phenomena of plants (Onwuka, 2016; Swami, 2017). For agricultural growth models, the effect of temperature on vegetation is of significant importance (Subedi & Ma, 2011).

Organisms' growth as well as development occurs between two cardinal temperatures, a base temperature (T_b) and a maximum lethal temperature (T_{ml}). Thus development is assumed to be zero at T_b and reaches maximum at an optimum temperature (T_{opt}), before falling again to zero at T_{ml}. This is the basis of using GDD to describe and predict crop development.

Thermal time is a measure of crop development rate. It is independent of the temperature regime, in which the crop is grown, thus can be used to predict crop development more reliably than calendar days (Stone at al., 1999). Estimating heat units or accumulated degree-days provides a more biologically accurate snap shot of an organism's stages of development than using calendar days based upon variations in yearly climate records. While organisms will grow faster in warmer temperatures, and they are exposed to greater heat for fewer days, the net accumulation of heat units (degree-days) required for development is about the same as for organisms developing under cooler conditions for more days (Fatima et al., 2020). Since temperatures fluctuate from cool to hot during a growing season, it is the total heat accumulation derived between the lower and upper threshold temperatures for each plant species that determines the time to complete development. In some cases, GDD is used to describe the timing of certain physiological processes, estimate or predict the length of each growth stage and also to determine the appropriate harvesting time for the best outcome when selecting an appropriate planting date (Hadi and Abdullah, 2018).)

The GDD index used is as shown below:

$$\text{GDD} = \left[\frac{(T_{\text{MAX}} + T_{\text{MIN}})}{2}\right] - T_{\text{BASE}}$$

T_{MAX}=maximum daily temperature, T_{MIN} =minimum daily temperature T_{BASE}= base temperature for maize development, which is 8°C (Torres-Olivar et al., 2016).

GDD units are summed from planting to maturity where if $T_{MAX}<T_{BASE}$, then $T_{MAX}=T_{BASE}$, and if $T_{MIN}<T_{BASE}$, then $T_{MIN}= T_{BASE}$. However, $T_{MAX} = 30^oC$, $T_{BASE} = 8^oC$ and 41^oC considered as T_{ML}. Plant development ceases when a temperature falls below a lower threshold T_{BASE}, and also begins to decline and ultimately stop development when the temperature exceeds an upper threshold T_{ML}.This is the most commonly used method in calculating GDD for maize and other

crops as well (Zhou & Wang, 2018). Accumulated GDD are useful in tracking the development of several important crops and insect pests. More importantly, GDD can be used to predict plant growth rates, maturity, harvest dates as well as well as the yield (Salazar-Gutierrez et al., 2013 and Subrahmaniyan et al. 2018). Apart from that, GDD has been used for the characterization of maize development and classifying maize hybrid maturities. This is because different crop varieties are differently sensitive to temperatures and require specific accumulated heat units for growth. Accordingly, Khade et al., 2021, found that different groundnut varieties have different GDD where the total GDD requirement of SB-XI is greater than TAG-24 and LGN-1. This applies to different crops.

The length of time it takes for transplants to complete their life cycle has been the primary focus of much of the research work. However, it is important to consider how the transplanting level affects the amount of accumulated warmth a maize plant needs to complete its life cycle. This is because warmth (temperature) is an increasing factor as opposed to time. In order to achieve better results than direct seeded maize, the examination thus provides a chance to evaluate the timing of the transplanting level, accumulated warmth devices, and their impact at the plant life agronomic dwellings (Rylander et al., 2020 and Zhou & Wang, 2018).

2.9.3 GDD under Green House Conditions

Growing degree days (GDD) commonly referred to as heat units, can have a significant impact on the growth and development of crops, such as baby corn (*Zea mays* L.). Growing degree days (GDD) are used to connect a plant's growth and development to air temperature and are also known as developing degree devices (GDU) or warmth devices (HU) (Sepat et al., 2019). It is determined by computing the average daily air temperature, which is obtained by subtracting a base temperature for the particular crop from the daily maximum air temperature and daily minimum air temperature. The minimum temperature for maize is 10^0 C (Torres-Olivar et al., 2016). The GDDs are restricted at a maximum temperature of 30^0 C.

The GDDs are amassed throughout the course of the season. The GDD is zero if the daily average air temperature is below the base temperature. Even in Langdon, which is quite near the Canadian border, the GDDs are lower than in Fargo, North Dakota, where the average GDD is over 1300 (Zhran et al., 2013).

Greenhouse conditions can have an impact on how GDD accumulate and ultimately affect crop yield. Ranjan & Sow (2021) found that baby corn's GDD accumulation was affected by greenhouse conditions. According to the study, compared to open-field circumstances, greenhouse conditions, such as high temperature and humidity, led to a larger buildup of GDD. They hypothesized that the greenhouse's regulated climatic conditions boosted the buildup of GDD, which could cause baby corn to grow more quickly and reach maturity earlier. In comparison to calendar-based scheduling, the study indicated that GDD-based scheduling, which considers the cumulative influence of temperature on crop growth, produced higher yields and higher quality crops (Ranjan & Sow, 2021). Therefore, the timing of baby corn production in greenhouse environments can be optimized based on GDD scheduling (Wang et al., 2021).

Salehi et al., (2020) realized that greenhouse cultivation yielded and produced baby corn of higher quality and yield than open-field farming. The scientists hypothesized that the improved production of baby corn was a result of the greenhouse's controlled environmental factors, including temperature, light, and CO_2 concentration. Additionally, employing a semi-transparent greenhouse design, this allows for natural light penetration and lowers energy use, led to a higher yield and higher quality of produce than using a conventional greenhouse design (Wang et al., 2021). However, producing baby corn in greenhouses can be more sustainably done if energy-efficient greenhouse designs are used (Chen et al., 2015).

Baby corn produced in a greenhouse was the subject of a study by Bakhsh et al. (2020) that looked at the impact of various planting dates and cultivars on heat unit accumulation and yield. The study discovered that particular cultivars and early planting dates led to higher heat unit accumulation and yield. Early planting dates, according to the authors, can enable adequate heat unit accumulation during the growth period, improving yield. A study by Li et al., (2020) found that some cultivars had higher levels of stress tolerance, which caused them to produce more when under water stress and accumulate more heat. A good cultivar selection can maximize stress tolerance while increasing yield and heat unit accumulation.

2.9.4 Plastic Mulch Colour

Mulching with plant residues and synthetic materials is a well-established technique for increasing the profitability of many horticultural crops (Gimenez et al., 2002). It is an agricultural farming technique that involves laying down natural or manufactured materials on the soil's surface across growing plants. This provides a favorable environment for crop growth and development (Kefelegn & Desta, 2021). The majority of plastic mulch films were given for research purposes in the late 1950s. Since the early 1960s, they have been utilized commercially for the production of vegetables (DeChristopher& Tucker, 2020). Since then, many horticultural plants had been covered with plastic mulch (Iqbal et al., 2020; Kumar et al., 2021; Singh, Lavlesh, et al., 2020 and Subedi & Ma, 2011).

In the last ten years, the use of plastic mulch films has quickly increased across the globe. This may be related to a number of benefits, such as an increase in soil temperature, a decrease in weed population, the preservation of soil moisture, a decline in the population of specific crop pests, an increase in yields, an earlier crop maturity and harvest, and the environmentally friendly use of soil nutrients (reduced leaching) and water (Kader et al., 2019). Studies have confirmed that plastic film mulching decreases the amount of water loss caused by evaporation (Li et al., 2013), enhances soil water infiltration (Gan et al., 2013), improves crop yields (Liu, 2015), increases water use efficiency (WUE) (Mo et al., 2017), and significantly increases topsoil temperature. However, although higher soil temperatures under a plastic film mulch could prompt crop growth (Liu, 2015), the additional increase in temperature shortens the crops growth (Subrahmaniyan & Zhou 2008), induces heat stress in crop’s late growth stages (Zhao et al., 2014 and accelerates leaf senescence after the flowering of maize, leading to a decrease in maize productivity (Bu et al., 2013).Additionally, it produces rapid and consistent crop insurance, resulting in high and consistent yields (Li et al., 2018). They alter the soil's strength and stability and restrict soil water evaporation, which impacts plant growth and yield, by having an impact on the microclimate that surrounds the plant and soil (Kader et al., 2017).

Utilizing mulches, which cover the ground and alter root zone temperature to boost crop growth and yield, is one method of managing the effects of temperature (Anandhi, 2015). By altering the soil's electrical balance and the amount of solar radiation that is absorbed by the soil or reflected back into the environment, mulches can change the temperature of the soil. Mulches that are reflective and black may also help to reduce soil temperature depending on the environment. However, on the soil surface, transparent mulches result in an incredibly large net radiation (Angelakis et al., 2020). Mulches can also be used to suppress weed development, lower evaporation, maintain soil moisture, and shield plants from disease (Kader et al., 2017).Plastic mulch increased minimum temperature of soil, accelerated early growth and plant height, fruiting of plants and gave satisfactory weed control without any application of herbicides (Mahajan, et al., 2007).

Mulches come in a wide variety depending on the needs of the producer. Using plastic mulches can increase soil temperature, improve early yield, and hasten crop maturity (Burrows et al., 1990). Mulches made of dark plastic colours can control the growth of weeds by reducing the amount of light that reaches the soil. Additionally, there are unique forms of biodegradable mulches that function similarly to plastic mulches but can be kept in place and may decompose over time.

The growth of baby corn is influenced by a number of variables, including planting date, variety, planting density, soil conditions, etc. In the Fargo, North Dakota area, as well as when the average air temperature conditions consistently maintain under the 10^{o}C range, maize, such as baby corn, is frequently planted between mid- and late-may (Uribelarrea et al., 2007). Additionally, during this time of year, the nighttime air temperature might drop below 0^{o} C.

Sometimes the spring weather is significantly cooler than usual, which might cause planting to be done weeks or months later than usual. Due to the need to plant a crop with a shorter growth season as a result of the shorter growing season, this can result in decreased maize yields.

The explosion and development of baby corn are greatly influenced by the planting date which is dictated by the soil and air temperatures. This is because the low soil and air temperatures have an impact on the germination and development of the plants, which dictates the growing season. The sweet corn may also need to be replanted if the plants are damaged by frost or have poor germination. The baby corn needs a minimum temperature of 10^{o} C in order to survive and grow. Thus seed producers use that base temperature as the absolute minimum for planting, even though it may vary for each variety (Huang et al., 2019).

The soil temperature in the spring varies widely from year to year. In North Dakota, some years' springs are warm enough to allow planting of the baby corn sooner than usual, while other years, cold conditions force a delay on planting date. Baby corn has the possibility of frost damage in the fall if harvest is delayed by a great deal, which could result in no yield (Thavaprakaash & Velayudham, 2016).

To overcome this, producers use the technique of staggering the baby corn planting dates at different times. Using plastic mulches enables growers to spread out the planting of crops over a span of 10 to 15 days, starting from the earliest feasible planting date. This practice minimizes the potential harm caused by frost during the spring and/or late fall seasons and prolongs the period available for cultivating baby corn. Moreover, producers can further elongate the baby corn growing season by employing mulch and adopting a strategy of planting at different intervals (Varga et al., 2004).

Mulches are used to increase soil temperature, reduce weed growth, and help maintain soil moisture. Plastic mulches have been utilized internationally and in the United States at various times. They are employed to increase plant growth and yield, particularly in high-value plants like sweet corn and other vegetable plants. Growing cucumbers on plastic mulches has been found to produce more fruit than growing them directly in the ground (Jahan et al., 2018).

Mulches increase soil temperature through altering the soil's strength balance. There is a thin layer of air trapped between the earth and the plastic mulch, which is affixed inside the spring. This accumulation of air serves as a soil insulator in transparent mulches. The warmth from both the water and the soil at the ground will typically radiate out of the soil into the surrounds at night as the temperature drops (Goyal et al., 2012).

If there is mulch in the area, heat loss may be reduced by the insulating layer, yet it won't completely trap the heat because it still has a chance to escape through areas where there may be no mulch or where the mulch is touching the soil. The reflectance of the material and the thickness of the air layer between the mulch and the soil determine the temperature of the soil beneath opaque mulches. If the mulch touches the soil, only then does it become opaque (Sadras et al., 2016).

Mulches can slow the growth of weeds, reducing the time and money needed for weed control (Kaisrajan & Ngouajio, 2012; Kumar & Kalita, 2017). This means less herbicide application to the area on a large scale, which lowers the cost of the herbicides.

Mulches can play an important role in organic farming when used in conjunction with weed control and without the use of herbicides. Mulches provide a constrictive layer on top of the soil, which helps to store moisture. The amount of water evaporating into the environment will be reduced thanks to this restricted layer. Black plastic mulch has been found in Jordan to improve soil water retention and decrease soil water evaporation under rainy conditions when compared to an unmulched region (Maughan & Drost, 2016).

The utilization of plastic mulch in cultivating baby corn has a correlation with the growth and productivity of the crop. However, it is important to note that other factors such as the choice of variety also influence the development and yield of baby corn (Kumar & Kalita, 2017). Different varieties or hybrids of baby corn possess distinct characteristics such as variations in sweetness, maturity time, yield, and the number of growing degree days (GDD) required for growth. While an extended degree day variety may take longer to mature, it has the potential to produce a higher yield compared to a shorter GDD variety that matures more quickly (Kumar et al., 2022).

2.9.4.1 Types of mulch materials

Mulches come in a wide range of types, including natural, plastic, and biodegradable ones. Each type of mulch has unique advantages and downsides. Mulches don't all fall into the plastic category only. Straw, grass clippings, or wood chips are examples of natural mulches that can be used in nurseries, flower beds, and private gardens. For mass production, those organic mulches are impractical.

Thus, organic mulches made of leaves; grass clippings, wood chips, and straw are transient and subject to degradation. This kind of mulch could cost less (grass clippings, leaves), though their decomposition and leaching impacts on the soil cell nitrogen content (Liang & Wang, 2020). However, soil and environmental factors influence how quickly organic mulch decomposes.

The most well-known types of mulch are plastic sheets, which come in a wide range of colour, thickness, and transparency. Mulch made of black, pristine plastic can raise soil temperature more quickly than bare ground. The temperature of the soil rises more slowly with white plastic and plastic sheeting with reflecting properties (similar to tinfoil) (Karuma et al., 2015). The most common type of plastic, polyethylene polymers, are used to create plastic mulch. This mulch must be removed from the soil at the end of the growing season since it may contaminate the soil and hinder seed germination for the next season.

While clear plastic mulch can raise soil temperatures more quickly, it also runs the risk of scorching the soil when exposed to prolonged periods of intense heat. To protect plant life from heat harm, white or reflective biodegradable mulch is laid over black plastic in the southern states. The black plastic underneath will become visible as this top layer deteriorates. As a result, temperatures rise more slowly during the beginning of the season, while plants are still young. The crop can also control weeds thanks to the black mulch at the bottom (Grote et al., 2021).

Another well-known type of mulch is biodegradable. It is intended to function initially like plastic mulch. It can be plowed into the soil after harvest and will disintegrate over time, usually in one to two years. These mulch types can be produced using a wide range of products. A few are made of plant starches that have been combined with other polymers to produce degradable mulch that looks and feels like plastic. Mulches can also be made from special papers that have been coated in plant starches (Silva et al., 2018). These mulch films offer similar benefits to the plastic mulch while being more permeable, allowing more water into the soil.

There are methods by which biodegradable mulches break down. When mulch is exposed to visible sunlight, it deteriorates, becoming brittle and beginning to rip. This is known as image degradation. The problem with this technique is that any mulch that is buried below the floor and not exposed to sunlight will not deteriorate until it is. It is followed by biodegradation. Mulches decay through this mechanism when they are exposed to the soil's microbes (Gordon et al., 2010). Mulch made of plastic that decomposes is offered in a variety of hues. Some of the most popular colours include clean, white, and black.

Plastic mulches are used to control the conditions in which a crop or institution of plants can develop. The most well-known advantageous result of most plastic mulches is an increase in temperature, which has been shown to be favourable to most flowers. Additional benefits of coloured plastic mulches include enhanced fruit quality (Singh, et al., 2020), decreased weed problems (Anandhi, 2015), decreased water evaporation (Moore & Wszelaki, 2019), increased yield (Malhotra, 2017), decreased soil compaction (Abrol et al., 2017), accelerated phytochrome reaction (Basson et al., 2021), and other advantages (El-Hamed et al., 2011). Some coloured plastic mulches have been recommended for use with specific plants and during advantageous times during the growth season.

Polyethylene plastic was created for commercial usage. Polyethylene resin, which comes in the form of pellets, is used to make polyethylene plastic. The pellets are heated, then processed into flexible plastic film using either the "slot casting" or "blown bubble" techniques (DeChristopher & Tucker, 2020). The mulch films are created using polymer resins. Low density polyethylene linear density polyethylene (LDPE), high density polyethylene (HDPE), and metallocene are some of the most frequently chosen mulch films (Bisgaard, 2015).

The LDPE resins typically produce films with mechanical stretch houses and puncture resistance. The HDPE resins generate films with dependable vapour and moisture barriers. The metallocene resins extend dwellings and upload electricity to films (De Christopher & Tucker, 2020). Normally, it is impossible to mix these special resins to give all the top-notch homes in a single film (Adamtey et al., 2016). The ideal plastic mulch film should be flexible and resilient enough to be easily removed from a growing environment. It is accomplished by using several polymer blends along with the appropriate thermal and UV stabilizers.

Low-density polyethylene, which is made by polymerizing ethylene under high pressure, is the main type of polyethylene used in mulches (Iqbal et al., 2020; Kaisrajan & Ngouajio, 2012). The normal plastic mulch used in the United States is 122 cm broad and 1.25 millimeters thick. It is produced in rolls that are 731 meters long and range in width from 91 to 152 cm, depending on the crop and cropping equipment in use (Adamtey et al., 2016). These are available in either simple or embossed plastic form.

The embossed's diamond-shaped pattern helps to reduce the plastic's swelling and shrinking, which can cause the mulch around a raised mattress to come loose. Numerous additives are added to plastic to enhance the finished product's precise properties. Antiblocking agents, antioxidants, colour pigments, flame retardants, and photodegradable elements are a few of the additives that may be given (Mishra & Salokhe, 2008).

Polyethylene (plastic) mulch became known for its capacity to raise soil temperature (Kumar & Kalita, 2017). Due to the high cost of many horticultural crops, it is beneficial to modify the soil's microclimate in order to lengthen the growing season and increase plant development (Kwabiah, 2004). The "reflectivity, absorptivity, and transmittancy" of plastic and how they interact with solar radiation can immediately affect the soil temperatures underneath the plastic mulch (Abdul-Baki et al., 1996 and Grote et al., 2021). Radiation is necessary for plant growth as a source of energy for photosynthesis, the process through which solar radiation is converted to chemical energy (Kefelegn & Desta, 2021).

The degradation period of mulch can vary significantly based on its colour and the type of polymers used in its composition (Ferrari et al., 2018). In particular, white mulch tends to degrade relatively quickly, typically within two weeks, whereas black mulch takes approximately eight weeks to break down. The duration of degradation is influenced by the specific polymer blends incorporated with plant starches during mulch production. Therefore, understanding these variations in breakdown time is crucial for farmers and growers when selecting the most suitable mulch type for their crops. Black mulch will likely have a similar impact to black plastic mulch because it will take longer to decompose. Due to the lack of photosynthesis and minimal growth of weeds beneath black mulch, it will also manage weeds better than clean and white biodegradable mulches.

The colour of plastic mulch plays a crucial role in altering the soil temperature conditions, thereby influencing vegetable production (Palma & Laurance, 2015). This has led to a transformative impact on vegetable cultivation globally, allowing for year-round growth and extending the growing period of plants with tropical origins in temperate regions (Bonachela et al., 2012). The optical properties of the mulch material determine its ability to modify the soil temperature regime, creating an environment conducive to continuous vegetable growth. By harnessing the advantages of plastic mulch, farmers have gained the ability to cultivate vegetables throughout the year, even in regions with cooler climates. This breakthrough has expanded the possibilities of crop production, fostering agricultural sustainability and enhancing food availability.

Similar to this, the use of plastic mulches in agriculture helps to increase the production per unit area for all types of plants, with coloured polyethylene mulch films increasing soil temperature by using 5 to 7°C, thereby enabling quicker germination and greater root proliferation while also preventing weed growth, maintaining the shape of the soil, and preserving soil moisture (Rouf et al., 2016).

