Use Of Heat Units To Predict The Optimum Transplanting Stage Of Baby Corn (*Zea mays L.*) Seedlings Under Field Conditions In Meru County - Kenya

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ABSTRACT

Baby corn (*Zea mays L.*) is a type of maize belonging to the Poaceae family of plants. It is grown as a vegetable in a wide range of Agro-ecological zones in Kenya. The plant is mainly grown for its immature unfertilized ears harvested within 2 to 3 days after silk emergence. However, due to continued demand for water, rainfall unreliability and the need for accelerated maturity, transplanting has to be adopted as an intervention of choice with good outcomes. The optimum transplanting stage is influenced mainly by the altitude (area temperature) of the locality due to difference in plants growth rate hence a universal transplanting stage parameter of heat units was used to establish the collect stage. The experiment was conducted under field conditions to determine the best transplanting age of baby corn seedlings. It involved two Baby corn varieties namely Thai-gold and Pan-14 which were raised in potted sleeves in the nursery and later transplanted at different stages to establish the effect of transplanting stage on their performance. Transplanting was done at 200, 300 and 400 GDD apart from the directly planted Babycorn at 0GDD. In both varieties, results showed that baby corn plants transplanted at 200 GDD had higher flowering height (MH), fewer maturity GDD, longer cob length, larger cob diameter and more marketable cobs per plant.

Keywords: Growing Degree Days, Maturity Height, PAN 14, TH- Thai GOLD, Field Condition and GreenHouse

1. INTRODUCTION

Corn *(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., 2008). 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., 2008).

Baby corn, a type of corn 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).

Babycorn can be established through direct seeding or through transplants. Transplants are widely used in establishing various high-value vegetable crops (Vavrina et al., 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; Kaleem et al., 2009). 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 (Kingra and Kaur 2012). 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 favorable 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 and Drennan 2007).

The effect of transplanting age on yield is an issue often broached by the growers of horticultural and agronomic 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 were 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 (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., 2014).

Considering the wide range of 3-4 weeks transplanting age of maize seedlings, there is need to develop a more accurate transplanting stage suitable for optimal production. Thus the objective of this study was to ascertain the optimum stage of baby corn transplants in heat units (GDD) for maximum performance.

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 2017 and July to October 2017. The experiment was laid out on a split- split plot design with four replications. The main factor being the planting conditions: Field condition (FC) and Greenhouse condition (GH). Variety was allocated to subplot at two levels: Pan 14 and Thai Gold. Transplanting stages were allocated to the sub subplot at four levels: 0, 200, 300 and 400 GDD.

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). 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 number of GDD) accumulated by the plants in the nursery. Seedlings were transplanted to the main seedbed after accumulating 200, 300 and 400 GDD. They were transplanted on a 4m by 4m sized plots at a spacing of 60cm by 20cm (Ganesh et al., 2015). The plots were arranged in a split-split plot design. 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 were controlled using Pyriproxyfen (Profen™) 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.

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 meter ruler. Similarly, the cob length was determined by measuring from the base up to the cob tip using a meter ruler, while the cob diameter was obtained by measuring the thickness of the cob at the base by use of digital vernier caliper (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).

The GDD was determined by recording both the daily maximum (T_{MAX}) and minimum (T_{MIN}) temperatures using a maximum and minimum thermometer. 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.

$GDD = \sum\{0.5(T_{MAX} + T_{MIN}) - T_{BASE}\}$ where T_{BASE} is that temperature below which plant growth is zero. For maize crop T_{BASE} is 10^oC (Muchow et al., 1990), GDUs are accumulated by adding each day's GDs contribution as the season progressed.

3. DATA ANALYSIS

Data on GDD, maturity height and yield parameters were collected and subjected to analysis of variance (ANOVA) using a normal excel programme as well as SAS version-20. The means were considered different if the p-value was less or equal to 0.05 ($p \leq 0.05$).