The three primary hues of plastic mulch that are typically used on farms are black, white, and clear (Alenazi, 2015). According to Kumar et al., 2022, black plastic mulch is the most widely used mulch colour among farmers and is also the least expensive. Under specific conditions where their specific properties are needed, such as in areas of high temperatures, the other two plastics-white and clean-are preferred over black. Additionally, there are several shades of plastic mulch available, including red, yellow, blue, gray, and orange. There are various possibilities for plastic mulch made of infrared transmission (IRT) polymers that are green or brown(Swami, 2017). IRT plastic allows infrared light rays to pass through it on a selective basis, which leads to extensive soil warming while also reducing weed growth. Different hues have some remarkable effects, particularly on the capacity of infrared warmth waves to transmit, which causes soil warming. The impact of various plastic mulch colours on soil temperature, radiation, and weed control is summarized in table 2

Table 2 demonstrates the impact of mulch colour on the soil temperature below the mulch and the air layer above it. The optical properties of the plastic mulch colour control the temperature of the soil floor(Liu et al., 2014). Based on their thermal characteristics, such as reflectivity, absorbitivity, and transmittancy in proportion to the incoming solar radiation, which impacts the root sector temperature, plastic mulch colour has an effect on soil temperature and crop cover microclimate(Williams, 2008).

Table 2: Comparison of the effect of different colours of plastic on light and weed control

Plastic colour	**Soil temp. (2-4'' depth)**	**Light Reflectivity**	**Light Absorptivity**	**Light Transmission**	**Weed Suppression**	**Comments**
Black	Increases (3 to 5° F)	Low	High	Low	Excellent	Most common. Does well in temperature climates
Clear	Increases (6 to 14º F)	Low	Low	Very high	Poor	Best in cool regions and for fall crops.
White Silver	Decreases (-2 to 0.7° F)	High	Low	Low	Excellent	Reflection interferes with movement of aphids. Best for tropical climates
Infrared Transmitting (IRT)	Increases (5 to 8°F	Low	High	High	Excellent	Selective light transmission. Transmits the sun's warming wavelengths (like clear), but not those that allow weeds to grow (like black)

Source: Adapted from Angima 2009, Penn State Extension 2015, and Sanders 2001.

According to several studies by Bradford et al. (2019); Kefelegn & Desta (2021); Kresnatita et al. (2020) and Morrison-Smith & Ruiz (2020), the physiological activities in the roots, such as the uptake of nutrients and water from the soil as well as the transfer of nutrients, are influenced by the root sector's temperature. This affects the development and growth of plants (Kader et al., 2017).

Crop emergence is accelerated by higher soil temperatures, and as a result, more crops are harvested at an earlier stage of population growth (Rajablarijani et al., 2012). This complements the sun's radiation absorption in turn, increasing crop output (Kader et al., 2017). Use of plastic mulch shades may also result in excessive or low sector-temperature circumstances that could harm plant growth and yields depending on the crop's temperature requirements, the local weather at the time, or the cropping season (Saritha et al., 2020).

However, advances in plastics chemistry have led to the development of films with optical properties that are perfect for a particular crop in a specific location without compromising the plant root sector soil temperature to be employed by growers (Grote et al., 2021). For instance, cucumber plants cultivated under plastic mulches matured 7 to 14 days earlier and produced two to four times as much produce as plants grown in bare soil (Adesina et al., 2014).

The plastic film colour selected for soil mulching determines the performance of radiant energy and the microclimate around the planted vegetation. How plants react to the colourful film is determined by the interaction of the bright reflected light from the plastic film's surface, the capacity to transfer solar energy, and the rise in soil temperature close to the roots. Thus different types and hues of plastic mulch have unique optical qualities that reflect mild radiation levels onto the soil, either boosting or lowering the soil temperature (Kader et al., 2019). In this instance, it is possible to alter the soil's temperature by employing coloured plastic mulch films to promote quicker plant development in regions with either excessively high or low temperatures. For instance, coloured mulch treatments significantly affect certain lettuce plant parameters like the percentage of seedling survival, the length of the roots and the variety of leaves at harvest, the length and diameter of the common leaf, the height of the plant, and the weight of the plant, with pink mulch treatment demonstrating superior results to the other plastic shades (Machanoff et al., 2022).

Worldwide, farmers have overwhelmingly favoured black plastic mulch (Ibarra-Jiménez et al., 2015). As a result, it has long been the preferred mulching material in horticultural production, where it is used to control the plant's growing environment by increasing soil temperatures (Ibarra-Jiménez et al., 2015) and retaining more soil moisture (Torres-Olivar et al., 2016) in comparison to bare soil. However, compared to other coloured mulches, particularly pink and blue mulches, black plastic mulch offer a lower quality of diffused light. The spectral distribution of the light mediated by pink and blue mulch hues is more effective for processes like photomorphogenesis and photosynthesis (Singh et al., 2020).

Regarding the quantity of pink to far-pink wavelengths and blue light, respectively, red and blue plastic mulches emit the best light spectrum, each of which largely regulates photomorphogenesis through the usage of particular photoreceptors like phytochrome(Wang et al., 2021). Due to increased root zone soil temperature (RTZ) and soil water conservation, black plastic mulch expanded cover established over other colours and increased grain output in maize (Torres-Olivar et al., 2016).

The utilization of black and white plastic mulch films leads to a rise in average temperature, as measured by (GDD), when compared to bare soil conditions. This temperature elevation promotes earlier seed germination and accelerates the overall duration of the growing season (Li et al., 2021). The application of these specific mulch films modifies the thermal properties of the soil, creating an environment that encourages faster plant growth and development. This effect is attributed to the increased accumulation of heat in the soil due to the use of black and white plastic mulch, allowing for expedited seed germination and a reduced time span for crop maturation.

Increased GDD at the beginning of a season has been seen to increase the likelihood of success for a farmer in a number of ways, including expanding the types of plants that can be grown, lowering the risk of germination and increasing the likelihood that plants will grow, giving the farmer more control over when plants can be harvested while increasing the farmer's capacity to supply produce when demand and price are high (Bradford et al., 2019).

When compared to black plastic, the shade produced by white plastic mulch results in milder soil temperatures (Li et al., 2021). As a result, white shading is preferred over black shading during recent growing seasons and in hotter regions because it can maintain soil moisture while providing cooler soil temperatures. This discrepancy in temperature is attributed to the increased penetration of sunlight when using white film instead of black film. When compared to bare soil, white mulch hardly lowers soil temperature because it absorbs less radiant energy and reflects it back into the plant canopy, which blocks the majority of incoming solar radiation (Li et al., 2018).

As a result, it is advised that lower soil temperatures are best for growing horticultural plants, especially in summertime production and beneath hot desert regions (Zhran et al., 2013). Comparatively to opaque mulches, clear plastic mulch results in more intermittent radiation behind the mulch and is more effective at raising soil temperature (Kader et al., 2017). Transparent plastic mulch transmits more solar radiation and increase soil temperatures more than black plastic mulch, which is beneficial for seedling emergence of crops planted in spring Qin et al., 2018). However, the higher soil temperatures in summer can cause premature senescence (Bu et al., 2013). Clear mulch transmits more sunlight than it absorbs, with the amount of sunlight transmitted depending on the thickness and degree of opacity of the polyethylene (Hu et al., 2020).

On the surface of clean plastic mulch, there are typically water droplets that have condensed (Bradford et al., 2019). The water droplets are opaque to incoming short-wave infrared light but transparent to long-wave infrared radiation (Wang et al., 2021). Thus, a significant amount of the heat lost by bare soil to the environment as a result of infrared radiation is conserved by employing clean plastic mulch. The lowest and maximum soil temperatures are increased by transparent and translucent mulches, which improve soil warmth movement and sell an incredibly big quantity of radiation on the soil surface (Seck et al., 2012).

The shade provided by the plastic mulching cloth has a unique impact on the growth and production of vegetation (Abdul-Baki et al., 2016; Singh et al., 2015).Research conducted by Ramakrishna et al. (2006), Moreno and Moreno (2008), and Haque et al. (2018) indicates that black polyethylene film mulches outperform transparent polyethylene film mulches in the cultivation of groundnuts, tomatoes, and winter rapeseed, respectively. However, small-scale farmers in Kenya's Meru County do not use plastic mulching as a method of cultivation. The objective of the study was to determine the effects of various coloured plastic mulch films on soil temperature, growth, and yield of varieties of baby corn transplanted at different stages.

2.9.4.2 Effects of Mulch Colour on Net Radiation

Net radiation which is the disparity between the emitted longwave radiation and the combined sum of absorbed shortwave and longwave radiation affects soil conditions (Bianchi et al., 2019). Plastic mulch is exposed to various sources of net radiation, including shortwave radiation emitted by the soil's surface, longwave radiation from the sky and soil, and global irradiance. When calculating net radiation, it is crucial to consider the radiation released from the soil as well as the radiation emitted by the mulch itself (Dhasarathan et al., 2012; Hussain, 2021). Research conducted by Kumar et al. (2021) demonstrated that the net radiation was higher in the presence of plastic mulch compared to non-plastic mulch conditions. This indicates that plastic mulch has a greater impact on the net radiation levels, influencing the energy exchange within the system.This is excellent evidence that the plastic mulch’s spectral characteristics had a significant influence on the short and longwave. The flux of latent warmth in relation to soil evaporation, convection of practical temperature into the layer of air between the soil surface and the mulch, and conduction of heat into the floor are three non-radiative additions to radiant electricity on the soil floor (Dhasarathan et al., 2012). The classical idea of heat float in a semi-endless homogeneous medium can be used to predict the charge at which a soil will increase or decrease heat over a period of twenty-four hours. This relationship between the soil's heat production and loss and the diurnal cycle of surface temperature is very close (Wang, 2021).

The ability of plastic mulch to radiate heat energy depends on its colour. Black plastic films retain more of the sun energy that is radiated on them and get hot as a result. With black plastic mulch, the radiation entering the area is first absorbed by the plastic before being directed to the soil (Kumar et al., 2021).

Black plastic is expected to raise soil temperatures the fastest because of its high shortwave absorption and intense shortwave transmittance (Seck et al., 2012). The soil temperature may be 10-15 ^{0}C hotter below black coating than on bare soil (Maddela, 2009). On plastic mulches with significant shortwave absorption (black) or excessive shortwave transmittance (clean), the best noon soil temperatures are often seen (Dai et al., 2016). Compared to other coloured mulches, black mulch typically results in the soil being the hottest (Eltlbany et al., 2019).

White plastic's longwave radiation is significantly less than that of black plastic since it has a lower temperature (Bradford et al., 2019). White plastic seems to have the capacity to diminish daytime soil heating and draw nighttime soil warmth below the mulch (Dukare et al., 2020). In areas with high levels of solar radiation and in locations where it is necessary to lower transmitted radiation and soil temperature, white film is used. Additionally, white plastic is employed to increase the amount of thought-about light on the lower and center plant leaves (Kefelegn & Desta, 2021).

When compared to various coloured plastic mulches, different colour mulches have yielded the best soil temperature in other trials. Researchers (Maddela, 2009; Sardar et al., 2020; Singh et al., 2020) discovered that blue had the best soil temperature of all the treatments. In comparison to other coloured plastic mulches, red plastic mulch produced the highest soil temperatures, according to (Bradford et al., 2019; Ibarra-Jiménez et al., 2011) findings. Compared to other shade plastic mulches, silver plastic mulch typically results in cooler soil temperatures, with white plastic mulch being the exception (Reynolds et al., 2015).

To raise the temperature of the soil, there should be close contact between coloured plastic mulch and the ground surface. The air space between the plastic and the soil is reduced and heat is passed through conduction, which might lead to an increase in temperature if the mulch has been installed tightly and is in actual contact with the soil (Kefelegn & Desta, 2021). There is a growing region where the consistency of the touch between the mulch and the ground can lead to variations in soil temperature (Nleya et al., 2016). The soil will warm up the fastest when coloured plastic mulch has a reasonable structure to it (Silva et al., 2018).

According to Abrol et al.(2017), increasing the touch resistance (the degree of contact between the soil and plastic mulch) caused the mulch's temperature to increase while the soil's temperature to drop. The simplest way for the soil temperature to have increased was through a decrease in contact resistance. Coloured mulch can continue to absorb shortwave radiation due to its increased contact resistance, but it cannot transfer the energy to the soil (Ibarra-Jiménez et al., 2011). The amount of rainfall, the kind of soil, the thickness and width of the mulch, the depth of the daylight, the humidity of the immediate environment, and the plant canopy are additional considerations in the efficiency of plastic mulches to warm a soil.

Compared to using bare soil, applying coloured plastic mulch has produced more boom and earlier yields (Nleya et al., 2016). The usage of plastic mulch led to an earlier rise in tomato production, according to (Silva et al., 2018). In comparison to bare soil, (Kader et al., 2019) found that the use of pink, silver, and blue plastic mulch accelerated the development of radicchio heads.

Filho et al., (2020) observed an earlier rise of watermelon with the use of coloured plastic mulch in a test carried out in Virginia. The number of days needed for eggplant to flower was shortened by coloured plastic mulch(Singh et al., 2020). Compared to using bare soil, the application of pink and black plastic mulch helped establish an early production of bell pepper (Asharafuzzaman et al., 2011). Contrary to bare soil, plastic mulch limits the amount of light that reaches the soil beneath it in the PAR (photosynthetically active region) of 400-700 nm (Onwuka, 2016).

Plastic mulch plays a crucial role in enhancing plant growth and development by effectively preserving soil moisture. When utilizing plastic mulch, the preferred irrigation method for vegetables is drip tape. This combination of plastic mulch and drip tape not only ensures that the vegetable crops receive sufficient moisture but also offers environmental benefits compared to overhead watering methods. Retaining soil moisture is one of the most widely recognized advantages of plastic mulch, as documented in studies by Ibarra-Jiménez et al. (2011) and Kefelegn & Desta (2021). Extensive research has consistently demonstrated that soil with plastic mulch and drip tape maintains moisture more effectively than soil without these materials, as highlighted by studies such as Porazinska et al. (2018).

According to Kefelegn & Desta (2021); Zhou & Wang (2018), plastic mulches' ability to limit soil water evaporation is a key factor in their ability to control the microenvironment of plants. Oughton & Ritson, (2007) found that using black plastic mulch alongside drip irrigation reduced water application by 40% when comparing drip irrigation to furrow irrigation. Additionally, plastic mulches have the ability to increase soil moisture in a way that increases plant access to nitrogen (Hatfield, 2015).

When plastic mulch serves as a barrier to rain, it reduces leaching because it stops precipitation from penetrating the soil and removing nutrients beneath the point of contact for roots. According to experts studying okra, plastic mulch reduced the leaching of nutrients(Ibarra-Jiménez et al., 2017; Kader et al., 2019; Kresnatita et al., 2020).

According to Kader et al.(2019), black plastic mulch had no difference in yields of summer squash from bare ground treatments. In comparison to bare soil treatments, Huerta et al.(2017) observed significantly higher yields of zucchini squash on various coloured mulches (red, yellow, gray, blue, and black). Utilizing black plastic mulch resulted in a significant increase in calabaza and butternut squash yield (Singh, 2019).

Angelakis et al., (2020) reported 96% better yields of summer squash with aluminum plastic mulch than with bare soil. Kader et al. (2017) found that using reflecting mulch increased the yields of summer squash. According to Shrestha et al.(2021), growing zucchini squash on reflecting mulch results in significantly higher yields than growing it on bare soil.

Studies on the impact of plastic mulch on okra yield have been conducted. (Araujo et al., 2017; Bonachela et al., 2011) discovered that polyethylene mulch increased okra yield when compared to bare soil. Kefelegn & Desta (2021) reported increased yield in okra grown on black mulch as comparison to bare soil due to the plastic mulch's potential to lessen weeds and decrease leaching of fertilizers. Huang et al. (2011) and Hughner et al. (2017) found that special varieties of okra produced noticeably more fruit when planted on plastic mulch rather than bare soil.

Because plastic mulch improved soil moisture retention, it produced noticeably higher yields of okra than bare soil (Babatunde et al., 2020; Singh, 2019). Okra grown on plastic mulch has reportedly produced more than okra cultivated on bare soil due to the increase in ambient temperatures it provides (Castro et al., 2013; Kefelegn & Desta, 2021).

Additionally, the plastic cover's hole is required to reduce humidity and water condensation (Li et al., 2018; Roy et al., 2018). Slitted polyethylene covers raised daytime temperatures by 4 to 5^{o}C above ambient levels (El-Hamed et al., 2011; Roy et al., 2018; Rylander et al., 2020). This increase in temperature made it possible for pistillate flowering in melons to mature earlier than it would have under conditions of bare soil or black plastic mulch. Slitted covers were found to have boosted the production of muskmelon in an experiment that succeeded in New Hampshire, according to (Dai et al., 2016).

Compared to bare soil treatments, the use of plastic mulch increased muskmelon yields and improved soil temperatures (Filho et al., 2020; Singh et al., 2020). It has been demonstrated that squash responds well to the microclimate changes caused by plastic mulch and plastic mulch. According to Kresnatita et al. (2020) and Zhou & Wang (2018), the mulches that produced the best temperatures also produced the best squash yields. (Uribelarrea et al., 2016) used plastic mulch to produce large yields of squash in Alaska. The increase in warmth brought on by the use of plastic mulch resulted in a boom in the height and maturity of squash plants (Hooda & Kawatra, 2013; Li et al., 2018). Squash plants can be protected from frost by using plastic mulch, which promotes plant maturity (Kumar & Kalita, 2017).

According to Murphy et al. (2014), the improved leaf range and stem length in squash flowers were the result of the increased temperatures (soil and air) and conservation brought about by the use of plastic mulch. It has been proven that squash grown on plastic mulch mature larger and more quickly than squash grown on bare soil alone (Kumar et al., 2021; Kwabiah, 2004). Problems could arise as a result of the microclimate modification caused by the usage plastic mulch. According to Mishra & Salokhe (2018) and Shrestha et al. (2021), temperatures inside row covers with plastic mulch treatments were so high that they caused plant damage to pumpkin plants, which are part of the cucurbit family.

The improvement of okra is dynamically impacted by the adjustment of the microclimate using plastic mulch and plastic mulch with row covers. Okra cultivated with plastic mulch and with plastic mulch plus row coverings showed earlier seed emergence than bare soil (Dai et al., 2016 ; Zhou & Wang, 2018). Compared to bare soil treatments, plastic mulch was found to promote increase branching of the okra flora (Adamczewska-Sowińska & Sowiński, 2020 and Li et al., 2020).

When compared to bare soil, plastic mulch, both with and without row covers, has been shown to increase the number of pods per plant (Gheshm & Brown, 2020; Li et al., 2020; Raggio Aonso & Gámbaro, 2018) According to (Hossain et al., 2011; Adonia, 2015; Snyder et al., 2015), black plastic mulch no longer affected summer squash yields when compared to bare ground soil. When compared to squash grown on black plastic, (Ellis et al., 2006) found that aluminum-protected mulch reduced cucumber beetles but did not significantly increase production.

According to (Awika, 2011; Li et al., 2018), zucchini squash cultivated on reflecting mulch produces noticeably higher yields than zucchini squash grown on bare soil. A study conducted by Abdul-Baki et al. (1996); Ibarra-Jiménez et al., 2011; Machanoff et al., 2022) discovered that polyethylene mulch produced more okra per acre than bare soil. Punia et al. (2020; Shrestha et al. (2021) noted improved yield in okra grown on black mulch rather than naked soil due to the plastic mulch's potential to lessen weeds and reduce leaching of fertilizers.

Different species of okra had noticeably higher yields when planted on plastic mulch rather than bare soil (Johnson et al., 2008; Ngongo et al., 2021). Due to the soil's improved ability to retain moisture, the usage of plastic mulch led to noticeably larger okra yields than bare soil (Onwuka, 2016; Zhran et al., 2013). Okra cultivated on plastic mulch out produced okra grown on bare soil due to an increase in ambient temperatures brought on by the use of the plastic mulch (Kader et al., 2017; Rylander et al., 2020; Svotwa et al., 2014).

Plastic film mulching of the soil results in less water loss and more evenly regulated soil temperature (Machanoff et al., 2022). Due to an increase in soil temperature beneath the plastic mulch, a greater germination ratio was obtained within it compared to straw mulch and bare soil (Awata et al., 2019). This facilitated speedier crop improvement (Maughan & Drost, 2016; Moore & Wszelaki, 2019). The plastic film acts as a barrier, reducing soil water evaporation and maintaining a more consistent moisture regime inside the root quarter. This might reduce the need for watering (Palai et al., 2018), specific types of plastic mulch colours have functional optical properties that alter the amounts of light reaching the soil, causing increases or drops in soil temperature (Ibrahim et al., 2021).

2.9.5 Temperature Effects (Use of Heat Units) on baby corn production

Temperature has been shown to be a key factor in determining the rate of plant growth, improvement, and productivity (Silva et al., 2016). For plants to complete their growth cycles, a specific amount of heat, measured in (GDD), is necessary (Adonia, 2015).

GDD is used to predict the length of developmental phases, harvest ages, and plant life flowering dates (Zhou et al., 2015). Additionally, it is believed that temperature affects how quickly successive new leaves appear at the stem's tip (Rychtecká et al., 2013). In determining the adaption of many plant species growing in various environments, temperature is a major factor. One of the main constraints in the commercial production of maize is the occurrence of sub-optimal temperatures at the time of sowing (Alazem & Lin, 2013). Temperature will have an immediate impact on plant growth through seed germination and seedling emergence, and indirectly through its effects on nutrient uptake and availability, as well as on the decomposition of soil residue. Temperature affects several physiological processes.

Root characteristics are influenced by temperature, as highlighted by Bradford et al. (2019). Basson et al. (2021) identified several factors that hinder water absorption by roots at low temperatures, such as delayed root elongation, reduced permeability of root cells, increased viscosity of cell protoplasm, and increased viscosity of water. Rani et al. (2019) observed that root zone temperatures ranging from 10 to 14°C had negative effects on the emergence and growth of maize seedlings.

According to Castro et al. (2013), the optimal base temperature for most plant species is around 5°C, gradually increasing to a maximum of 25 °C. Above this temperature, there tends to be a decline in root development. Adamtey et al. (2016) found that the ideal temperature ranges for the growth of beans (*Phaseolus vulgaris*), potatoes (*Solanum tuberosum*), onions (*Allium cepa*), and tomatoes (*Lycopersicum esculentum)* was between 26 and 34°C and between 18 and 22°C, respectively. In their study on tomatoes, Singh (2019) observed a significant growth boost in tomato seedlings as the base temperature increased from 12.8 to 15.6°C.

According to Mishra and Salokhe (2018), maize growth is hindered when soil temperatures drop below 12.3°C, while other plants like peas, radish, and spinach can experience slowed growth only when soil temperatures fall below 10°C. Common plants are particularly vulnerable to sub-optimal soil temperatures due to the fact that the growing portion of the shoot remains below the soil surface for nearly five weeks after germination (Rosen et al., 2012).

Plants, depending on their adaptation, exhibit varying rates of nutrients absorption from the soil. While low soil temperatures no longer have a significant impact on the rate of nitrogen absorption, they do affect the roots' ability to reduce absorbed nitrate and convert it into natural nitrogen (Kader et al., 2017). The study by Ibrahim et al. (2021) revealed that roots are more sensitive to nitrates at lower temperatures compared to shoots, as nitrates are transported to roots more rapidly than shoots. Furthermore, Kader et al. (2017) found no evidence supporting slow growth in rye grass (*Lolium perenne*) at temperatures between 3 and 9°C, even with restricted ammonium or nitrate uptake by the plants. According to Akinnuoye-Adelabu and Modi (2017), low soil temperatures can hinder root growth by affecting metabolic processes and the roots capacity to serve as a sink for photosynthates, which are necessary for nutrient absorption from the soil. Moore and Wszelaki (2019) stated that the impact of low temperatures on tomato growth is linked to biological factors such as water viscosity and membrane permeability.

A typical reduction in water and nutrient uptake at sub-optimal root temperatures, according to Abrol et al. (2017), can be attributed to changes in the internal viscosity of water and changes in the permeability of root membranes. Low root-region temperatures have been linked to an inhibition of leaf elongation due to a decrease in biochemical methods inside the meristematic region, which also results in a reduction in both mobileular elongation and division (Svotwa et al., 2014).

One major obstacle to the commercial production of maize in many areas is the frequency of temperatures that are not optimal at the time of sowing (Oughton & Ritson, 2017).

The temperature will have an immediate impact on plant growth through seed germination and seedling emergence, as well as indirectly through its impact on nutrient availability and absorption as well as on the decomposition of soil residue. Many physiological processes are temperature-sensitive. All root capacities depend on temperature (Alazem & Lin, 2013).

Kwabiah (2004) listed a number of factors, such as delayed root elongation, decreased permeability of root cells, increased viscosity of cell protoplasm, and multiplied viscosity of water, as being responsible for the lower absorption of water by employing roots at low temperatures. According to Jabran & Farooq, (2007) and Adamczewska-Sowińska & Sowiński (2020), emergence and seedling expansion of maize flora were negatively impacted by root area temperatures between 10 and 14^{o}C. This is because low temperatures cause the production of hormones such cytokinin and gibberellin, which are reduced in the roots.

According to Dukhnytskyi (2019), the main impact of cold temperatures on shoot growth is a gradual distribution of plant hormones and nitrates to the foliage rather than a decrease in the cost of their manufacture. At a root zone temperature of 10°C, Liu et al. (2014) and Shiferaw et al. (2013) reported a reduction in the weight of the roots of seedlings. Suboptimal temperatures also limit root expansion and reduce the total root mass.

According to Eltlbany et al. (2019), the foundation growth of the majority of plant species is lowest at 5°C and rises continuously up to 25°C. However, a reduction in the growth of roots can be seen above this temperature. Araujo et al. (2017) Ellis et al. (2006) and Filho et al. (2020) suggested that tomato seedling development increased significantly as the foundation temperature climbed from 12.8 to 15.6°C in their experiment with tomatoes.

According to Wilcox and Pfeiffer (1990), maize growth was inhibited when soil temperatures dropped below 12.3^{o}C, while the growth of other plants including peas, radish, and spinach was only suppressed when temperatures dropped below 10^{o}C.

Depending on their kind, different plants absorb nutrients from the earth at different costs. Low soil temperatures influence the roots' ability to reduce ingested nitrate and convert it into organic nitrogen (Kader et al., 2017; Troyjack et al., 2018). According to El-Hamed et al. (2011), roots have higher nitrate concentrations at lower temperatures than shoots due to a faster nitrate translocation to the roots.

Increase in soil temperatures from 10 to 15^{o}C, resulted in a significant increase in the uptake of magnesium ions by 20-day vintage wheat seedlings (Akinnuoye-Adelabu & Modi, 2017). Consequently, at low soil temperatures, such as in the early spring, a slight increase in root temperature may also significantly enhance the rate of uptake of minerals, such as magnesium, by young seedlings whose root systems are still in the process of developing.

Kusuma & Bugbee, (2020) reported the impact of low temperatures on tomato growth to influence body components like water viscosity and membrane permeability. Reduced water viscosity and decreased root membrane permeability were also mentioned by Torres-Olivar et al. (2016) as contributing factors to the overall decline in water and nutrient uptake at sub-optimal root temperatures. Additionally, low root-region temperatures have been linked to a reduction in biochemical processes in the meristematic area, which reduces both cellular elongation and division and inhibits leaf elongation (Ibrahim et al., 2021).

Examining the relationship between soil temperature and baby corn production in Meru County will enable a better understanding of how temperature influences the growth and yield of baby corn crops in this specific region. Studying the soil temperature dynamics, will help in identify optimal soil temperature ranges for baby corn production, determine the impact of temperature fluctuations on crop performance, and develop strategies to mitigate any negative effects. This study will also provide valuable insights for farmers in Meru County, helping them make informed decisions regarding crop management practices, such as selecting appropriate transplanting stages, using mulching techniques. Furthermore, the findings of this study can contribute to the overall knowledge base of baby corn production in similar agro-climatic regions.

CHAPTER 3: USE OF HEAT UNITS TO PREDICT THE OPTIMUM TRANSPLANTING STAGE OF BABY CORN (*ZEA MAYS L.*) SEEDLINGS UNDER FIELD CONDITIONS IN MERU COUNTY – KENYA

3.1 Introduction

Maize *(Zea mays L.)* belonging to the family Poaceae is considered the third most important cereal crop under production after wheat and rice (Biswas et al., 2009). It is regarded as the most important cereal crop in sub-Saharan Africa and a critical staple food for an estimated 50% of the population (Biswas et al., 2009).

Baby corn, a type of maize largely adopted by horticultural farmers in different parts of the world (Bar-Zur et al., 1990), is grown as a vegetable for its immature unfertilized ears harvested within 2 to 3 days after silk emergence (Manea et al., 2015). It enters into the reproductive phase within 45 – 55 days after sowing and completes its cycle in 60 – 70 days (Ajaz et al., 2013). The ears are ideal for use when they are 5–10 cm long and 0.8–1.6 cm in diameter at the base or butt-end (Bar-Zur et al., 1990).

Baby corn can be established through direct seeding or through transplants. Transplants are widely used in establishing various high-value vegetable crops (Vavrina, 1998). The optimum stage of transplanting seedlings is influenced by several factors of growth among them soil moisture, nutrients level, temperature, light as well as the cultural practices (Shukla et al., 2011). Among these, temperature has been shown as a major factor that determines the rate of plant growth, development and productivity (Qadir et al., 2006). Plants require a certain amount of heat expressed in “growing degree-day” (GDD) to complete their growth cycles (Parthasarathi et al., 2013). GDD is used to estimate plants flowering dates, harvest maturity and predict the duration between two developmental stages (Kaur et al., 2017). Also temperature is known to control the rate at which successive new leaves emerge at the stem apex (Wilhelm et al., 1995).

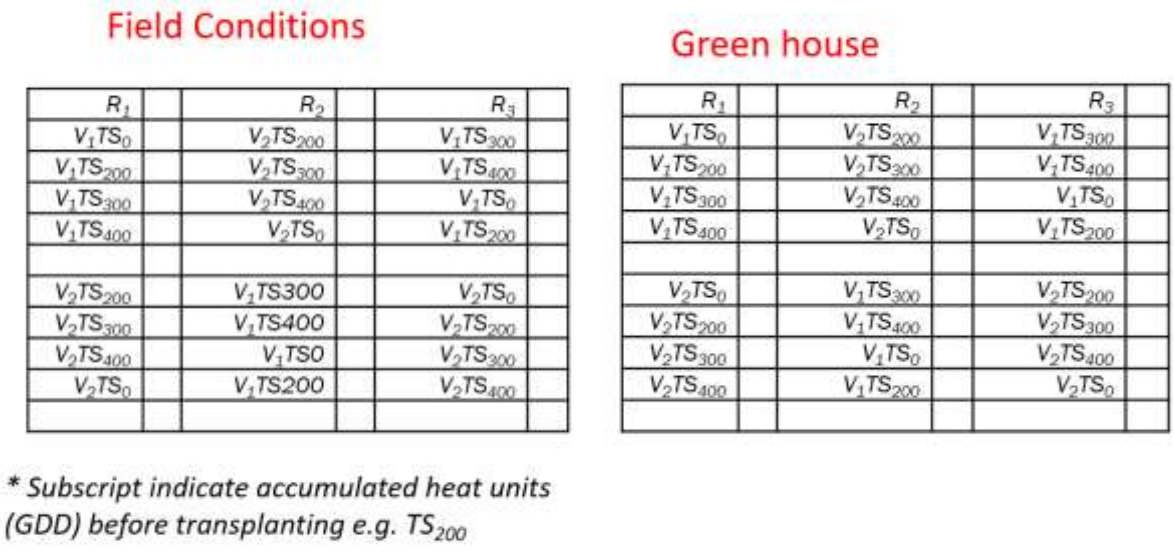
Transplants are used to establish crops in less favourable conditions such as when birds, soil borne pests and water deficiency pose a threat to seedlings (Fanadzo et al., 2009). Transplanting involves careful movement of seedlings at an appropriate stage from the nursery to the field. Seedlings belonging to the family of Solanaceae and Brassicaceae are transplanted at an optimum age of 5-7 weeks while those from Poaceae and Cucurbitaceae are transplanted at an optimal age of 3-4 weeks (Vavrina, 1998). Maize established through transplants has been shown to have shorter growth period in the field making late-maturing high yielding cultivars fit into the growing season based on the rainfall or temperature (Dale & Drennan, 2007).

The effect of transplanting age on yield is an issue often broached by the growers of horticultural crops in an effort to maximise production potentials (Vavrina, 1998). This is because transplanting time has a great impact on seedling establishment, plant growth and development. The age of cotton seedling has significant effects on yield and yield attributes of *Bt* cotton with 20 day old seedlings performing better than the direct seeded as well as the 30 day old seedlings (Kulvir et al., 2013). Similarly transplanting has effect on the maturity age of maize where 14 day old seedlings resulted in reducing maturity age by 8-15 days (Biswas, 2008). The age of capsicum transplants was found to influence the number of fruits, fruit weight as well as the harvest duration per plant (Shukla et al., 2011). Three weeks old maize seedlings were shown to have higher plant establishment, grain per cob, grain yield per unit area, plant height as well as straw yield than the direct planted ones (Chudasama et al., 2017). Similarly transplanted maize was reported to mature 10-12 days earlier than direct seeded maize (Sanjeev et al., 2014). Maize seedlings transplanted after 14 and 21 days matured 6 and 12 days respectively earlier than the direct planted maize (Biswas et al., 2015).

Considering the wide range of 3-4 weeks transplanting age of maize seedlings, there is need to develop a more accurate transplanting stage protocol for optimal production. Thus the objective of this study was to evaluate the impact of different GDD-related transplanting stages on the performance of baby corn varieties under farmer conditions.

3.2 Materials and methods

The experiment was conducted in Abothuguchi west, Meru County in Kenya (Latitude 0^0 01'and Longitude 36^0 37') at an altitude of 1,800 m above sea level in the month of February to May 2016 and July to October 2016. The experiment was laid out on a split plot randomized complete block design with three replications. The main plots were the Baby corn plant variety (PAN 14 and Thai Gold (TH)) while the subplots were transplanting stages (0, 200, 300 and 400 GDD) (Figure 1), The experiment was carried out in both Field condition (FC) and greenhouse condition (GH).



Field Conditions

R_1		R_2		R_3	
V_1TS_0		V_2TS_{200}		V_1TS_{300}	
V_1TS_{200}		V_2TS_{300}		V_1TS_{400}	
V_1TS_{300}		V_2TS_{400}		V_1TS_0	
V_1TS_{400}		V_2TS_0		V_1TS_{200}	
V_2TS_{200}		V_1TS300		V_2TS_0	
V_2TS_{300}		V_1TS400		V_2TS_{200}	
V_2TS_{400}		V_1TSO		V_2TS_{300}	
V_2TS_0		V_1TS200		V_2TS_{400}	

Green house

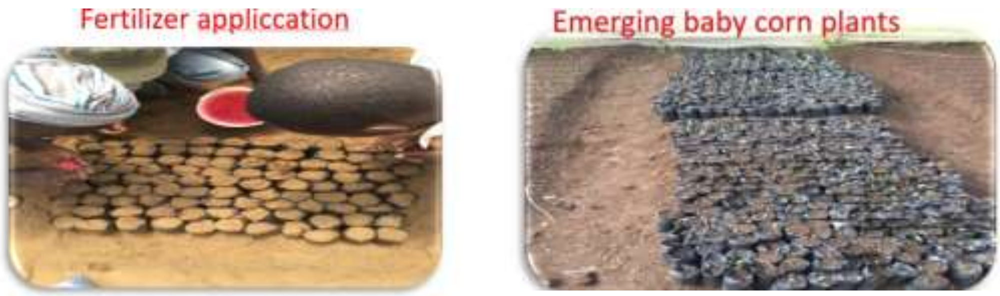
R_1		R_2		R_3	
V_1TS_0		V_2TS_{200}		V_1TS_{300}	
V_1TS_{200}		V_2TS_{300}		V_1TS_{400}	
V_1TS_{300}		V_2TS_{400}		V_1TS_0	
V_1TS_{400}		V_2TS_0		V_1TS_{200}	
V_2TS_0		V_1TS_{300}		V_2TS_{200}	
V_2TS_{200}		V_1TS_{400}		V_2TS_{300}	
V_2TS_{300}		V_1TS_0		V_2TS_{400}	
V_2TS_{400}		V_1TS_{200}		V_2TS_0	

** Subscript indicate accumulated heat units (GDD) before transplanting e.g. TS_{200}*

Figure 1: Experimental Layout

The plants were established through direct seeding (0GDD) and transplants raised in the nursery. Seedlings were established in soil pots of 10 cm by 15 cm size filled with a mixture of soil and 10g of DiAmmoniun Phosphate (DAP) (Figure 2). Both direct planting and nursery establishment were done the same time. Crop management practices including weeding, thinning, watering, pests and diseases control were carried out in both direct seeded and indirect established plants.

Transplanting stage was determined by the amount of heat units (GDD) accumulated by the plants in the nursery. Seedlings were transplanted to the main seedbed after accumulating 200, 300 and 400 heat units. They were transplanted on 4m by 4m sized plots at a spacing of 60cm by 20cm (Ganesh et al., 2012).



Fertilizer appliccation

Emerging baby corn plants

Figure 2: Fertilizer and emergence of baby corn plants

Water application was done through drip irrigation while weeding was done by light cultivation using forked hoes at two stages. Insect pests especially fall armyworms *(Spodoptera frugiperda)* were controlled using Pyriproxyfen (Profen^{TM}) insecticides spray on the entire crop plant. Top dressing was carried out using CAN (26%N) fertilizer once the plants attained 0.5 m plant height (figure 2).

Data was collected from four randomly selected plants per plot and recorded on an excel sheet. This involved the summation of all daily growing degree day (GDD) up to flowering to determine the flowering GDD, measuring of plants flowering height and cob parameters (length, diameter, fresh weight as well as the number of marketable cobs).

Flowering height was determined by measuring the plant height from the ground level up to the flag leaf using a metre ruler. Similarly, the cob length was determined by measuring from the base up to the cob tip using a metre ruler, while the cob diameter was obtained by measuring the thickness of the cob at the base by use of digital Vernier caliper (Figure 3)

(Model 500- 196; Mitutoyo Digimatic, Kanagawa, Japan). The number of marketable cobs was obtained by counting those cobs which attained the acceptable market standard size of 0.8–1.6 cm base diameter and 5.0–10.0 cm length within 48 hours since silking (Bar-Zur et al., 1990).

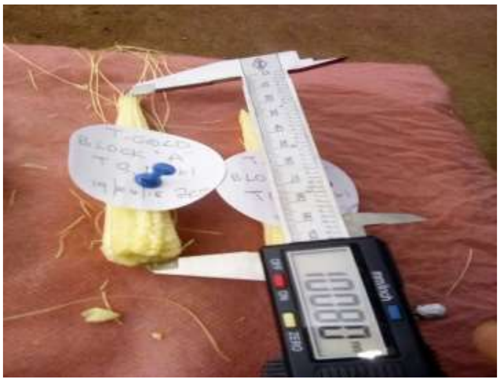


Figure 3: Cob length measurement

The GDD also known as the accumulated heat units was determined by recording both the daily maximum (T_{MAX}) and minimum (T_{MIN}) temperatures using a maximum and minimum thermometer (Figure 4). The daily GDD are calculated each day as maximum temperature plus the minimum temperature divided by 2 (or the mean temperature), minus the base temperature.

Figure 4:Air Temperature measurement

$GDD = \sum\{0.5(T_{MAX} + T_{MIN}) - T_{BASE}\}$ where T_{BASE} is that temperature below which plant growth is zero. For maize crop T_{BASE}is10°C (Torres-Olivar et al., 2016), GDDs are accumulated by adding each day's GDDs contribution as the season progressed.

3.3 Data Analysis

Data analysis was conducted using Statistical Analysis System (SAS, 2007). The means were subjected to analysis of variance (ANOVA) using Least Significant Difference (LSD) option to determine statistical differences at 95% confidence level. The means were considered significantly different at $P \leq 0.05$.

3.4 Results and discussion

3.4.1 Effect of transplanting stage and varietal differences on maturity GDD of Baby corn

There were significant interactions ($P \leq 0.05$) between transplanting stage and baby corn varieties on the maturity GDD across the two seasons under different conditions (Table 3). Interactions were observed between the two varieties at 200 GDD transplanting stage under field conditions for season 1. Interactions were also registered at 300 GDD stage in both PAN 14 and Thai Gold in greenhouse season 1 and 2 and also field conditions at season 2. In field conditions (FC), PAN 14 transplants at 200 GDD recorded a significant low GDD while at 400 resulted to a high GDD in both season 1 and 2. The same results were observed under greenhouse conditions. Similarly, under field conditions Thai Gold transplants at 200 gave a significant low GDD while at 400 resulted to a high GDD in both season 1 and 2. Similar results were observed under greenhouse conditions.

Table 3: Maturity GDD of Baby corn as influenced by interactions of variety and transplanting under different growing conditions.