4. RESULTS AND DISCUSSION

4.1 EFFECT OF TRANSPLANTING STAGE AND VARIETAL DIFFERENCES ON MATURITY GDD OF BABYCORN

Table 1. Maturity GDD of Babycorn as influenced by variety, transplanting stage and growing conditions.

Transplanting stage (GDD)	February-May 2017				July-October 2017			
	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	1047.4^{g}	1110.6^{d}	1082.2^{e}	1205.0^{b}	1023.3^{g}	1090.1^{e}	1061.9^{e}	1197.3^{b}
200	983.4^{i}	1075.6^{f}	991.9^{h}	1119.2^{d}	970.6^{i}	1056.7^{g}	970.8^{i}	1110.0^{d}
300	1052.5^{g}	1105.8^{d}	1086.9^{e}	1231.8^{a}	1033.1^{g}	1085.3^{e}	1058.4^{g}	1226.9^{ab}
400	1138.1^{c}	1213.5^{b}	1148.3^{c}	1240.1^{a}	1119.9^{d}	1121.1^{d}	1132.5^{d}	1233.2^{a}

Superscripts letters indicate significant differences ($P \leq 0.05$).

The results show that there was significant difference between the three factors; season, Babycorn variety and the planting conditions. In both seasons, there seems to be no difference with regard to number of GDD needed to flower. Lowest maturity GDD was recorded on PAN 14 transplanted at 200 GDD seedling stage under FC during the July-October 2017 season. The longest GDD was realised on a combination of TH and 400 GDD transplanting stage under GH. PAN 14 transplanted at 200 GDD stage, tended to take 6.11% and 5.15% fewer number of GDD to mature as compared to the direct transplanted plants in season 1 and season 2 respectively under FC. Similarly TH variety showed a small decline of 4.05% and 3.06% in season1 and season 2 respectively. The trend was repeated under GH 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. These results agree with the findings by Biswas (2014) that maize seedlings transplanted after 14 and 21 days matured 6 and 12 days respectively earlier than the direct planted maize. Similarly, Dale and Drennan (2007) reported that maize established through transplants tend to have shorter growth period in the field. 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 corn. Similarly, Dhane and Drennan (1997) found that the transplanted crop matured significantly earlier than direct sown maize and tended to give higher grain yield. Basu and Sharma (2003) 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

4.2 PLANT MATURITY HEIGHT IS DEPENDENT ON TRANSPLANTING STAGE AND GROWTH CONDITIONS

Table 2. Flowering height of Babycorn as influenced by the variety, planting condition and the transplanting stage.

Transplanting stage (GDD	February-May 2017				July-October 2017			
	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	221.1^{b}	195.9^{d}	243.9^{a}	223.9^{b}	225.2^{b}	198.4^{d}	248.1^{a}	226.7^{b}
200	221.1^{b}	206.2^{c}	249.2^{a}	228.4^{b}	233.7^{ab}	211.b^{i}	253.3^{a}	235.0^{ab}
300	215.7^{b}	191.7^{d}	240.8^{a}	217.3^{b}	219.8^{b}	192.1^{d}	219.7^{b}	219.9^{b}
400	192.9^{d}	195.9^{d}	199.7^{d}	199.2^{d}	203.2^{cd}	193.4^{d}	197.1^{d}	197.2^{d}

Superscripts letters indicate significant differences ($P \leq 0.05$).

The results indicate that the flowering height was significantly influenced by the variety planting conditions as well as the. 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 Biswas (2008) who found out that delay in transplanting reduced plant maturity height. Similar studies have also reported that delayed transplanting results in shorter maturity heights (Cong et al., 2016; Sudipta et al 2003). However, Chudasama et al (2017) found that three weeks old maize seedlings had higher plant height than the directly planted maize. Earlier studies showed that transplanted maize does not do well because of disrupted and poor root replacement compared to cabbage and tomato (Wellbaum et al., 2001). Additionally, root disturbance in transplanted seedlings caused changes in physiological process and decreased growth Mckee (1981).