	Season 1				Season 2			
	Field condition (FC)		Greenhouse condition (GH)		Field condition (FC)		Greenhouse condition (GH)	
Transplanting stage (GDD)	PAN 14	TH	PAN 14	TH	PAN 14	TH	PAN 14	TH
0	1047.4^{b}	1110.6^{b}	1082.2^{b}	1205.0^{b}	1023.3^{b}	1090.1^{b}	1061.9^{b}	1197.3^{b}
200	983.4^{c}	1085.6^{b}	991.9^{c}	1119.2^{c}	970.6^{c}	1056.7^{c}	970.8^{c}	1110.0^{c}
300	1052.5^{b}	1105.8^{b}	1086.9^{b}	1231.8^{a}	1033.1^{b}	1099.3^{a}	1058.4^{b}	1226.9^{a}
400	1138.1^{a}	1213.5^{a}	1148.3^{a}	1240.1^{a}	1119.9^{a}	1121.1^{a}	1132.5^{a}	1233.2^{a}
lsd	23.1		25.9		22.3		23.9	

Means followed by the same letter down the column are not significantly different ($P \leq 0.05$), TH- Thai Gold.

Under field conditions, maturity GDD of PAN 14transplanted at 400 GDD increased by 15.8 % and 15.3 % as compared to 200 GDD transplants in season 1 and 2 respectively. The readings were significantly different ($P \leq 0.05$) among the two transplanting stages 400 GDD and 200 GDD. A decrease of 10.5% and 5.7% were registered in Thai Gold transplants at 200

GDD, had a fewer maturity GDD as compared to 400 GDD transplants under field conditions in the two seasons. Under greenhouse conditions PAN 14 and Thai Gold had an increase of 15.8-16.7% and 10.8-11.1% when transplanted at 400 GDD compared to 200 GDD respectively in both seasons. Compared to the control (transplants at 0 GDD), PAN 14 took 5.4- 6.5% while Thai Gold took 2.3-3.2 % more heat units to mature than the best transplants at 200 GDD under FC conditions. Similarly, in Green house conditions 0 GDD PAN 14 transplants took about9% while Thai Gold took about 8% more heat units to mature than the best transplants at 200 GDD.

Delaying transplanting stage increased heat unit requirements in all varieties under both FC and GH conditions. The increase in heat units with delayed transplanting may be associated with the restriction of root growth in the nursery sleeves, destruction of the protruding roots of the older seedlings during transplanting, as well as exhaustion of nutrients in the soil sleeves before transplanting. Rattin (2008), demonstrated that inability of roots to regenerate faster after transplanting caused slow rate of nutrients and water absorption resulting in stunted and slow growth rate leading to delayed flowering in maize. Similarly, Dhane and Drennan (1997) found that the transplanted crop matured significantly earlier than direct sown maize and tended to give higher grain yield. Adesina et al. (2014) demonstrated that transplanting of maize shortened the crop maturity period by 8-10 days compared to directly sown maize. Additionally, it was reported that time to harvesting reduced by 1-3 weeks in the USA and 10-12 days in France depending on the age of maize seedling (Waters et al., 1990). The result indicates that delayed transplanting increases heat unit requirement and subsequently delays maturity.

Directly planted plants require more time to reach maturity compared to transplants due to their smaller root system. Leskovar and Othman (2021) reported that transplanted plants had a larger root system hence enhances nitrogen and water use efficiency, leading to higher growth rates and increased yields when compared to directed seeded plants which had smaller roots.

3.4.2 Effect of transplanting stage and varietal differences on maturity Height of Baby corn

There were significant interactions ($P \leq 0.05$) between transplanting stage and baby corn varieties on the flowering height across the two seasons under different growing conditions (Table 4). Major interactions were observed between the two varieties at 0 GDD transplanting stage under field conditions for season 1 and greenhouse conditions for both season 1 and 2.

Table 4: Maturity height of baby corn as influenced by the interaction of variety, and the transplanting stage under different growing conditions.

Maturity height (cm)

	Season 1				Season 2			
Transplanting stage (GDD)	Field condition (FC)		Greenhouse condition (GH)		Field condition (FC)		Greenhouse condition (GH)	
	PAN 14	TH	PAN 14	TH	PAN 14	TH	PAN 14	TH
0	221.1^{a}	195.9^{b}	243.9^{ab}	225.9^{a}	225.2^{b}	198.4^{b}	248.1^{a}	226.7^{b}
200	225.1^{a}	206.2^{a}	249.2^{a}	228.4^{a}	233.7^{a}	211.6^{a}	253.3^{a}	235.0^{a}
300	218.7^{a}	191.7^{b}	240.8^{b}	217.3^{b}	219.8^{c}	192.1^{c}	219.7^{b}	219.9^{c}
400	192.9^{b}	195.9^{b}	199.7^{c}	199.2^{c}	203.2^{d}	193.4^{c}	197.1^{c}	197.2^{d}
Lsd	7.69		6.85		4.24		5.91	

Means followed by the same letter down the column are not significantly different ($P \leq 0.05$), TH- Thai Gold.

Interactions were also registered at 300GDD stage in both PAN 14 and Thai Gold in field conditions in season 1 and also under greenhouse conditions at season 2. In field conditions, PAN 14 transplants at 200 gave a significantly high flowering height while 400 GDD transplants resulted to a low flowering height in both growing conditions and varieties. During season 1, transplants grown at 200 GDD experienced a 16.7% rise in PAN 14 and a 7.6% increase in Thai Gold compared to transplants grown at 400 GDD in Field conditions. In greenhouse conditions, when compared to transplants at 400 GDD, PAN 14 and Thai Gold in season 1 exhibited a flowering height increase of 24.8% and 14.7% respectively. This trend was also observed in season 2.

In season 1, when grown under field conditions, PAN 14 had a height that was 18.9 cm greater than Thai Gold. However, when cultivated in a greenhouse environment, Thai Gold exhibited a height that was 20.8 cm lower. This pattern was observed again in season 2.

In both PAN 14 and TH varieties, seedlings transplanted at 200 GDD produced the tallest plants at the time of flowering under FC and GH planting conditions. This indicated that transplanting seedling at 200 GDD provided plants with the best growth conditions for optimal growth and development. Seedling transplanted at 300 GDD and 400 GDD showed a declining trend in height suggesting that delayed transplanting resulted in plants with short height. These results concur with Asaduzzaman et al., 2014 who found out that delay in transplanting reduced plant maturity height which increases the production costs. Similar studies have also reported that delayed transplanting results in shorter maturity heights (Zhao et al., 2016 and Sudipta et al 2003). Earlier studies showed that transplanted maize does not do well because of disrupted and poor root replacement compared to cabbage and tomato (Wellbaumet al., 2001). Additionally, root disturbance in transplanted seedlings caused changes in physiological process and decreased growth Mckee (1981).

3.4.3 Effect of transplanting stage and varietal differences on Cob length of Baby corn

There were significant interactions ($P \leq 0.05$) between transplanting stage and baby corn varieties on cob length across the two seasons under different growing conditions (Table 5). Significant interactions were detected between the two varieties during the transplanting stage at 0 GDD in both field and greenhouse conditions during season 2. Likewise, interactions were observed at the 300 GDD stage in both PAN 14 and Thai Gold under greenhouse conditions in season 1, as well as at the 400 GDD stage in both greenhouse and field conditions during season 1.

Table 5: Cob length as influenced by the interaction of variety and transplanting stages under different growing conditions

Cob length (cm)

	Season 1				Season 2			
	Field condition (FC)		Greenhouse condition GH		Field condition (FC)		Green house condition GH	
Transplanting stage (GDD)	PAN 14	TH	PAN 14	TH	PAN 14	TH	PAN 14	TH
0	175.9^{b}	125.8^{b}	159.8^{b}	134.2^{b}	180.1^{b}	126.9^{b}	162.2^{c}	131.3^{b}
200	198.3^{a}	182.9^{a}	174.4^{a}	139.1^{a}	203.3^{a}	188.9^{a}	180.7^{a}	137.5^{a}
300	172.3^{b}	113.1^{c}	172.0^{a}	115.4^{c}	173.7^{bc}	118.3^{c}	173.8^{b}	116.4^{c}
400	87.5^{c}	79.9^{d}	80.8^{c}	73.6^{d}	87.9^{d}	80.1^{d}	81.3^{d}	70.1^{d}
lsd	10.15		4.76		8.19		5.47	

Means followed by the same letter down the column are not significantly different (P≤0.05), TH- Thai Gold.

In both planting conditions, PAN 14 showed longer cob length compared to TH. Under FC, directly planted PAN 14 had longer cob length (180.1mm) in season 2 compared to TH with 125.8mm in season1. Similarly PAN 14 seedlings transplanted at 200 GDD showed significantly longer cob length (203.3mm) in season 2 than any other transplants in both varieties and growth conditions. Baby corn transplanted at 400 GDD had the shortest cobs in both varieties under the two growth conditions. PAN 14 established under FC at 300 GDD showed significantly longer cob length (172.3mm) compared to TH at the same stage (113.1mm). Similar observations were made under GH conditions.

Under field conditions (FC), PAN 14 transplants grown at 200 GDD demonstrated a significantly greater cob length, whereas transplants at 400 GDD resulted in a lower cob length for both varieties and growing conditions. In season 1, transplants cultivated at 200 GDD experienced a substantial increase of 126.6% in cob length for PAN 14 and a 128.9% increase for Thai Gold, compared to transplants grown at 400 GDD in field conditions. In greenhouse conditions, when compared to transplants at 400 GDD, PAN 14 and Thai Gold in season 1 exhibited a cob length increase of 115.8% and 138.1% respectively. This trend was also observed in season 2.

During season 1, when PAN 14 transplants at 200 GDD were grown under field conditions, a cob length that was 15.4 mm greater than Thai Gold was observed. However, in a greenhouse environment, Thai Gold exhibited a cob length that was 35.3 mm lower. This pattern persisted in season 2 as well.

These observations indicate that varietal differences between PAN 14 and TH significantly influence cob length whether established directly or transplanted at 200 GDD and 300 GDD. This concurs with Asaduzzaman et al. (2014) that the interaction effect of variety and seedling age influences yield attributes like cob length. Further, Abrar et al. (2018) demonstrated that delayed transplanting of sweet corn resulted in significant decline in cob length.

3.4.4 Effect of transplanting stage and varietal differences on Cob diameter of Baby corn

Significant interactions ($P \leq 0.05$) were observed between the transplanting stage and the baby corn varieties concerning cob diameter throughout the two seasons under various growing conditions, as indicated in Table 6. Significant interactions were detected between the two varieties during the transplanting stage at the 300 GDD under greenhouse conditions in season 1 and 2 and field conditions during season 2. At 400 GDD stage interactions were also registered under greenhouse conditions during season 1 and 2.

Table 6: Cob diameter (mm) as influenced by interaction of variety and transplanting stages under different growing conditions

Transplanting stage (GDD)	Season 1				Season 2			
	Field condition (FC)		Greenhouse condition GH		Field condition (FC)		Green house condition GH	
	PAN 14	TH	PAN 14	TH	PAN 14	TH	PAN 14	TH
0	33.5^{b}	25.7^{b}	25.0^{c}	27.4^{a}	37.2^{a}	27.2^{b}	28.3^{b}	28.9^{a}
200	37.8^{a}	35.3^{a}	27.0^{b}	23.3^{c}	39.1^{a}	37.6^{a}	29.5^{b}	26.0^{b}
300	32.8^{b}	24.9^{b}	29.4^{a}	25.4^{b}	34.2^{b}	25.5^{b}	33.5^{a}	26.2^{b}
400	26.7^{c}	23.5^{b}	22.6^{d}	21.4^{d}	27.0^{c}	26.1^{b}	23.2^{c}	22.2^{c}
lsd	2.59		0.76		2.37		1.69	

Means followed by the same letter down the column are not significantly different ($P \leq 0.05$), TH- Thai Gold.

In both planting conditions, PAN 14 exhibited a thicker cob diameter compared to TH. Under FC, PAN 14 directly planted showed a cob diameter of 39.1mm in season 2, whereas TH had a cob diameter of 35.3mm in season 1. Similarly, when PAN 14 seedlings were transplanted at 200 GDD, they displayed significantly thicker cob diameter (39.1mm) in season 2 compared to other transplants in both varieties and growth conditions. Baby corn transplants at 400 GDD had the smallest cob diameter, measuring 22.6mm in PAN 14 and 21.4mm in Thai Gold, under both growing conditions. The smallest cob diameters of 22.6mm and 21.4mm were recorded under greenhouse conditions in season 1 for PAN 14 and Thai Gold respectively. Similar observations were made under greenhouse conditions in season 2.

In season 1, transplants grown at 200 GDD experienced a significant increase of 41.6% in cob diameter for PAN 14 and a 50.2% increase for Thai Gold, in comparison to transplants grown at 400 GDD in field conditions. Under greenhouse conditions, PAN 14 and Thai Gold in season 1 showed a cob diameter increase of 21.2% and 26.2% respectively, when compared to transplants at 400 GDD. This trend was also observed in season 2.

During season 1, when PAN 14 transplants at 200 GDD were cultivated under field conditions, a cob diameter that was 2.5 mm greater than Thai Gold was recorded. However, in a greenhouse environment, Thai Gold exhibited a cob diameter that was 0.4 mm lower. This pattern remained consistent in season 2 as well.

Previous studies in sweet corn have shown that cob size (length and diameter) reduce with seedling age (thermal accumulation in the nursery) (Gabriel et al., 2014). Similarly, Abrar et al. (2018) showed that delayed transplanting of sweet corn resulted in significant decline in cob girth, number of cobs per plant and number of grains per cob. This effect was previously attributed to more severe root damage on older seedlings with a subsequent increase in plant stress (Waters et al., 1990). These results indicate that PAN 14 performed better than TH under FC conditions. In view of a wide range of maximum and minimum temperatures recorded under FC during this study, PAN 14 appears to be best suited in growth conditions with varying temperatures. This also suggests that PAN 14 would be more adapted to stressful growth conditions than TH.

Higher temperature difference has been shown to be stressful conditions and prepares plants to transit to reproductive and senescence phase. This is because response to temperature throughout the plants life cycle is primarily a phenological response (Hatfield & Prueger,2015). Thus the result indicates that varietal difference, growing conditions and planting stage influence cob diameter.

3.4.5 Effect of transplanting stage and varietal differences on Cob weight of Baby corn

Table 7 demonstrates that there were significant interactions (with a significance level of $P \leq 0.05$) between the transplanting stage and the baby corn varieties regarding cob weight across the two seasons under different growing conditions. These significant interactions were observed in relation to field conditions in both season 1 and season 2, specifically at the 0 GDD stage. Additionally, interactions were registered at the 300 GDD stage under greenhouse conditions in both season 1 and season 2. Furthermore, significant interactions were also detected in both varieties, across both growing conditions and seasons, for plants transplanted at 400 GDD.

Table 7: Weight (g) of the first cob as influenced by interaction of variety and transplanting stages under different growing conditions.

Transplanting stage (GDD)	Season 1				Season 2			
	Field condition (FC)		Green house condition GH		Field condition (FC)		Green house condition GH	
	PAN 14	TH	PAN 14	TH	PAN 14	TH	PAN 14	TH
0	82.4^{b}	37.1^{c}	39.6^{b}	38.2^{b}	84.2^{b}	38.3^{c}	40.5^{ab}	39.9^{b}
200	101.0^{a}	101.9^{a}	43.1^{a}	44.3^{a}	104.1^{a}	103.2^{a}	47.3^{a}	47.7^{a}
300	77.7^{b}	62.8^{b}	41.1^{ab}	30.1^{c}	79.8^{b}	63.5^{b}	43.5^{a}	31.9^{c}
400	73.1^{bc}	28.6^{d}	31.3^{c}	23.0^{d}	74.0^{c}	29.1^{d}	33.2^{c}	24.5^{d}
lsd	5.19		2.43		4.67		4.80	

Means followed by the same letter down the column are not significantly different ($P \leq 0.05$), TH- Thai Gold.

In both planting conditions, PAN 14 exhibited a higher cob weight compared to TH. Under FC, PAN 14 directly planted showed a cob weight of 84.2g in season 2, whereas TH had a cob weight of 37.1g in season 1. Similarly, when PAN 14 seedlings were transplanted at 200 GDD, they displayed significantly higher cob weight (104.1g) in season 2 compared to other transplants in both varieties and growth conditions, however it was not significantly different from Thai Gold transplanted under the same conditions. Baby corn transplants at 400 GDD had the smallest cob weight, measuring 31.3g in PAN 14 and 23.0g in Thai Gold, under both greenhouse conditions in season 1. The highest cob weight was recorded at 200 GDD followed by 300 GDD and direct sown plants while 400 GDD had the least cob weight in both varieties. GH growing conditions produced cobs with the lowest weight compared to FC condition grown baby corn in both varieties. Similar to observations made in other parameters, cob weight reduced with delayed transplanting.

In season 1, transplants cultivated at 200 GDD demonstrated a significant increase of 38.2% in cob weight for PAN 14 and a substantial increase of 256.3% for Thai Gold, in comparison to transplants grown at 400 GDD under field conditions. When grown in greenhouse conditions, PAN 14 and Thai Gold in season 1 exhibited a cob weight increase of 37.7% and 47.2% respectively, when compared to transplants at 400 GDD. This pattern was also observed in season 2.

During season 1, when PAN 14 transplants at 200 GDD were cultivated under field conditions, a cob weight that was 0.9g greater than Thai Gold was recorded. However, in a greenhouse environment, Thai Gold exhibited a cob weight that was 0.2g lower. This pattern remained consistent in season 2 as well.

The highest weight was recorded on plants grown under FC while those raised under GH had the least weight. The variation in cob weight between baby corn plants grown in field conditions and those grown in greenhouses may have been caused by different factors. Baby corn plants in field conditions benefitted from natural sunlight, which supplied the necessary spectrum of light for photosynthesis and growth (Poorter et al., 2016). Conversely, greenhouses typically used filtered light, which may not have replicated the intensity and quality of natural sunlight (Timmermans et al., 2020). This insufficient light in the greenhouse could have hindered photosynthesis and slowed down growth, ultimately leading to smaller cob weights.

Additionally, field conditions exposed the plants to natural temperature and humidity fluctuations, which stimulated their growth. In contrast, greenhouses maintained controlled environmental conditions, including temperature and humidity. Since, these greenhouse conditions were not optimized specifically for baby corn growth it could have led to different results; if the temperature was too high or the humidity too low it could have had a negative impact on plant development, resulting in reduced cob weight.

Furthermore, the better air circulation in field conditions allowed for proper ventilation, which is crucial for photosynthesis (Poorter et al., 2016). In a greenhouse with limited air movement, photosynthesis could have been hampered, leading to inadequate cob development.

The differences observed between the baby corn varieties can be attributed to their distinct genetic makeup, which influenced the development of their cobs. PAN 14, specifically, had larger and heavier cobs due to specific genetic traits associated with cob size. These genetic variations accounted for the disparities in cob weight. Additionally, PAN 14 exhibited different growth habits, such as taller plant height during flowering (Table 4) and overall vigour. These growth characteristics allowed it to allocate more energy towards cob development, resulting in larger and heavier cobs compared to varieties with less robust growth (Mubarak et al., 2023).

Furthermore, the varieties could have differed in their ability to absorb and utilize nutrients from the soil (Lazcano et al., 2013). PAN 14 may have been more efficient at nutrient uptake and utilization, leading to better nutrient availability for cob development. The environmental conditions, including sunlight, temperature, humidity, and soil conditions, strongly influenced the growth and development of baby corn varieties in both greenhouse and field conditions (Poorter et al., 2016). PAN 14 performed better and produced heavier cobs under field conditions compared to greenhouse conditions. Field conditions provided superior air circulation, facilitating proper ventilation. In contrast, limited air movement in the greenhouse could have hindered photosynthesis, resulting in suboptimal cob development.

These results agree with Asaduzzaman et al., 2014 who showed that cob weight tended to decrease with the age of the seedling while direct seeded plants had the least cob weight. Pendleton and Egli (1969) noted that transplants yields less than the early seedlings because of their shorter plant height and less leaf surface area. Previous works have reported a slower growth rate and a lower yield of sweet corn transplants that were more than 3 weeks old at the time of transplanting (Waters et al., 1990).

3.5 Conclusion

There were statistically significant interactions (at a significance level of $P \leq 0.05$) observed between the transplanting stage and baby corn varieties in terms of maturity GDD, flowering height, cob length, cob diameter, and cob weight during two seasons and under various growing conditions.

This study found that transplanting baby corn at 200 GDD resulted in the best growth performance and productivity. Additionally, PAN 14 variety exhibited greater resilience to dynamic growth conditions compared to Thai Gold, suggesting its suitability for stressful environments. The variation in cob weight between field and greenhouse conditions could be attributed to differences in sunlight exposure, with natural sunlight providing the necessary light spectrum for optimal growth, while filtered light in greenhouses may have hindered photosynthesis and resulted in smaller cob lengths, diameter and weights.

Field conditions, with their natural temperature and humidity fluctuations, promoted plant growth in baby corn. In contrast, greenhouses, which maintained controlled environmental conditions, may have hindered plant development and resulted in reduced cob weight if the conditions were not optimized for baby corn growth. The variation in cob weight between baby corn varieties was attributed to differences in their genetic makeup, with PAN 14 exhibiting specific traits related to cob size, as well as different growth habits allocated more energy towards baby corn growth and development, leading to larger and heavier cobs compared to Thai Goldwith less vigorous growth.

CHAPTER 4: EFFECT OF PLASTIC MULCH COLOUR AND TRANSPLANTING STAGE ON BABY CORN PLANT PERFORMANCE

4.1 Introduction

Mulches are materials that are applied to the soil's surface for a variety of functions. Conversely, different coloured plastic mulches have been made and used in various crop production methods (Amare and Desta, 2021; Ibrahim et al., 2021). The main goals of using coloured plastic mulches are to change the radiation budget and reduce soil water loss (Kader et al., 2017). In addition, it aids in controlling weed and insect infestation as well as soil temperature, water use efficiency, plant development, yield, and quality (Kader et al., 2019). The mulches used in farming systems come in a variety of types and qualities. The most popular mulches are made of gravel, pebbles, polyethylene film, organic materials like straw, hyacinth, wood, or leaves that can be used alone or in mixes, or living elements like turf grass, rye, and clover (Franquera and Mabesa, 2015; Li et al., 2018).

In the Global South, organic mulches, primarily organic straws, are most frequently used. However, organic mulches decompose, are less efficient, require more work, and are weather dependent (Zribi et al., 2018). The use of polyethylene (PE) as a plastic mulch for vegetable crop production in the 1950s after its discovery as a plastic film in 1938 significantly improved commercial crop productivity (Li et al., 2021). In the year 2018, 360 million tonnes of plastic mulch were produced worldwide with the distribution being as follows: Asia 51%, Europe 17%, NAFTA (18%), Africa 7%, Commonwealth of Independent States 3%, and Latin America 4% (Leal Filho et al., 2021; Kumar et al., 2021). Nevertheless, nearly 4% of the plastics produced are used in agricultural agriculture for various tasks, including mulching (Leal Filho et al., 2021).

The farming community has used a variety of polyethylene coloured plastic mulches with various formulas for various purposes. Previously, vegetable cultivation employed black, clear, and white plastic mulches. Today's most popular plastic colours include black, white, green, brown, red, silver, and blue. These colours were created taking into account of how they affect plant physiology and light absorption. Numerous researchers have evaluated the effects of these coloured plastic mulches on various crops (Gordon et al., 2010; Tigist et al., 2012and Franquera and Mabesa, 2015).

The most widely used and widely available plastic mulch is black. It effectively absorbs solar radiation from the sun's ultraviolet, visible, and infrared wavelengths. By absorbing a significant amount of radiation, it significantly increased soil heat. The black plastic mulch is the opposite of the white variety. The latter reduces soil heating requirements for crops by cooling the soil (Maughan and Drost, 2016 and Forcella et al., 2011). Plastic mulches come in a variety of colours with the goal of changing the microclimate at the soil and plant levels. The spectral balance, quality, and quantity of light are all impacted by the colour of plastic mulch, and this has an impact on several aspects of plant growth and development, including plant yield (Torres-Olivar et al., 2016 and Helalyet al., 2017).

By altering the radiation budget and reducing soil water loss, plastic mulches also have a direct impact on the microclimate in the area around the plant. By raising fruit quality, gross yield, and early production, this improves crop productivity (Bonachela et al., 2012 and Basnet, 2022). Additionally, coloured plastic mulches significantly affected soil water loss, soil temperature, plant morphology, and weed control (Basnet, 2022). The aim of colour variation is to influence FR: R (far-red to red) ratios, which regulate phytochrome absorption and reflection. Thus increased plant height and above-ground biomass are the reactions of plants receiving high FR: R light ratios (Kusuma and Bugbee, 2020).

Black plastic mulch is utilized to absorb more light and heat, white mulch to reflect, and transparent mulch to generate intense heat (Babatundeet al., 2020; Hutton and Handley, 2007). Various plastic mulches have been produced recently in a variety of colours and compositions.

These coloured plastic mulches are utilized in various plant cropping systems for a variety of objectives.

Any procedure or technological use intended to promote plant growth and development has a significant impact on the soil. These technical inputs have an impact on the soil’s physical, chemical, and biological characteristics. One of the primary characteristics of soil that influences crop production is soil temperature. Temperature of the soil affects a variety of systems and activities, including nutrient uptake, water absorption, root growth, and the existence of soil microbes (Onwuka and Mang, 2018 and Pregitzer and king, 2005). The temperature of the soil is significantly changed by coloured plastic mulch. According to (Amare and Desta, 2021; Ibarra-Jiménez et al., 2011), coloured plastic mulches raised the soil's temperature above that of bare soil.

The effect that coloured plastic mulches on soil temperature have been found vary from region to region and from crop to crop. According to a research report by Amare and Desta (2021) and Jahan et al. (2018), black plastic mulches recorded greater temperatures than olive, silver, white, and blue mulches. However, according to (Machanoff et al., 2022), the soil temperature was higher under the brown and blue plastic mulches than it was under the black and other mulches. This variation results from differences in the soil types and local climates. Reports’ confirming this stated that black plastic mulch is more effective than white/black or aluminum/black plastic mulching systems in raising the minimum, maximum, and mean soil temperature (Machanoff et al., 2022 and Svotwa et al., 2014).

Baby corn is a dehusked maize ear harvested within 2 - 3 days after silking but before fertilisation (Mohamed et al., 2020; Singhet al., 2010). It is used to prepare various traditional and intercontinental dishes, besides being canned. The immature, unfertilized ears of baby corn, a kind of maize widely used by horticultural farmers around the world (Ranjan and Sow, 2021) are harvested within two to three days of the silk emergence (Mohamed et al., 2020). After seeding, it begins the reproductive phase within 45–55 days and finishes the cycle in 60–

70 days (Eich-Greatorex et al., 2018: Akinnuoye-Adelabu and Modi, 2017). When the ears are 5–10 cm long and 0.8–1.6 cm in diameter at the base or butt-end, they are ready for use (Akinnuoye-Adelabu and Modi, 2017). In order to grow baby corn, either direct seeding or transplanting is possible. Many high-value vegetable crops are established by the use of transplants (Singh et al., 2020). The best time to transplant seedlings depends on a number of growth parameters, including soil moisture, nutrients, temperature, light, and cultural techniques (Ginigaddara & Ranamukhaarachchi, 2016). Among them, it has been demonstrated that temperature plays a significant role in determining the rate of plant growth, development, and production (Hatfield and Prueger, 2015)

To complete their growth cycles, plants need a particular amount of heat, measured in GDD (Yousef et al., 2013). Plant flowering dates, harvest ripeness, and the interval between two developmental stages are all estimated using GDD (Akinnuoye-Adelabu and Modi, 2017; Olesenet al., 2012). Additionally, it is known that temperature affects how quickly successive new leaves appear at the stem's apex (Kirk and Marshall, 1992)

The quantity of fruits, fruit weight, and the length of the harvest per plant for capsicum plants were found to be influenced by the age of the transplants (Olesen et al., 2012). Greater plant establishment, grain yield per cob, grain yield per unit area, plant height, and straw production were found in maize seedlings that were three weeks old (Wang et al., 2001). Maize seedlings transferred after 14 and 21 days reached maturity 6 and 12 days earlier than maize planted directly (El-Hamed et al., 2011). According to Singh (2019), baby corn is majorly grown for the export market in Kenya. Poor germination, scanty rainfall and soil temperature are some of the major limiting factors that affect the quality and production of baby corn for the premium market. However, mulching can control soil temperature (Singh et al., 2012; Amare and Desta, 2021) . Small-scale farmers in Meru County, Kenya, have not adequately adopted plastic mulching. Thus there is a need to develop a more precise transplanting stage suitable for optimal production given the wide range of 3–4 weeks transplanting age of maize seedlings.

The objective of the research was to determine interaction between different treatments (plastic mulch colours and phased transplanting stages) on the performance of baby corn plant varieties.

4.1.1 Impact of colour on the efficiency of plastic mulches

The effect of plastic films on the temperature of the soil and crop canopy microclimate relies on their thermal properties. These involve reflectivity, absorptivity, or transmittance depending on incoming solar radiation (Chia et al., 2021; Gordon et al., 2010). Black plastic mulch accelerated canopy establishment and grain yield due to increased root zone soil temperature and conservation of soil water (Mahadeen et a., 2014). Advancements in material (plastics)science have resulted in the development of films with optical properties that are ideal for a specific crop in specific locations without compromising the soil temperature at the plant root for farmers (Amare and Desta, 2021).

The changes in root zone soil temperature influences root physiological processes like absorption of water &soil nutrients and translocation of essential nutrients, which influences shoot and root growth. Elevated soil temperatures quicken crop emergence and growth, making the plants achieve the desired population structures at early growth stages (Gordon et al., 2010)As a result, it enhances the absorption of solar energy, thus enhancing crop yield(Iqbal et al., 2020) For instance, cucumber crops grown under plastic mulch films matured 7 to 14 days earlier and increased yields by 2 to 3 times compared to those grown on bare soil (Torres-Olivar et al., 2016)

The colour of the plastic mulch film used for mulching the soil determines the performance of the radiant energy, thus impacting the microclimate around the cultivated plants (Chia et al., 2021;Maughan and Drost, 2016 andFranquera, 2015). . The interaction between the quality of the light reflected by the surface of the plastic mulch film, the capacity for transmission of solar energy and the increase in soil temperature determines the response of plants to the coloured film. The different types and colours of plastic mulch have characteristic optical properties that change the levels of light radiation reaching the soil. Therefore, the soil temperature can be modified by changing the colour of plastic mulch films in regions of substantially high or low temperatures, thus encouraging faster plant development (Amare and Desta, 2021). Kader et al. (2017) reckon that depending on the crop variety, geographical location, and season, different colours of plastic mulches create high root zone-temperature conditions that might damage the growth, compromising vegetables' yield. Plastic mulch includes but is not limited to transparent, black, red, white and yellow, and the choice of colour depends on the intended purpose of the mulch.

Black-coloured plastic film is the most popular among growers worldwide (Maughan and Drost, 2016.) Over an extended period, it has been the standard plastic mulch in vegetable production as it changes the plant's growing environment by increasing the root-zone soil temperature and holding more soil moisture compared to un-mulched soil (Olesen et al., 2012). However, according to (Onwuka and Mang, 2018),black plastic mulch lowers the quality of reflected light compared to other coloured mulches, like red and blue mulches. The spectral distribution of the light reflected by these red and blue mulches is better utilised for photosynthesis and photomorphogenesis (Franquera, 2015). These colours (blue & red) change the quality of the light spectrum regarding the proportions of the red to far-red wavelengths and blue light which predominantly control the photomorphogenesis mediated by the different photoreceptors like phytochrome (Arakawa et al., 2016).

Using black and transparent plastic mulch films causes an average temperature increase compared to un-mulched soil temperature. The significant increase in temperature leads to early germination and shorter growing seasons due to the increased growing degree days of the soil. The increased GDD at the beginning of a season increases the chances of success in production in several ways. For instance, it enables crops to be grown with lower risk and a higher likelihood of germination; increases the choices of crops that can be grown (for instance, those demanding a higher price and requiring longer, warmer growing seasons); provides crop produce when price and demand are high; and, provides the farmer with more choices as to when plants may be harvested (Amare and Desta, 2021; Singh, 2019; Arakawa et al., 2016and Franquera, 2015)

White plastic mulch film generates cooler soil temperatures than black plastic (Haque et al., 2018) This colour is preferable during hot/summer growing seasons in warmer regions compared to black as it provides cooler soil temperatures. On the other hand, clear mulch provides more significant net radiation under the mulch and is thus more effective in increasing soil temperature than opaque mulches (Gordon et al., 2010). It absorbs lower solar radiation but transmits 85% to 95% of this energy depending on the plastic mulch film's thickness and degree of opacity. In addition, the underside of the clear plastic mulch usually is covered with condensed water droplets. These water droplets are transparent to incoming short-wave radiation but opaque to outgoing long-wave infrared radiation. Therefore, much of the heat lost to the atmosphere from a bare soil by infrared radiation is conserved by clear plastic mulch. The clear (transparent and translucent) mulches promote a relatively large net radiation at the soil surface, increase soil heat flux hence, increasing the minimum and maximum soil temperature (Qin et al., 2022): He et al., 2021Black, clear and white coloured plastic mulches have been the most popular in vegetable farming (Lamont, 2017 and Franquera, 2015).

4.2 Materials and Methods

4.2.1 Study Location

The research was conducted at Abothuguchi West Division, Meru Central sub-county of Meru County in Kenya (Latitude 00 01'and Longitude 36^0 37'). A field experiment was conducted in one season January-March 2018.

4.2.2 Study Design

The experimental plots were arranged in a split-split plot randomized complete block design according to a method described by (Bisgaard, 2000), with three replications. This gave a 4 x 4 x 2 x 3 factorial amounting to 96 plots (Figure 5). Two Baby corn varieties (PAN 14 and Thai Gold) were subjected to three plastic mulch sheets of different colours: black (B), yellow (Y) and transparent (T) and control (non-mulched, N) at different GDD transplanting stages: 0 GDD (direct planting), 200 GDD,300 GDD and 400 GDD.

R1					R2					R3			
$V1BTS_0$	V_1YTS_{400}	V_1TTS_{200}	V_1NTS_{400}		V_2TTS_0	V_2TS_{200}	V_2YTS_{300}	V_2BTS_0		V_1TTS_{300}	V_1NTS_0	V_1YTS_{200}	V_1BTS_0
V_1BTS_{200}	V_1YTS_0	V_1TTS_{300}	V_1NTS_{200}		V_2TTS_{400}	V_2NTS_0	V_2YTS_0	V_2BTS_{200}		V_1TTS_{200}	V_1NTS_{300}	V_1YTS_{400}	V_1BTS_{200}
V_1BTS_{300}	V_1YTS_{300}	V_1TTS_{400}	V_1NTS_0		V_2TTS_{300}	V_2NTS_{400}	V_2YTS_{200}	V_2BTS_{400}		V_1TTS_{400}	V_1NTS_{400}	V_1YTS_0	V_1BTS_{300}
V_1BTS_{400}	V_1YTS2_{00}	V_1TTS_0	V_1NTS_{300}		V_2TTS_{200}	V_2NTS_{300}	V_2YTS_{400}	V_2BTS_{300}		V_1TTS_0	V_1NTS_0	V_1YTS_{300}	V_1BTS_{400}
V_2BTS_0	V_2TTS_{200}	V_2YTS_0	V_2NTS_{300}		V_1NTS_{300}	$V1BTS_0$	V_1YTS_{200}	V_1TTS_{400}		V_2BTS_0	V_2YTS_{400}	V_2NTS_{200}	V_2TTS_{400}
V_2BTS_{200}	V_2TTS_0	V_2YTS_{300}	V_2NTS_0		V_1NTS_0	V_1BTS_{200}	V_1YTS_{300}	V_1TTS_{200}		V_2BTS_{300}	V_2YTS_0	V_2NTS_0	V_2TTS_0
V_2BTS_{300}	V_2TTS_{400}	V_2YTS_{400}	V_2NTS_{200}		V_1NTS_{400}	V_1BTS_{300}	V_1YTS_0	V_1TTS_{300}		V_2BTS_0	V_2YTS_{200}	V_2NTS_{300}	V_2TTS_{300}
V_2BTS_{400}	V_2TTS_{300}	V_2YTS_{200}	V_2NTS_{400}		V_1NTS_{200}	V_1BTS_{400}	V_1YTS_{400}	V_1TTS_0		V_2BTS_{400}	V_2YTS_{300}	V_2NTS_{400}	V_2TTS_{200}

Figure 5: Experimental layout

Planting holes were made on the polythene mulch plastic sheets using a hot round metallic bar of 2 cm diameter at a spacing of 60cm by 25cm (Figure 6). The plastic mulches were spread over the plots on the same day of planting. One seed was planted per hole while transplanting seedlings were raised in a half kg polythene sleeves before transplanting. Both direct planting seeds and seeds in the polythene sleeves were planted the same time and day.

Figure 6: Soil temperature measurement and layout of plastic mulches

The field plots were established between January and June 2018 to evaluate the influence of different plastic mulch colours and transplanting stages on the production and growth of two baby corn varieties (PAN 14 and Thai Gold). The field plots were 1.5m long and 1.5m wide. The coloured plastic mulches and plastic drip irrigation lines were applied simultaneously on raised beds (15 cm in height) (Figure 6).

4.3 Data Collection

Data was collected from four randomly selected plants in each plot. The data collected included soil and air temperature, vegetative and yield parameters. Vegetative parameters included flowering period, Growing Degree Days (GDD) stage and height. The yield parameters included the cob length, cob diameter and fresh weight of the first cob. Soil temperatures were recorded using minimum and maximum thermometers and inserted to a depth of 3cm in the soil (figure 7). For comparison, air temperatures were measured by placing the same thermometer 50 cm above the ground. Both air and soil temperatures were recorded daily at 13:00 Hrs East African Time (EAT) during the entire baby corn growth period.

Figure 7: Soil temperature measurement and growing of baby corn

Using a meter rule, the plants' flowering heights were determined by measuring the distance from the second node to the flag leaf level. The maturity period (maturity GDD) was determined by counting the days from planting date to flowering date for directly planted plants. Cob length and diameter were determined using a digital Vernier Caliper (Model 500-196; Mitutoyo-Digimatic, Kanagawa, Japan). The cob weight was determined using a digital weighing scale (Model KSH, KST, Kaushik Scale Corporation, Delhi, India). All the yield parameters were obtained on cobs harvested two days after silking.

Figure 8: Cob weight measurement

4.4 Data Analysis

Data analysis was conducted using Statistical Analysis System (SAS, 2007). The means were subjected to analysis of variance (ANOVA) using Least Significant Difference (LSD) option to determine statistical differences at 95% confidence level. The means were considered significantly different at $P \leq 0.05$.

4.5 Results and Discussion

4.5.1 Effect of plastic mulch colour on soil and air temperature

Colour of the plastic mulch determined the degree of soil warming. Different kinds of mulch colour treatments had remarkable influence on soil temperature. Figure 9below shows that the control, yellow, transparent and black plastic mulch treatment had average soil temperature of 20.0ºC, 22.2ºC, 24.7ºC and 29.2ºC respectively.

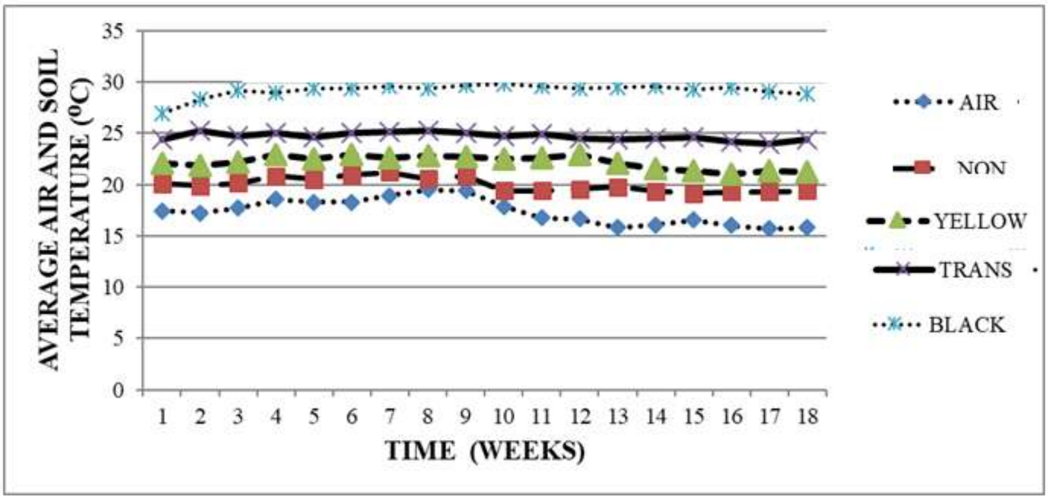


Figure 9: Air and soil temperature as influenced by plastic mulch colour during the crop growing period

Yellow, transparent and black mulch treatments had 2.2ºC, 4.7ºC and 9.2ºC higher temperature than the control respectively. Therefore, yellow plastic mulch led to relatively warm soils while transparent and black mulch kept the soil hotter (figure 1). These results agree with findings of Bradford et al.(2019)where black plastic mulch was found to cause a 1.4ºC increases in soil temperature compared to the un-mulched control. The same group also reported that soil temperature under light coloured plastic mulches (clear, violet, light-green) was 2.5 to 2.9 ºC higher when compared with bare soil. Similarly soil temperature was increased by 5.0 to 10.0°C by the application of plastic mulches as compared to bare soil (Li et al., 2018). The results indicate that black and clear plastic mulches had the greatest soil warming potential among the various mulch colours as found by Moore &Wszelaki (2019) even though they heated the soil in different ways. The dissimilarities in soil temperature between different coloured plastic mulch could be due to the differences in the reflection, absorption and transmission of solar energy by the coloured plastic mulch (Jabran& Farooq, 2007; Sardar et al., 2020; Troyjack et al., 2018).