4.3 THE EFFECT OF TRANSPLANTING STAGE, VARIETY AND GROWING CONDITIONS ON LENGTH OF FIRST COB

Table 3: Length of the first cob as influenced by the variety, transplanting stage and the growing conditions

Transplanting stage (GDD)	February-May 2017				July-October 2017			
	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	175.9^{b}	125.8^{def}	159.8^{c}	139.1^{d}	180.1^{b}	126.9def	162.2^{bc}	131.3^{de}
200	198.3^{a}	182.9^{b}	174.4^{b}	134.2^{de}	203.3^{a}	188.9^{ab}	180.7^{b}	137.5^{d}
300	172.3^{b}	117.1^{f}	172.0^{b}	115.4^{f}	173.7^{b}	118.^{3f}	173.8^{b}	116.4^{f}
400	87.5^{g}	79.9^{gh}	80.8^{gh}	73.6^{gh}	87.9^{g}	80.1^{gh}	81.3^{gh}	70.1^{gh}

Superscripts letters indicate significant differences ($P \leq 0.05$).

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 (172.3mm) compared to TH at the same stage (117.1mm). 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 of 115.4 cm 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 Biswas (2008) 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.

4.4 COB DIAMETER AS INFLUENCED BY VARIETAL DIFFERENCE, TRANSPLANTING STAGE AND PLANTING CONDITION

Table 4: Cob diameter as influenced by variety, transplanting stage and growing conditions

Transplanting stage (GDD)	February-May 2017				July-October 2017			
	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}	25.74^{cd}	25.0^{d}	27.4^{cd}	37.2^{a}	27.2^{cd}	28.3	28.9^{c}
200	37.8^{a}	35.3^{ab}	27.0^{cd}	23.3^{d}	39.1^{a}	37.6^{a}	29.5^{c}	26.0^{cd}
300	32.8b	24.9^{d}	29.4^{c}	25.4^{cd}	34.2^{b}	25.5^{d}	33.5^{b}	26.2^{cd}
400	26.7cd	23.5^{d}	22.6^{d}	21.4^{d}	27.0^{cd}	26.1^{d}	23.2^{d}	22.2^{d}

Superscripts letters indicate significant differences ($P \leq 0.05$).

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 with cob diameter of 33.5mm (table 4). There was no difference observed in baby corn grown under GH conditions for both varieties. 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 at 35.3 mm indicating that transplanting Babycorn 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 (37.8mm) and 400 GDD with the lowest (26.7mm). 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 (Jerry and John 2015). Thus the result indicates that varietal difference, growing conditions and planting stage influence cob diameter.

4.5 COB WEIGHT AS A DEPENDANT OF VARIETAL DIFFERENCE, TRANSPLANTING STAGE AND PLANTING CONDITION

Table 5. Weight of the first cob as influenced by variety, transplanting stage and the planting condition

Transplanting stage (GDD)	February-May 2017				July-October 2017			
	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	82.4b	37.1efg	39.6ef	38.2ef	84.2b	38.3^{efg}	40.5^{ef}	39.9^{ef}
200	101.0a	101.9a	43.1ef	44.3e	104.1a	103.2^{a}	47.3^{e}	47.7^{e}
300	77.7bc	62.8d	41.1ef	30.1g	79.8bc	63.5d	43.5e	31.9g
400	73.1c	28.6g	31.3fg	23.0g	74.0c	29.1g	33.2fg	24.5g

Superscripts letters indicate significant differences ($P \leq 0.05$).In both PAN 14 and TH varieties, the weight of the first cob differed significantly under both growing conditions (table 5). 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 Babycorn in both varieties. Similar to observations made in other parameters, cob weight reduced with delayed transplanting.

These results agree with Biswas (2008) 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).

5. CONCLUSION

This study shows that Babycorn can either be directly planted or transplanted. Baby corn transplanted at 200 GDD showed the best growth performance and productivity. However further studies are required to test physiological responses that makes 200 GDD transplanted Babycorn more effective.

Further PAN 14 showed more resilience to dynamic growth condition than TH suggesting that it is more suited to stressful conditions than TH.

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