Black mulch has been reported to produce the hottest soil temperature compared to the other coloured mulch films (Awata et al., 2019). Black mulch warms the soil by absorbing light which is then conducted to the underlying soil, as long as the plastic mulch is in close contact with the soil. Black mulch absorbs much of the UV, visible, and infrared wavelengths from incoming solar radiation and re-radiates the absorbed energy as thermal radiation or long-wavelength infrared radiation. In addition, black plastic mulch has been found to have intense shortwave transmittance and high shortwave absorptance properties, causing soil temperatures to be quickly raised (Snyder et al., 2015). Thus black mulchproduces the hottest soil temperature compared to other coloured plastic mulches (Huang et al., 2019).

Clear plastic mulch had high soil temperature compared to yellow plastic mulch and the unmulched soil. Previous studies indicate that clear plastic mulch film absorbs little solar radiation of 5% of short-wave and reflects 11% while transmitting 85% to 95% depending on the thickness and degree of opacity of the material(Snyder et al., 2015b). For instance, daytime soil temperatures under clear plastic mulch are generally 8 to 14^{o}C higher at a 5.08 cm depth and 6 to 9^{o} C higher at a 10 cm depth compared to those of bare soil. The variability of soil temperature in the upper few cm of the soil layer is affected by the colour of the plastic mulch (Bakshi et al., 2016). In addition, the variation in soil temperature with different colours of plastic mulch could be based on the components of radiation balance, which is due to the effect of mulch on albedo, sensible heat flux, latent heat flux and soil heat flux (Freedman & Keast, 2011).

Table 8: Analysis of variance for the effects of plastic mulch colour (PC), Transplanting stages (Ts) and Baby corn varieties (V) on growth and yield parameters.

Varriables	**Maturity Height**	**Maturity Days**	**GDD**	**Cob Length**	**Cob Diameter**	**Cob weight**
PC	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Ts	0.0001	<.0001	<.0001	<.0001	<.0001	<.0001
V	0.0001	<.0001	<.0001	ns	<.0001	<.0001
PC x Ts	0.0029	<.0001	<.0001	0.0084	0.0145	0.004
PC x V	0.0014	0.0003	<.0001	0.0004	ns	<.0001
Ts x V	ns	<.0001	0.0023	0.0152	ns	<.0001
PC x Ts xV	0.0083	<.0001	<.0001	ns	ns	ns
CV	3.77	2.25	3.03	8.23	9.51	9.561

* ns (not significant) signifies that the p values were >0.05.

4.5.2 Plant Performance

Table 9: Interaction of plastic mulch colour, transplanting stages and varieties on growth parameters of baby corn.

	Maturity Height (MH) (cm)		**Maturity Days (MD)**		**Soil GDD**	
	PAN 14	**Thai Gold**	**PAN 14**	**Thai Gold**	**PAN 14**	**Thai Gold**
Transplanting stage 0						
Control	163.27e	210.60c	75.20b	81.70ab	772.47fg	846.07f
Yellow	198.37c	235.77b	74.27b	75.1c	780.20f	921.40ef
Transparent	216.10b	245.77ab	61.10ef	63.63ef	841.23e	945.90e
Black	225.83ab	255.30ab	60.67ef	61.07f	960.63c	1170.60bc
Transplanting stage 200						
Control	182.5d	219.00c	62.43e	75.77c	729.93g	776.30g
Yellow	193.9cd	244.90ab	59.80f	69.77d	778.87f	846.53f
Transparent	230.63a	250.97ab	58.73f	63.00f	809.07ef	915.57ef
Black	238.63a	257.86a	57.67f	57.83g	980.13bc	1077.90d
Transplanting stage 300						
Control	154.97e	209.17c	76.73ab	82.20ab	769.43fg	882.47f
Yellow	203.7bc	236.10b	71.40c	74.90c	825.43ef	908.10ef
Transparent	208.83bc	249.53ab	66.87d	66.00e	889.20d	933.70e
Black	210.77bc	250.73ab	61.2ef	64.93ef	915.90c	1215.53b
Transplanting stage 400						
Control	152.07e	209.13c	78.20a	83.07a	932.87cd	945.7e
Yellow	187.73cd	217.13c	72.93bc	82.77a	1005.73bc	1012.17cd
Transparent	188.4cd	218.17c	72.87bc	82.43ab	1018.80b	1145.40c
Black	190.00cd	242.2b	70.67c	81.43ab	1320.17a	1555.97a
lsd (0.05)	13.28		2.59		47.12	

Means followed by the same letter down the column are not significantly different (p > 0.05).

4.5.2.1 Maturity Height (MH)

Significant interactions ($p \leq 0.05$) were reported between plastic mulch colour, transplanting stages and varieties (Table 8) (Table 9). The Maturity height of PAN 14 and Thai Gold were influenced by different plastic colour at different transplanting stages. Interactions were registered when PAN 14 and Thai Gold were planted under control and yellow plastic mulch under 0 and 200 transplanting stages,

Under all the colours, black plastic mulch performed significantly ($P \leq 0.05$) better followed by the transparent while yellow performed least at all the transplanting (Table 9). The best interactions were reported when PAN 14 and Thai Gold were planted under black plastic mulch and a transplanting stage of 200 GDD with a mean maturity height (MH) of 238.63cm and 257.86cm, followed by transparent mulch which recorded 230.63 cm under the same transplanting stage even though the two were not significantly($p > 0.05$) different. This was followed by black and transparent transplants planted directly in the farm at 225.83 and 216.10cm respectively.

Under all transplanting stages, Varieties planted at 200 GDD performed significantly($p \leq 0.05$) better compared to other stages, while 400 GDD had the least maturity height (MH). The least interactions were recorded when PAN 14 and Thai Gold were planted under control and a transplanting stage of 0 GDD with a mean maturity height (MH) of 152.07cm and 209.13 cm respectively. In all treatments control recorded the shortest maturity height of 163.27cm, 182.5cm, 154.97cm and 152.07cm in 0 stage, 200 stage, 300 stage and 400 stage respectively (Table 9).

Thai Gold variety performed better in all transplanting stages and plastic colour mulch with a mean height ranging between 209.13-257.86 cm as compared to PAN 14 variety with a lower mean height ranging between 152-238 cm in all transplanting stages and plastic colour mulch. Thai God variety performed better under black plastic mulch with a mean of 257.86 cm under

200 GDD and the lowest height of 209.13cm was recorded under control at 400GDD transplanting stage (Table 9).

An increase of 6% and 2 % were recorded in PAN 14 and Thai Gold under black plastic mulch at 200 GDD transplanting stages compared to control at 400 GDD. In 0 GDD stage of transplanting under black plastic mulch there was 5% and 4% higher maturity height than transparent plastic mulch while, transparent mulch was 9% and 4.2% higher than yellow plastic mulch in PAN 14 and Thai Gold respectively. Yellow plastic much was 21% higher than control which recorded the shortest maturity height at 0 GDD. Against the control, transparent, yellow and plastic mulches recorded 4.3%, 23.4% and 27.7% lower MH than the black plastic mulch.

In transplanting stage 200GDD, black recorded 3.4% and 2.7% MH higher than the transparent in PAN 14 and Thai Gold respectively. Similarly, transparent recorded 18.9% higher MH than yellow while yellow had 6.2% higher MH than the control. Compared to the control, black, transparent and yellow plastic mulches recorded 30.8%, 26.4% and 6.3% higher MH than the control respectively.

The higher maturity height observed under Black plastic mulch across all transplanting stages and varieties is due to high soil temperature. The interaction of black plastic mulch and transplanting at 200 GDD could potentially enhance plant growth and, subsequently, maturity height in the Thai Gold variety. The high maturity height was due to the black plastic mulch absorbing and retaining heat from sunlight, leading to elevated soil temperatures. This warmth promoted root development, enhancing nutrient uptake, and overall stimulating baby corn growth. With a well-established root system, baby corn accessed more water and nutrients, which contributed to increased height as they mature. In addition, black plastic mulch acted as a barrier, black plastic mulch reduced evaporation and helped to conserve soil moisture. This sustained moisture availability supported continuous plant growth, even during critical stages of development.

Availability of moisture contributed to taller baby corn plants as they progressed through maturity. Generally, plants under plastic mulches films showed superior plant height than the control indicating that mulches had positive effect on plant growth and development. It was observed that baby corn grown from black mulch were the tallest followed by transparent mulch while yellow coloured mulch had the lowest. This was in agreement with (Xalxo et al., 2020), that black plastic mulch gave taller tomato plants than the transparent mulched plants after 45 days since transplanting date. Increased flowering height in mulched plants could be as a result of better availability of soil moisture and optimum soil and air temperature. The lighter colour mulches reflected more total light resulting in a lower ratio of far-red relative to red light. The increase in light intensity affected plant development and yield through greater photosynthetic rates, while the ratio of far red to red (FR: R) ratio is important in phytochrome regulation of plant physiological processes which affect internodes lengths and stem elongation, chloroplast ultra-structure, photosynthetic efficiency, and photosynthate partitioning among leaves, stems and roots (Xalxo et al., 2020)

4.5.2.2 Maturity Days

Plastic mulch colours, transplanting stages and baby corn varieties had significant interaction on maturity Days (Table 8) (Table 9). Major interactions were registered when PAN 14 and Thai Gold were planted under yellow at 0 GDD, 200 GDD as well as 400 GDD transplanting stages. Plastic Mulch colour influenced the maturity period of PAN 14 and Thai Gold under all transplanting stages. Black Plastic mulch colours recorded the least maturity period in days in all transplanting stages. The least maturity period was recorded in PAN 14 and Thai Gold variety at 200 GDD with a period of 57.67 and 57.83 days respectively. Among the colours, the longest maturity period (MD) was registered under yellow plastic mulch at all transplanting stages. PAN 14 under yellow plastic mulch recoded the longest period of 74.27 days at 0 GDD while Thai Gold variety recorded the longest period of 82.77 days at 400 GDD transplanting stage. However, control recorded the longest maturity period in all the transplanting stages. Transplanting stages had a significant influence on the maturity period of baby corn under different plastic mulch colours (Table 9). Among the different transplanting stages, 400 GDD recorded the longest period of 78.20 and 83.07 days under control in PAN 14 and Thai Gold respectively. Apart from the directly planted Baby corn varieties (0 GDD), the maturity days increased with the delay in the transplanting period among all the mulch colours. 200 GDD transplanting stage resulted in the shortest maturity period across all the varieties and mulch colour, while the longest maturity period was observed at 400 GDD transplanting stage

Baby corn varieties significantly influenced the maturity period in days across all colour mulch and transplanting stages. Thai Gold variety took the longest time to mature compared to PAN 14. The longest maturity period was registered when Thai Gold variety was transplanted under yellow plastic mulch at 400 GDD followed 300 GDD and 200 GDD. On the other hand, PAN 14 variety took the shortest period to mature with a mean of 57.67 days under black plastic mulch at 200 GDD, while the longest period was 78.20 days under control at 400 GDD transplanting stage.

In PAN 14 variety the maturity period decreased by 26% when planted under black plastic mulch at 200GDD as compared to planting PAN 14 under control at 400 GDD. Similarly, Thai Gold resulted in a decrease of 30% when planted under black mulch at 200 GDD compared to control at 400 GDD transplanting stage.

Black plastic mulch absorbs and retains more heat from the sun compared to other types of mulch or bare soil leading to higher soil temperatures. Warmer soil temperatures stimulated root development, nutrient uptake, and overall plant metabolism. In addition, black plastic mulch created a favourable environment for root development. It provided a protected area for roots, shielding them from extreme temperatures and drying out. The warm soil temperatures under the mulch stimulated root growth, allowing baby corn to establish a strong root system more quickly. The increased soil temperature promoted earlier and faster growth of baby corn plants, leading to accelerated maturity. Black plastic mulch absorbs and reflects light, particularly in the infrared spectrum. This reflection of specific wavelengths of light influenced growth and development. Baby corn varieties, being sensitive to light quality, and may have responded to the specific light reflected by the black plastic mulch, triggering physiological changes thus hastening their maturation

These findings agree with He et al. (2021) ; Qin et al. (2022) and Murphy et al.(1999), black plastic mulches showed better performance by producing crops of higher heights within a comparatively shorter time than transparent mulches. However, (Uribelarrea et al., 2007) suggested that transparent mulches showed no significant impact on the maturity period compared to black plastic mulch but accumulated more heat that could be detrimental to the plant yield. For maize production, Bye et al.(2016) suggested that plastic mulches could influence plant nutrient uptake as they provide a favourable environment for better root growth by increasing the soil temperature and conserving soil moisture by reducing soil water loss via evaporation.

4.5.2.3 Maturity soil GDD

There was significant interaction ($p<0.05$) between the plastic mulch colour, transplanting stages and varieties (Table 8) and (Table 9). These interactions were pronounced under the black plastic mulch and transparent colour at 200 GDD, 300 GDD and 400 GDD transplanting stages in the two baby corn varieties. Plastic mulch colour influenced the maturity soil GDD for both PAN 14 and Thai Gold under all transplanting stages. Among the colours black plastic mulch recorded the highest soil GDD at all transplanting stages of the two baby corn varieties. A soil GDD of 1320.17 and 1555.97 was recorded under black colour at 400 GDD transplanting stage. On the other hand, the lowest GDD was reported under yellow plastic mulch across all stages of transplanting baby corn varieties. The lowest mean GDD of 778.87 and 846.53 was recorded under yellow mulch at the 200 GDD in PAN 14 and Thai Gold respectively. Control recorded the least GDD of 729.93 and 776.30 at 200 GDD transplanting stage in PAN 14 and Thai Gold varieties respectively.

Transplanting stages significantly influenced the plants soil GDD. 400 GDD recorded the highest soil GDD across all the plastic mulch colours compared to corresponding colours at other transplanting stages. The highest soil GDD was recorded when baby corn varieties were grown at 400 GDD compared to transplanting at 200 GDD. Although 0GDD transplanting stage had a higher soil GDD compared to 200 GDD, there were no significant differences among the corresponding colours.

PAN 14 and Thai Gold recorded different soil GDD values across the various transplanting stages and plastic mulch colours. However, comparatively, Thai Gold recorded higher values at the same colour in similar stage. Soil GDD for Thai Gold variety ranged between 776.30-1555.97 while that of PAN 14 ranged between 729.93-1320.17.

Black plastic mulch colour in Thai Gold variety at 400GDD had an increase of 100% compared to Control at 200 GDD. Similarly, PAN 14 soil GDD under black plastic mulch at 400 GDD transplanting stage recorded 81 % increase compared to Control at 200 GDD. Transplanting Thai Gold variety at 400 GDD under black plastic mulch led to a 44% increase as compared to transplanting at 200 GDD under the same plastic mulch. On the other transplanting PAN 14 at 400 GDD also led to 35 % increase in the soil GDD under similar conditions. Direct planting (0 GDD) of baby corn varieties registered a 25-27% decrease in soil GDD as compared to transplanting at 400GDD under black plastic mulch.

The use of black plastic mulch modified the microclimate around the plants, primarily affecting soil GDD. The black mulch absorbed and retained solar radiation more efficiently than bare soil. This barrier reduced heat loss and promoted heat absorption, leading to warmer soil conditions compared to uncovered soil. The increased soil temperature resulting from black mulch directly impacted the accumulation of GDD. The accelerated heat accumulation in the warmer soil potentially contributed to a faster accumulation of GDD. The interaction of black plastic mulch and transplanting at 200 GDD, showed that the combination of these practices created a favourable growing environment which enhanced soil temperature. The warmer soil conditions promoted heat accumulation of Growing degree days.

Black plastic mulch tended to have a higher soil temperature compared to transparent plastic mulch due to its ability to absorb and retain more heat. The dark colour of black plastic mulch absorbed a broader spectrum of light, including visible and infrared wavelengths, converting it into heat energy (Rajapakse & Shahak, 2008). This absorption and retention of heat by black plastic mulch led to increased soil temperature in the root zone (Pandey et al., 2015). In contrast, transparent plastic mulch allowed more light to penetrate the soil surface, reducing heat absorption and resulting in lower soil temperatures (Lamont, 2017).

Additionally, black plastic mulch tended to have a higher soil temperature compared to yellow mulch due to its colour and heat-absorbing properties. Black mulch has a darker colour that absorbs a broad spectrum of light which was converted into heat, leading to increased soil temperatures (Rajapakse and Shahak, 2008). On the other hand, yellow mulch reflected a significant amount of light, including yellow and green wavelengths. As a result, it did not absorb as much light or heat as black mulch does. The reflected light helps maintain lower soil temperatures under yellow mulch compared to black mulch (Lamont, 2017). Kader et al. (2020) also used soybean and found similar GDD trends using black, transparent and non-mulched conditions citing that mulch colour influences both long-wave radiation, short-wave reflection, and total radiant energy and latent heat flux, which in turn leads to the significant effect on soil hydro-thermal characteristics.

4.5.2.4 Interaction of coloured plastic mulch and transplanting stages on Cob length, Cob diameter and Cob weight.

There were no significant interactions among plastic colour mulch, transplanting stages and varieties on cob length, cob diameter and cob weight. However, there were significant interaction between plastic mulch colour and transplanting stages on cob length, cob diameter and cob weight of baby corn varieties (Table 8) (Table 10). Major interactions were registered across the yellow plastic mulch and control. The longest cob length of 54.28cm was recorded when baby corn was transplanted at 200 GDD under transparent plastic mulch. The shortest cob length of 33.03cm was registered at 400 GDD under yellow plastic mulch. However, the control at 400 GDD transplanting stage registered the least cob length.

A higher significant Cob length was recorded under transparent plastic mulch uder all transplanting stages. The cob length mean ranged between 41.45cm, 54.28cm, 50.97cm, 43.1cm at 0, 200, 300, 400 GDD respectively under transparent plastic mulch. On the other hand, control recorded the least cob length across the various transplanting stages with a mean range of 26.08cm under 400 GDD to 38.88cm at 200 GDD. Transplanting baby corn varieties at 400 GDD recorded the shortest cob length across all mulch treatments while 200 GDD transplanting stage registered the longest cobs. At 400 GDD the cob length ranged between 26-41cm while 2000 GDD ranged between 38-52cm.

Transplanting baby corn varieties at 0,200, 300, 400 GDD under transparent mulch led to 20%,12%, 16% and 25% increase in cob length compared to yellow plastic mulch. Similarly, transplanting Baby corn under transparent plastic mulch at 0,200, 300, 400 GDD resulted to 48%, 40%,73% and 59% increase in cob length compared to control.

Table 10: Interaction of Coloured plastic mulch and transplanting stages on Cob length, Cob length and Cob weight of baby corn.

Plastic Mulch	Cob Length in cm (CL)				Cob Diameter in mm(CD)				Cob Weight in g CW)			
	Transplanting Stages											
	0	200	300	400	0	200	300	400	0	200	300	400
Control	29.08b	38.88b	29.32c	26.08c	22.92ab	26.02c	22.63c	18.7b	99.87b	105.00b	82.07b	50.37b
Yellow	36.02a	48.95a	43.93ab	33.03b	27.52a	32.72b	28.38ab	23.92a	104.95ab	111.45ab	100.28a	63.75b
Transparent	43.1a	54.28a	50.97a	41.45a	29.03a	39.65a	33.93a	26.35a	123.08a	138.55a	108.13a	88.37a
Black	41.27a	51.85a	47.43a	38.73a	26.43a	37.48a	30.03a	25.78a	109.35a	123.20a	100.3a	80.03a
lsd (0.05)	5.5				4.39				15.53			

Means followed by the same letter down the column are not significantly different P ≥ 0.05.

A thicker cob diameter of 39.65mmwas observed under transparent plastic mulch at 200 GDD transplanting stage (Table 10). However, among the colours the smallest diameter of 23.86 mm was recorded under yellow plastic mulch at 400 GDD. At 200 GDD transparent recorded the thickest cob diameter of 39.65mm followed by black with 37.48mm, then yellow with 32.72 mm while the control recorded the least diameter of 26.02mm. A similar trend was recorded among the other three transplanting stages. There were no significant differences under transparent and black plastic mulch under all transplanting stages.

Transplanting baby corn at 0, 200, 300 and 400 GDD under transparent plastic mulch resulted to 5%, 21%, 20%, and 10% increase in cob diameter as compared to yellow plastic mulch. Transplanting baby corn at 0, 200, 300 and 400 GDD under transparent plastic mulch resulted to 20%, 25%, 25%, and 27% increase in cob diameter as compared to control plastic mulch.

The highest cob weight was recorded in baby corn at transplanting stage 200 GDD under transparent plastic mulch. While the least weight was recorded when baby corn was transplanted at 400 under yellow mulch among different treatments. At 200 GDD transplanting stage the weight of the cob weight ranged between 105-123g, while baby corn transplanted at 400 GDD recorded a cob weight mean ranging between 50.37-80.03g. Direct planting of baby corn resulted to cob weights of between 99-109g. There were no significant differences in cob weight means between yellow and black plastic mulch colour under all transplanting stages.

Transplanting baby corn at 0, 200, 300 and 400 GDD under transparent plastic mulch resulted to 5%, 21%, 20%, and 10% increase in cob weight as compared to yellow plastic mulch. Transplanting baby corn at 0, 200, 300 and 400 GDD under transparent plastic mulch resulted to 20%, 25%, 25%, and 27% increase in cob weight as compared to control plastic mulch.

Yellow plastic mulch tended to reflect more light and heat compared to black plastic mulch. This resulted in reduced light availability and altered light spectrum under yellow plastic mulch leading to decreased biomass production, fewer leaves, and smaller plant size. These factors directly influenced cob development, resulting in shorter and lighter cobs compared to plants grown under black plastic mulch. On the other hand, excessive heat accumulation around the baby corn plants may have had negative effects, such as heat stress which resulted in reduced cob elongation and lighter cobs. In contrast, black plastic mulch absorbed more heat, which created a slightly warmer soil environment that is more conducive to cob elongation resulting to heavier combs.

Transparent plastic mulch, in combination with 200 GDD transplanting stage, induced longer maize cobs compared to black plastic mulch. The combination of these factors created a favourable environment for baby corn growth and cob development. Transparent plastic mulch reflected more light to reach the plants, including the critical red and blue wavelengths required for photosynthesis and growth. The increased light availability stimulated greater photosynthetic activity, leading to enhanced elongation of the cobs consequently heavier cobs. Transparent plastic and black mulch created a microclimate that is warmer and more favourable for plant growth compared to control and yellow plastic mulch. The higher soil temperature under transparent and black mulch promoted root development and nutrient uptake, supporting the overall growth and development of baby corn plants.

Transplanting maize plants at 200 GDD stage, typically when they are younger and smaller, promoted better root development compared to late stages of 300, 400 GDD. Younger transplants have a higher potential for root growth and branching due to their active cell division and elongation processes. This resulted in a more extensive and well-developed root system (Di Benedetto, 2011). In addition, Early transplanting generally increased the success rate of root transplants compared to late-stage transplanting. Younger seedlings have a higher capacity to adapt to the new planting location and establish new root systems. They can quickly form new root-soil interactions, allowing for better water and nutrient uptake from the surrounding soil (Cebula, 2009)

Late-stage transplanting (400 GDD), on the other hand, may lead to delayed root development and reduced transplant success. Older baby corn seedlings have already undergone some level of root system development in the original planting location. Transplanting them at a later stage disrupted root growth, resulting in potential root damage and slower establishment in the new soil environment (Di Benedetto, 2011).

Castro et al. (2013), also found similar trends by comparing black, transparent, silver and green mulches. Transparent plastic mulching showed significantly improved results compared to black and yellow mulches in terms of cob sizes (length and diameter) as it is favourable for solarisation that increases soil-surface temperature hence, enhancing the optimum conditions for maize growth. However, transparent mulching encourages weed growth and is less regarded for mulching than black plastic mulching (Rajablariani et al., 2012).

4.5.2.5 Interaction of coloured plastic mulch and varieties on cob length and cob weight.

There were significant interactions between plastic mulch colour and baby corn varieties on cob length and cob weight (Table 8) (Table 11). There was no significant interaction between plastic mulch colour and baby corn varieties on cob diameter.

There were major interactions when PAN 14 and Thai Gold were planted under control and yellow plastic mulch on cob length (Table 11). The longest cob length in PAN 14 variety of 47.33 cm was reported under the transparent plastic mulch. However, there were no significant differences registered between Transparent and black plastic mulch in PAN 14. The shortest cob length of 28.06 cm was registered under control in PAN 14.

Table 11: Interaction of coloured plastic mulch and varieties on cob length and cob weight.

	Cob Length(cm)		**Cob Weight (g)**	
Plastic Mulch	**PAN 14**	**Thai Gold**	**PAN 14**	**Thai Gold**
Control	28.06c	33.63b	58.02a	109.25c
Yellow	41.28b	40.90a	63.01a	125.41b
Transparent	47.33a	46.39a	71.94a	153.21a
Black	46.76ab	45.60a	66.09a	147.35a
lsd (0.05)	5.5		15.53	

Means followed by the same letter down the column are not significantly different P > 0.05.

In Thai Gold variety, the highest cob length of 46.39 cm under transparent plastic mulch. However, there were no significant differences between Thai Gold under black and yellow plastic mulch. The shortest cob length was recorded under the control with a mean of 33.63 cm. The cob length of Thai Gold ranged between 33.63-46.39cm. On the other hand, PAN 14 had a cob length ranging between 28.06-47.33cm.

Under transparent plastic mulch, PAN 14 cob length increased by 15% and 69 % when compared to yellow plastic mulch and control respectively. Additionally, under black plastic mulch cob length increased by 13% compared to yellow plastic mulch. Under transparent plastic mulch, Thai Gold cob length increased by 13% and 38 % when compared to yellow plastic mulch and control respectively. Additionally, under black plastic mulch cob length increased by 11% compared to yellow plastic mulch.

There were major interactions when PAN 14 and Thai Gold were planted under control and yellow plastic mulch on cob weight. The highest cob weight in PAN 14 variety was reported under the transparent plastic mulch with a mean of 71.94g. However, there were no significant differences among transparent, black and plastic mulch. PAN 14 under control treatment produced the lowest cob weight of 58.02g.

Thai Gold had the highest cob weight of 153.21g under transparent plastic mulch. However, there were no significant differences between Thai Gold under black and yellow plastic mulch. The lowest cob weight was registered under the control with a mean of 109.25g. The cob weight of Thai Gold ranged between 109.25-153.21g which was higher compared to PAN 14 with a cob weight ranging between 58.02-71.94g.

Under transparent plastic mulch, PAN 14 cob weight increased by 14% and 24 % when compared to yellow plastic mulch and control respectively. Additionally, under black plastic mulch cob weight increased by 5% compared to yellow plastic mulch. Under transparent plastic mulch, Thai Gold cob length increased by 22 % and 40 % when compared to yellow plastic mulch and control respectively. In addition, under black plastic mulch cob weight increased by 17 % compared to yellow plastic mulch.

The interaction of mulch colour and baby corn variety resulted in varying effects on growth and yield outcomes especially cob length and cob weight. Thus, Thai Gold variety performed better under all mulch colours and bare ground compared to PAN 14 variety.

Black, yellow and transparent plastic mulch affected the microclimate around the plants by influencing light reflection, absorption, and transmission (Amare and Desta, 2021). These variations in light availability and temperature may have impacted plant growth and development resulting in different cob lengths and weights. Yellow plastic mulch reflected more light, keeping the soil cooler compared to black mulch (Helaly et al., 2017).

However, different baby corn varieties may have responded differently to these microclimate variations (Kwabiah, 2004). Baby corn variety exhibited genetic variability, including variations in traits like cob length and cob weight. Different varieties may respond differently to environmental factors, including mulch colour. Baby corn varieties have different genetic diversity which plays a significant role in determining the potential for cob length in a given variety. Cob length being a trait controlled by multiple genes, it could have contributed to the ultimate expression of cob length and cob weight in a variety (Aaliya et al., 2016). Some genes may have promoted cob elongation while others may have restricted it resulting in cobs of different lengths and weights. According to Shogren et al. (2011), cobs involve the central core of an ear of corn where kernels grow. The size of maize cobs shows different maize varieties' overall performance (Blandino et al., 2016)

Zhou et al. (2015) reported 197.2 g and 125 g more fruit weight in Chilli under black and transparent, respectively, compared to the control. Similarly, Zhang et al. (2018) found that black plastic mulch produced cobs of significantly more weight on maize. On the contrary in strawberries, yellow plastic mulch led to the highest fruit weight of 19.06 g, followed by black at 16.98 g; non-mulch had 14.14 g (Sharma et al., 2013).

4.5.2.6 Interaction of transplanting stages and varieties on cob length and cob weight.

There was significant interaction between transplanting stages and baby corn varieties on Cob length and cob weight (Table 8) (Table 12). However, major interactions were observed when PAN 14 and Thai Gold were transplanted at 300 GDD and direct planting (0 GDD). The longest cob length of 48.32cm was registered when PAN 14 was transplanted at 200 GDD, while the lowest cob length was reported when PAN 14 was directly planted. Transplanting PAN 14 at 300 the cob length was not significantly different from transplanting at 400 GDD.

Table 12: Interaction of transplanting stages and varieties on cob length and cob weight

Transplanting stage (GDD)	**Cob Length (cm)**		**Cob Weight (g)**	
	PAN 14	Thai Gold	PAN 14	Thai Gold
0	35.61bc	33.51b	53.50b	97.76c
200	48.32a	48.67a	78.42a	160.68a
300	42.18b	43.64a	68.63ab	150.02a
400	36.97b	38.30b	60.61b	126.77b
Lsd(0.05)	5.5		15.53	

Means followed by the same letter down the column are not significantly different. (p > 0.05)

The cob length of Thai Gold variety was highest when transplanted at 200 GDD, however the cob length was not significantly different when transplanting at 300 GDD. The lowest cob length of 33.51cm was recorded at 0 GDD which was not significantly different when transplanting at 400 GDD.

PAN 14 recorded the highest cob length when directly transplanted compared to Thai Gold, while Thai Gold had the highest cob length compared to PAN 14 at corresponding transplanting stages (Table 12). This indicated that PAN 14 performed better when directly planted compared to Thai Gold variety

Transplanting PAN 14 at 200 GDD led to 32% and 15% increase in cob length compared to transplanting at 400 and 300 GDD respectively. Additionally, transplanting PAN 14 at 200 GDD registered 37 %increase compared to the control (0 GDD). On the other hand, Thai Gold cob length increased by 26% and 11 % when compared to transplanting at 400 and 300 GDD respectively. Additionally, transplanting at 200 GDD cob length increased by 44 % compared to 0 GDD.

Major interactions were observed when PAN 14 and Thai Gold were transplanted at 400 GDD and direct planting (Table 12). The highest cob weight of 78.42g was recorded when PAN 14 was transplanted at 200 GDD, while the lowest cob weight was registered when PAN 14 was directly planted. Transplanting PAN 14 at 400 GDD the cob weight was not significantly different from direct planting (0 GDD).

The cob weight of Thai Gold variety was highest with a mean of 160.68 when transplanted at 200 GDD, while its lowest cob weight of 97.76 g was registered upon direct planting. However, there was no significant difference when transplanting at 200 GDD and 300 GDD. Thai Gold had a higher cob weight ranging between 97.76-160.68g compared to PAN 14 which ranged from 53.50-78.42g.

Transplanting PAN 14 at 200 GDD led to 29% and 14% increase in cob weight compared to transplanting at 400 and 300 GDD respectively. Additionally, transplanting PAN 14 at 200 GDD registered 77% increase in cob weight compared to the control (0 GDD). On the other hand, Thai Gold cob weight increased by 27% and 7 % when compared to transplanting at 400 and 300 GDD respectively. Additionally, transplanting at 200 GDD cob length increased by 53 % compared to 0 GDD. The lower cob weight in direct planting of Thai Gold variety was in agreement with (Bakshi et al., 2016) who reported that direct planting decreased yellow baby corn by 68% when compared to transplanting.

Transplanting Baby corn seedlings at an early stage of 200 GDD provided seedlings with more time to establish a strong root system and develop vegetative growth. Additionally, it allowed the plants to have a longer growing season, potentially resulting in increased cob length and weight compared to late-stage transplanting. Transplanting Baby corn seedlings at a later stage (400 GDD) resulted in a shorter growing season and reduced time for the plants to develop. This limited the potential for cob growth and resulted to shorter cob length and lower cob weight compared to early transplanting 200GDD.

Different Baby corn varieties responded differently to transplanting stages. Thai Gold variety exhibited better growth and cob development when transplanted early compared to PAN 14 variety. The genetic makeup of the variety plays a significant role in its response to transplanting stages (Fanadzo et al.,2009).

Transplanting at different stages affected the growth and development of Baby corn plants. Early transplanting provided seedlings with a longer period to establish their root systems and vegetative growth before entering the reproductive stage. This extended growth phase potentially contributed to larger cob size and weight. Late transplanting, on the other hand, resulted in a shorter vegetative period and potentially smaller cobs.

The performance of baby corn varieties can vary based on whether they are transplanted or directly planted in the field (El-Hamed et al., 2011). The suitability of a specific planting method depends on several factors genetic characteristics. Baby corn varieties are developed with specific genetic traits and adaptations with some varieties having characteristics that make them more suitable for transplanting, such as better root development, stronger seedlings, or faster early growth as observe Thai Gold. These traits enable them to establish well when transplanted and lead to better performance in terms of cob length and weight.

Different baby corn varieties exhibit varying degrees of stress tolerance (Farooq et al., 2009). Transplanting is a stressful process for seedlings, involving root disturbance and changes in environmental conditions (Grossnickle, 2012). Thai Gold tended to be more resilient to transplant shock and quickly recovered from the stress hence performing better when transplanted. On the other hand, PAN 14 may have been better adapted to direct planting in the field, showing greater tolerance to field conditions, including temperature extremes and moisture variations.

4.5.3 Conclusion

The study concluded that black plastic mulch had the highest soil temperature, followed by clear plastic mulch, yellow plastic mulch, and non-mulched soil. The temperature differences between the mulch treatments were attributed to variations in solar energy reflection, absorption, and transmission. Clear plastic mulch exhibited higher temperatures compared to yellow plastic mulch and non-mulched soil. average soil temperature was between 20 - 29 ^{o}C.

The choice of plastic mulch colour, transplanting stages, and varieties had significant effects on factors such as maturity height, maturity days, and soil growing degree days (GDD). Black plastic mulch consistently performed the best, followed by transparent mulch, while yellow mulch performed the least. Varieties planted at 200 GDD showed superior performance, and the Thai Gold variety thrived across all transplanting stages and plastic mulch colours. The higher maturity height observed under black plastic mulch was attributed to its ability to act as a barrier, reduce evaporation, and maintain optimal soil moisture levels, supporting continuous plant growth throughout critical development stages.

Black plastic mulch resulted in the shortest maturity period across all transplanting stages, with PAN 14 and Thai Gold varieties at 200 GDD showing the least maturity period. Yellow plastic mulch had the longest maturity period, while the control group had the longest maturity period in all transplanting stages. The use of black plastic mulch facilitated higher soil temperatures, which promoted root development, nutrient uptake, and overall plant metabolism, creating a favourable environment for root growth by protecting them from extreme temperatures and drying out.

Black plastic mulch resulted in the highest soil growing degree days (GDD) at all transplanting stages for both PAN 14 and Thai Gold baby corn varieties. Yellow mulch at 200 GDD had the lowest soil mean GDD for both varieties. The use of black plastic mulch modified the microclimate, increasing soil GDD by efficiently absorbing and retaining solar radiation, while yellow mulch reflected light and maintained lower soil temperatures compared to black mulch.

Transparent plastic mulch combined with the 200 GDD transplanting stage resulted in the longest cob length, while yellow plastic mulch at 400 GDD produced the shortest cob length. Excessive heat accumulation around baby corn plants may have negatively affected cob elongation and led to lighter cobs. Transplanting maize plants at the 200 GDD stage promoted better root development compared to later stages, while late-stage transplanting (400 GDD) may result in delayed root development and reduced transplant success.

Thai Gold variety outperformed PAN 14 in terms of cob length and weight under transparent plastic mulch. This indicates that Thai Gold variety performed better across all mulch colours and bare ground compared to PAN 14. The microclimate around the plants was influenced by black, yellow, and transparent plastic mulch, affecting factors such as light reflection, absorption, and transmission. While yellow plastic mulch reflected more light, keeping the soil cooler compared to black mulch, different baby corn varieties may respond differently to these microclimate variations due to their genetic variability.

The cob length of Thai Gold variety was highest when transplanted at 200 GDD, while there was no significant difference in cob length when transplanted at 300 GDD. PAN 14 had the highest cob length when directly transplanted, but Thai Gold had the highest cob length compared to PAN 14 at corresponding transplanting stages. Early-stage transplanting at 200 GDD allowed for better root system establishment, longer growing season, and potentially increased cob length and weight. Thai Gold variety exhibited better growth and cob development when transplanted early, possibly due to its resilience to transplant shock and quicker recovery from stress compared to PAN 14.

CHAPTER 5: GENERAL DISCUSSIONS, CONCLUSIONS, RECOMMENDATIONS AND PUBLICATIONS

5.1 Discussions

There were significant interactions between the baby corn varieties and the planting conditions. In all tests undertaken, there appeared to be a gradual increase in number of GDD units needed to attain flowering on the two varieties and also on the growing conditions as the seedling age increased from 200 GDD to 400 GDD. Thus PAN 14 transplanted at 400 GDD under FC required an average of 152 extra GDD units to attain flowering at compared to 200 GDD transplants in both seasons. However, TH transplanted at 400 GDD needed an extra 9.5% GDD units compared to 200 GDD transplants to reach flowering stage.

There was varietal difference in planting condition and the planting seasons. Generally, TH seemed to require more GDD units to flower compared to PAN 14. The highest difference of 168.5 GDD was noted on 300 GDD transplants transplanted under GH during season 2 while the least increase was on 400 GDD transplants under GH. Thus delaying transplanting stage increased heat unit requirements in all varieties under both FC and GH conditions. The increase in heat units with delayed transplanting may be associated with the restriction of root growth in the nursery sleeves, destruction of the protruding roots of the older seedlings during transplanting, as well as exhaustion of nutrients in the soil sleeves before transplanting. Dhasarathan et al. (2012), demonstrated that inability of roots to regenerate faster after transplanting caused slow rate of nutrients and water absorption resulting in stunted and slow growth rate leading to delayed flowering in maize. Similarly, Ekasingh et al. (2000) found that the transplanted crop matured significantly earlier than direct sown maize and tended to give higher grain yield. Palma & Laurance (2015) demonstrated that transplanting of maize shortened the crop maturity period by 8-10 days compared to directly sown maize. Additionally, it was reported that time to harvesting reduced by 1-3 weeks in the USA and 10-12 days in France depending on the age of maize seedling (Huang et al., 2011). The result indicates that delayed transplanting increases heat unit requirement and subsequently delays maturity.

The study also sought to determine plant’s maturity height is dependent on transplanting stage and growth conditions. In both varieties, plants that were established under GH attained higher heights compared to those that were raised under FC. Generally, PAN 14 plants raised under GH were the tallest while TH plants under FC were the shortest. In both PAN 14 and TH varieties, seedlings transplanted at 200 GDD produced the tallest plants at the time of flowering under FC and GH planting conditions. This indicated that transplanting seedling at 200 GDD provided plants with the best growth conditions for optimal growth and development.

Seedling transplanted at 300 GDD and 400 GDD showed a declining trend in height suggesting that delayed transplanting resulted in plants with short height. These results concur with (Kumar &Kalita, 2017) who found out that delay in transplanting reduced plant maturity height. Similar studies have also reported that delayed transplanting results in shorter maturity heights (Zhao et al., 2016 and Sudipta et al 2003). Earlier studies showed that transplanted maize does not do well because of disrupted and poor root replacement compared to cabbage and tomato (Basnet, 2022). Additionally, root disturbance in transplanted seedlings caused changes in physiological process and decreased growth (Basson et al., 2021).There was significance difference among the transplanting stages, planting conditions as well as the varieties.

Plants established through direct seeding showed significance difference in cob length with regard to the two planting conditions. In both planting conditions, PAN 14 showed longer cob length compared to TH. Under FC, directly planted PAN 14 had longer cob length (180.1mm) in season 2 compared to TH with 125.8mm in season1. Similarly PAN 14 seedlings transplanted at 200 GDD showed significantly longer cob length (203.3mm) in season 2 than any other transplants in both varieties and growth conditions. Baby corn transplanted at 400 GDD had the shortest cobs in both varieties under the two growth conditions.

PAN 14 established under FC at 300 GDD showed significantly longer cob length compared to TH at the same stage. Similar observations were made under GH conditions. In both varieties under FC and GH conditions, delayed transplanting resulted in shorter cobs with PAN 14 transplanted at 400 GDD showing the biggest decrease compared to 200 GDD transplants under FC in season 2. These observations indicate that varietal differences between PAN 14 and TH significantly influence cob length whether established directly or transplanted at 200 GDD and 300 GDD. This concurs with (Merrill et al., 2009) that the interaction effect of variety and seedling age influences yield attributes like cob length.

Thirdly, the research investigated cob diameter as influenced by varietal difference, transplanting stage and planting condition. The results show that there was significance difference between the three factors; varieties, planting conditions and the transplanting stage. Baby corn established directly did not show any significance differences either under FC or GH except for PAN 14. PAN 14 grown under FC showed highest cob diameter with those transplanted at 200 GDD showing the highest cob diameter of 37.8mm. Notably, TH transplanted at 200 GDD had high cob diameter, indicating that transplanting Baby corn at 200 GDD was best for optimal growth and development. Also cob diameters of PAN 14 showed gradual decline with transplanting stage with 200 GDD showing highest and 400 GDD with the lowest. Previous studies in sweet corn have shown that cob size (length and diameter) reduce with seedling age (thermal accumulation in the nursery). Similarly, Dukhnytskyi (2019) showed that delayed transplanting of sweet corn resulted in significant decline in cob girth, number of cobs per plant and number of grains per cob. This effect was previously attributed to more severe root damage on older seedlings with a subsequent increase in plant stress (Awata et al., 2019). These results indicate that PAN 14 performed better than TH under FC conditions. In view of a wide range of maximum and minimum temperatures recorded under

FC during this study, PAN 14 appears to be best suited in growth conditions with varying temperatures. This also suggests that PAN 14 would be more adapted to stressful growth conditions than TH. Higher temperature difference has been shown to be stressful conditions and prepares plants to transit to reproductive and senescence phase. This is because response to temperature throughout the plants life cycle is primarily a phenological response (Awika, 2011). Thus the result indicates that varietal difference, growing conditions and planting stage influence cob diameter.

Regarding cob weight as a dependant of varietal difference, transplanting stage and planting condition; In both PAN 14 and TH varieties, the weight of the first cob differed significantly under both growing conditions. The highest weight was recorded on plants grown under FC while those raised under GH had the least weight. However, TH had the lowest weight compared to PAN 14 variety under each planting conditions. In regard to the transplanting stages, the cob weight (g) was found to be significant due to the age of seedlings. The highest cob weight was recorded at 200 GDD followed by 300 GDD and direct sown plants while 400 GDD had the least cob weight in both varieties. GH growing conditions produced cobs with the lowest weight compared to FC condition grown baby corn in both varieties. Similar to observations made in other parameters, cob weight reduced with delayed transplanting.

Different kinds of mulch colour treatments had remarkable influence on soil temperature. It was projected that the control, yellow, transparent and black plastic mulch treatment had average soil temperature of 20.0^{o}C, 22.2^{o}C, 24.7^{o}C and 29.2^{o}C respectively. This shows that yellow, transparent and black mulch treatments had 2.2^{o}C, 4.7^{o}C and 9.2^{o}C higher temperature than the control respectively. Therefore, yellow plastic mulch had relatively warm soils while transparent and black mulch kept the soil hot. These results are supported by the findings of Locher(2005). Black plastic mulch was found to increase soil temperature compared to the un-mulched control. The same group also reported that soil temperature under light coloured plastic mulches (clear, violet, light &green) was higher when compared with bare soil.

Similarly soil temperature was increased by 5.0 to 10.0°C by the application of plastic mulches as compared to bare soil (Kirk &Marshall, 2008). The results indicate that black and clear coloured plastic mulches had the greatest soil warming potential among the various mulch colours as found by (Leskovar et al., 2021) even though they heat the soil in different ways. The dissimilarities in soil temperature between different coloured plastic mulch could be due to the differences in the reflection, absorption and transmission of solar energy by the coloured plastic mulch (DeChristopher& Tucker, 2020).

Black mulch has been reported to produce the hottest soil temperature compared to the other coloured mulch films (Mishra &Salokhe, 2015). Black mulch warms the soil by absorbing light which is then conducted to the underlying soil, as long as the plastic mulch is in close contact with the soil. Black mulch absorbs much of the UV, visible, and infrared wavelengths from incoming solar radiation and re-radiates the absorbed energy as thermal radiation or long-wavelength infrared radiation. In addition, black plastic mulch has been found to have intense shortwave transmittance and high shortwave absorptance properties, causing soil temperatures to be quickly raised (Kader et al., 2017). Thus black mulchproduces the hottest soil temperature compared to other coloured plastic mulches (Ginigaddara& Ranamukhaarachchi, 2011).

Clear plastic mulch had high soil temperature compared to yellow plastic mulch and the unmulched soil. Previous studies indicate that clear plastic mulch film absorbs little solar radiation of 5% of short-wave and reflects 11% while transmitting 85% to 95% depending on the thickness and degree of opacity of the material (Dukare et al., 2020). For instance, daytime soil temperatures under clear plastic mulch are generally 8 to 14^{o}F higher at a 2-inch depth and 6 to 9^{o} F higher at a 4-inch depth compared to those of bare soil. The variability of soil temperature in the upper few cm of the soil layer is affected by the colour of the plastic mulch (Gordon et al., 2010). In addition, the variation in soil temperature with different colours of plastic mulch could be based on the components of radiation balance, which is due to the effect of mulch on albedo, sensible heat flux, latent heat flux and soil heat flux (Bradford et al., 2019).

The plant performance was determined under varied conditions. The performance examination observations were as follows: Significant differences between the treatments were found among the baby corn varieties, plastic mulch film colour as well as on the interaction between the baby variety and plastic upon all the parameters.

Both hybrids differed significantly with respect to plant flowering age in days, flowering height, flowering stage in GDD, number of harvestable cobs, cob length, cob diameter and the cob weight. Irrespective of mulching, the hybrid PAN 14 took longer to first flower while Thai Gold flowered earlier. Flowering height was maximum in PAN 14while the flowering GDD were highest in the same variety. PAN 14 outperformed Thai Gold in terms of cob weight and cob length. PAN 14 had the best performance than Thai Gold in six of the seven plants attributes. This shows that the genetic ability of individual hybrid has some effect on the plant performance. However, cob diameter was the only attribute that did not register significant change in the two varieties tested.

None mulched plants had the least performance in all the tested plant aspects. This shows that the low accumulated soil GDD affected the plants RZT which impacted negatively on root growth, soil and water absorption (Ibarra-Jimenez et al., 2011) which affected plant growth and development (Streck et al., 2008). Black plastic mulch had a positive effect on the plant growth parameters of flowering age in days, flowering height as well as the flowering GDD. Thus black mulched plants took the shortest time to mature, had the tallest flowering height and the largest accumulated flowering heat GDD.

Transparent plastic mulch had the highest positive impact on cob yield parameters including number of harvestable cobs, length and diameter of the first cob as well as the weight of the first cob. This can be attributed to its high soil temperature due to higher ability to transmit the little absorbed rays, ability to transmit short infrared rays into the soil and inability to transmit the long-waves from the soil by the trapped water droplet as well as its high photosynthetic active radiation (PAR) due to the reflective properties of plastic films (Bradford et al., 2019) yellow plastic mulch had the least performance among the three colours.

Plant performance grown on bare soil showed the longest performance as compared to plastic mulches(Nuss & Tanumihardjo, 2010). Plastic mulches were superior over and significantly different from control considering the flowering age. There was significant variation among tested plastic mulches in PAN 14 though there was no variation between transparent and black plastic mulches in Thai Gold. It was also observed that black and clear plastic mulches had the best performance in both varieties.

Highly significant variation was recorded between the control and the plastic mulches for flowering height. The flowering heights from plastic mulches were above average. However, there was statistically significant variation among plastic mulches though there was no significant variation between transparent and black plastic mulches in PAN 14. The tallest plants were recorded under black plastic mulches in PAN 14. Generally, plants under plastic mulches films showed superior plant height than the control indicating that mulches had positive effect on plant growth and development. It was observed that baby corn grown from black mulch were the tallest followed by transparent mulch while yellow coloured mulch had the lowest. This was in agreement with Ihab, (2018) that black plastic mulch gave taller tomato plants than the transparent mulched plants after 45 days since transplanting date. Increased flowering height in mulched plants could be as a result of better availability of soil moisture and optimum soil and air temperature. The lighter colour mulches reflected more total light resulting in a lower ratio of far-red relative to red light. The increase in light intensity affect plant development and yield through greater photosynthetic rates, while the ratio of far red to red (FR: R) ratio is important in phytochrome regulation of plant physiological processes which affect internodes lengths and stem elongation, chloroplast ultra-structure, photosynthetic efficiency, and photosynthate partitioning among leaves, stems and roots (Ihab, 2018).

There was high significant variation recorded between the control and the plastic mulch treatments for flowering GDD. However, there was no statistically significant variation between the control and the yellow plastic mulch for flowering GDD in Thai Gold variety. Black and transparent plastic mulch accumulated the highest amount of soil heat units. This is likely to shorten the plants lifespan in the field. Higher temperatures accelerate crop growth rate for crops whose phenology is predominantly regulated by temperature, such as maize resulting in shorter vegetative and reproductive phases (Lizaso, 2018). This reduces the time for plant and grain development, limiting the attainment of yield potential. By accelerating crop development, elevated temperatures limit the amount of solar radiation received by the plant during each developmental stage. Aggregated over the entire growing period, less interception of solar energy is problematic. Thus with less fuel to drive photo synthesis (i.e. the conversion of carbon dioxide to organic compounds), plant structures (such as leaves) tend to be smaller and less abundant, bringing matured plant biomass below potential levels (Rylander et al., 2020).

There was no significant variation among transparent and black plastic mulches on the length of the first cob among the two varieties. In PAN 14, there was no significant difference recorded between the control and the yellow plastic mulched plants though the highest length was recorded cob from the yellow mulched plants. Though there was no significant variation among the two plastic mulch colours, transparent mulch (41.88 cm) can be considered the best compared to black mulch (40.58 cm). Among the plastic mulch colours, yellow produced the least cob length. This is because yellow mulch decreases the red to far red (R:FR) ratio in the light reflected to the canopy, favouring the allocation of photosynthates to developing fruits, which is similar to red mulch, as previously seen (Jahan et al., 2018). Like observed in PAN 14 variety, there was no significance difference in transparent and black plastic mulched plants on Thai Gold variety. However, the longest cob was recorded from black plastic mulch (41.99 cm) followed by transparent coloured mulch (41.20cm).

The cob diameter was mainly significantly influenced by plastic mulch colour. Transparent mulch had the highest diameter in both varieties against the bare soil. Black mulch had the second best diameter in PAN 14 as yellow produced the second in Thai Gold variety. This is in agreement with Aniekwe&Nwite (2013) who found that the length and diameter of cucumber fruits were influenced by the plastic mulch with the transparent plastic mulch having the highest followed by the black plastic mulch while the un-mulched had the least. However, in PAN 14 yellow and un-mulched plants had similar performance. It was only the yellow plastic mulch that showed significant difference in cob diameter in both varieties. This is in line with Hussein (2015) who indicated that yellow plastic mulch treatment produced the lowest potato tuber diameter and weight.

The plastic mulch colour had significant effect on weight of the first cob. Transparent plastic mulch produced the heaviest cobs in both varieties PAN 14 and Thai Gold. In PAN 14 variety, yellow plastic mulch had the least cob weight while yellow mulch had the least weight in Thai Gold. The lower cob weight in yellow plastic mulch on Thai Gold variety was in agreement with Franquera, (2015) who reported that yellow mulch decreased lettuce yields. The difference in cob weight could have been due to differences inthe soil temperature within the plastic mulch. The soil temperature within the plastic mulch influences the temperature within the roots thus affecting the various activities within the roots like gas exchange and activity of various enzymes which affects the cob weight (Rouf et al., 2016). Therefore, root zone temperature is important in plant growth and development as it affects physiological processes in plant roots such as the uptake of water and nutrients. Nutrients and water play a great role in plant physiological processes which impact yield.

Another factor that accounts for difference in yields could be a result of the quality of light reflected from the plastic mulch colour. The spectra quality of light affects the plants nutrient uptake. The plant yield is in turn influenced by the light conditions that exist during plant growth and development. Changes in baby corn yield in response to the different coloured plastic mulch could be due to the range of reflected wavelengths produced by individual mulch colour with small differences in the reflected light causing certain responses from the plant (Maughan & Drost, 2016a). Thus higher fruit weight in black plastic mulch could be associated to the black plastic mulch ability to produce a greater far red to red light ratio which generated a positive phytochrome response within specific vegetables (Franquera., 2016).

Non-mulched plants had the least performance in terms of marketable cobs in both varieties. Among the coloured plastic mulches, yellow had the lowest number of marketable cobs. This shows that the low accumulated soil GDD affected the plants RZT which impacted negatively on root growth, soil and water absorption (Ibarra-Jimenez, 2011) which affected plant growth and development (Anandhi, 2015).Transparent plastic mulch had the highest positive impact on number of marketable cobs. This can be attributed to its high soil temperature due to higher ability to transmit the little absorbed rays, ability to transmit short infrared rays into the soil and inability to transmit the long-waves from the soil by the trapped water droplet as well as its high photosynthetic active radiation (PAR) due to the reflective properties of plastic films (Kwabiah, 2004). Yellow plastic mulch had the least performance among the three colours. This is in agreement with the findings on lettuce by (Dhasarathan et al., 2012).

5.2 Conclusion

According to this study, the best growth and productivity of baby corn were observed when it was transplanted at 200 Growing Degree Days (GDD). The PAN 14 variety demonstrated better adaptability to changing growth conditions compared to Thai Gold, indicating its suitability for challenging environments. The difference in cob weight between field and greenhouse conditions could be explained by variances in sunlight exposure. Natural sunlight provided the ideal light spectrum for optimal growth, while filtered light in greenhouses may have hindered photosynthesis, resulting in smaller cob sizes, diameters, and weights.

Field conditions, characterized by natural temperature and humidity fluctuations, positively influenced baby corn plant growth. Conversely, greenhouses, which maintained controlled environmental conditions, could have impeded plant development and led to decreased cob weight if the conditions were not optimized for baby corn growth. The variation in cob weight among different baby corn varieties could be attributed to their genetic characteristics. The PAN 14 variety possessed specific traits associated with cob size and allocated more energy toward the growth and development of baby corn, resulting in larger and heavier cobs compared to varieties with less vigorous growth.

In addition, the study discovered that black plastic mulch exhibited the highest soil temperature, followed by clear plastic mulch, yellow plastic mulch, and non-mulched soil. The temperature variations among the mulch treatments were attributed to differences in the reflection, absorption, and transmission of solar energy. Clear plastic mulch had higher temperatures compared to yellow plastic mulch and non-mulched soil. The average soil temperature ranged between 20 to 29 degrees Celsius.

The choice of plastic mulch colour, transplanting stages, and varieties had significant impacts on factors such as maturity height, maturity days, and soil growing degree days (GDD). Black plastic mulch consistently showed the best performance, followed by transparent mulch, while yellow mulch performed the least effectively. Varieties transplanted at 200 GDD demonstrated superior performance, with the Thai Gold variety thriving across all transplanting stages and plastic mulch colours. The increased maturity height observed under black plastic mulch was attributed to its ability to act as a barrier, reducing evaporation and maintaining optimal soil moisture levels, which supported continuous plant growth during critical development stages.

Black plastic mulch resulted in the shortest maturity period across all transplanting stages, particularly for PAN 14 and Thai Gold varieties at 200 GDD, which had the shortest maturity period. Yellow plastic mulch had the longest maturity period, while the control group exhibited the longest maturity period in all transplanting stages. The use of black plastic mulch facilitated higher soil temperatures, which promoted root development, nutrient absorption, and overall plant metabolism, creating a favourable environment for root growth by protecting them from extreme temperatures and drying out.

Black plastic mulch resulted in the highest soil growing degree days (GDD) at all transplanting stages for both PAN 14 and Thai Gold baby corn varieties. Yellow mulch at 200 GDD had the lowest mean soil GDD for both varieties. The use of black plastic mulch modified the microclimate by efficiently absorbing and retaining solar radiation, thereby increasing soil GDD, while yellow mulch reflected light and maintained lower soil temperatures compared to black mulch.

There were no significant interactions observed between plastic mulch colour, transplanting stages, and varieties regarding cob length, cob diameter, and cob weight. However, significant interactions were found between plastic mulch colour and baby corn varieties in relation to cob length and cob weight. Transparent plastic mulch combined with the 200 GDD transplanting stage resulted in the longest cob length, while yellow plastic mulch at 400 GDD led to the shortest cob length. Excessive heat accumulation around baby corn plants may have adversely affected cob elongation, resulting in lighter cobs. Transplanting maize plants at the 200 GDD stage promoted better root development compared to later stages, whereas late-stage transplanting (400 GDD) could lead to delayed root development and reduced transplant success.

The Thai Gold variety outperformed PAN 14 in terms of cob length and weight under transparent plastic mulch. This suggests that the Thai Gold variety performed better across all mulch colours and bare ground in comparison to PAN 14. The microclimate surrounding the plants was influenced by black, yellow, and transparent plastic mulch, impacting factors such as light reflection, absorption, and transmission. While yellow plastic mulch reflected more light, thus keeping the soil cooler compared to black mulch, different baby corn varieties may respond differently to these microclimate variations due to their genetic variability.

The cob length of the Thai Gold variety was highest when transplanted at 200 GDD, whereas there was no significant difference in cob length when transplanted at 300 GDD. PAN 14 exhibited the highest cob length when directly transplanted, but Thai Gold had the highest cob length compared to PAN 14 at the corresponding transplanting stages. Early-stage transplanting at 200 GDD allowed for better establishment of the root system, a longer growing season, and potentially increased cob length and weight. The Thai Gold variety demonstrated better growth and cob development when transplanted early, possibly due to its resilience to transplant shock and quicker recovery from stress compared to PAN 14.

5.3 Recommendations

The study recommends that transplanting baby corn at 200 Growing Degree Days (GDD) leads to the best growth performance and productivity. Therefore, it is recommended to transplant baby corn seedlings at this specific stage to achieve optimal results in terms of maturity GDD, flowering height, cob length, cob diameter, and cob weight. The PAN 14 variety exhibited greater resilience to dynamic growth conditions compared to Thai Gold, making it a preferable choice for cultivation in stressful environments. When selecting baby corn varieties, it is important to consider genetic traits that promote the desired cob characteristics.

The study recommends the use of black plastic mulch to enhance soil temperature, promote root development, and improve overall plant growth. Black mulch acts as a barrier, reducing evaporation and helping to maintain optimal soil moisture levels, which supports continuous plant growth during critical development stages. Considering the influence of plastic mulch on microclimate, transparent mulch is preferred to enhance plant performance by maximizing light reflection, absorption, and transmission.

The Thai Gold variety demonstrated better growth and cob development across all transplanting stages and plastic mulch colours. Farmers may consider selecting Thai Gold for higher yields and desired cob characteristics. Early-stage transplanting at 200 GDD proved beneficial, allowing for better establishment of the root system, longer growing seasons, and potentially increased cob length and weight. Late-stage transplanting (400 GDD) may result in delayed root development and reduced transplant success. Implementing these recommendations can help optimize baby corn production and improve overall crop yields.

Further research should explore additional factors that may impact baby corn production, such as irrigation practices, fertilization methods, and pest management strategies, in order to develop comprehensive cultivation recommendations.

5.4 Publications

Publication 1

Title: Effect of Plastic Mulch Colour and Transplanting Stage on Baby Corn Plant Performance

Authors: Richard Kirigiah, Peter Masinde, Mworia G. Erick

Journal: European Journal of Agriculture and Food Sciences (EJFOOD)
https://www.ejfood.org/index.php/ejfood/article/view/567.

Publication 2

Title: Use of Heat Units to Predict the Optimum Transplanting Stage of Baby corn (*Zea Mays* L.) Seedlings Under Field Conditions in Meru County - Kenya

Authors: Richard Kirigiah, Peter Masinde, Mworia G. Erick

Journal: Researchjournali's Journal of Agriculture

https://researchjournali.com/view.php?id=5001.

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APPENDIX I : PUBLICATIONS