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Research paper

Heat unit requirement of sweet corn under different planting methods and dates in temperate Kashmir, India

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ABSTRACT

In order to study the effect of establishment method and planting date on phenology, yield, and agrometeorological indices for sweet corn, a field experiment was carried out at the Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir Wadura, Sopore, over the course of two sessions in *kharif* 2020 and 2021. The experiment had two components: a distinct sowing date with a 20-day interval and two establishment methods (direct seeding and transplanting). The initial planting day was (25th of April, 2nd was 15th of May and third was 5th of June during both the years) Three replications in RCBD were confirmed. Following transplanting with the first date of sowing, direct seeding required the most days to attain different phenological stages and accumulate the most heat units. Transplanting with the initial date of sowing resulted in noticeably greater HUE, HTUE, PTUE, and HyTUE, resulting in the largest green cob and biological yield as compared to other dates of sowing and direct seeding. As a result, given the weather in Kashmir it was discovered that planting on the first day of sowing increased sweet corn yields economically.

Key words: Sweet corn, Planting, Establishment and Phenology.

The third-most significant cereal crop in the world is maize (*Zea mays* L. var. saccharata), coming in behind rice and wheat. Sweet corn is widely employed in both industrial products and human nutrition due to its high concentration of minerals like phosphorus, magnesium, iron, zinc, and vitamins and antioxidants. (Keerthi and Reddy, 2017) The United States is the leading producer of sweet corn, followed by Nigeria, Mexico, Indonesia, and Peru (Hacisalihoglu *et al*., 2018). Sweet corn is a thermophilic crop that grows best at temperatures between 21 and 27 degrees Celsius (Hacisalihoglu *et al*., 2018; Mao *et al.,* 2017) Cold temperatures (below 10 °C) can stifle plant growth and cause damage. Sweet corn is typically harvested between 75 and 100 days after planting (Dekhane and Dumbre, 2017) in order to maximize yields Sowing at the right time is critical because a delay in sowing led to reduction in yield, as number of heat accumulated over time has a direct impact on the plant's growth and yield (Saseendran *et al.*, 2005) Growing customer demand necessitates an increase in fresh sweet corn supply, which is difficult due to the kernel's quality deteriorating quickly after the milk stage (Kara *et al*., 2012) (Hacisalihoglu *et al.*, 2018). Currently, planting sweet corn at different periods of the year to increase availability and the market window is the most popular strategy for addressing this issue and lengthening the harvest period.

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(El-Hamed *et al.*, 2011) Direct sowing is a difficult task because seed is susceptible to bird damage and poor germination, resulting in the loss of valuable seed. Growing seedlings in polybags under protected conditions, such as a low tunnel near the main field, is one solution that should be investigated to help manage time while transplanting. Lower mortality compared to direct sowing, the capacity to choose robust and healthy seedlings in order to produce exceptional plant stands, and seed rate savings are all advantages of transplanting. (Keerthi and Reddy, 2017). In transplanting seed sowing in polybags beneath low tunnels are used as an alternative to direct sowing. The Kashmir valley's ample sunshine, temperate temperature, and pest-free climate are suitable for producing high-quality sweet corn in large quantities. Because the crop is perishable, appropriate sowing/transplanting dates are crucial for increasing productivity and sustaining supplies for a longer length of time. Sweet corn is heavily influenced by the planting date.

In all cases, it is believed that weather variation is a significant factor in the crop growth and yield variability of crops throughout time. Temperature, the number of hours of intense sunshine, relative humidity, and rainfall are agrometeorological variables that directly affect crop growth and development. At various phases of crop growth, agrometeorological indices including GDD, HTU, PTU, HyTU, and thermal usage efficiency are utilised to account for the impact of these variables. For a plant to progress through its various phenological stages, it needs to be at a specific temperature. The duration of each phenophase and the time it takes to attain a specific growth stage are both determined by the accumulation of heat units or rising degree days. Each phenophase has a unique heat need, and it takes a set amount of heat units to attain a particular phenological stage. Growing degree days' work under the premise that, for temperatures between mean and base, the length of time needed temperature has a linear relationship with the phenological stage to be reached. According to the heat unit idea, it is possible to estimate a crop potential for production under varied weather circumstances by assuming that temperature and growth have a linear and direct connection. Agroclimatic models based on thermal indices may achieve these goals. (Malo and Ghosh, 2018). Changes in sowing dates have a direct impact on the growth and development of crops. Crop growth is the gradual rise over time of a crop's weight, height, volume, or area. A crop's timing or movement from one phasic stage to the next is referred to as development. (Jan *et al*., 2021; Gudadhe *et al*., 2013). Calculating these effects can help in the choice of crop phenology and sowing time in some situations to attain higher heat and radiation usage efficiency. This investigation examined how ambient temperature affected the phenological development and thermal accumulation of hybrids of sweet corn grown using two distinct establishing techniques and subjected to varied microclimates by altering their planting dates.

MATERIAL AND METHODS

Site description

The research was done at the Wadura campus of the Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, which is situated 1524 metres above mean sea level and is situated at $34^0 17'$ N latitude and $74^0 33'$ E longitude in Sopore, Kashmir. Level topography and sufficient drainage are present at the test site. The highest temperatures for *Kharif* 2020 and 2021 were between 22.8 and 38 ^{0}C, while the weekly minimums ranged between 8.7 and 19.3 ^{0}C, according to meteorological data acquired throughout the investigation.

Laboratory testing methodology

The treatment procedure included two establishment method (transplanting and direct sowing) and three sowing dates having an interval of 20 days (25th April, 15th May and 5th June during both the growing seasons). The hybrid of sweet corn was sowing/transplanted on same date at a spacing of 70 cm x 20 cm. Both transplanting and direct sowing methods of establishment were carried out on the same day. By spreading seeds at various times spaced 20 days apart, transplanting seedlings were nurtured in poly bags. To facilitate transplanting, the poly bags were maintained in the Low tunnel close to the main field. Regular cultural procedures including watering and weeding were also adhered to. Starting on the day of transplantation, it was noted how many days were needed to reach various phenological stages, knee height, 50% silking, 50% tasseling, and milking, for example (maturity). During harvest, the yield of green cobs, the biological yield, and the quantity of cobs per plant were all noted. Using weather data for daily maximum and minimum temperatures, sunshine hours, day length, and average relative humidity, we examined agrometeorological indices such as growing degree days (GDD), heliothermal units (HTU), photothermal units (PTU), and hydrothermal units (HyTU) at various growth stages of the crop.

GDD = $\sum \underline{(\text{Tmax} + \text{Tmin})} /2 = - \text{Tbase}$

$HTU = \Sigma(GDD * SSH)$ where, SSH (hour) is the daily duration of sunlight.

$PTU = \Sigma(GDD * DL)$ where, DL (hours) is the day length.

$HYTU = \Sigma(GDD * RH)$ where, RH (%) is the daily mean relative humidity.

The number of days needed to reach various thermal consumption efficiencies, including HUE, HTUE, PTUE, and HyTU, might be calculated by dividing the biological yield of sweet corn by GDD, HUE, PTU, and HyTU.

By using correlation analysis, the relationship between biological yield and green cob and agrometeorological characteristics was found. Regression study of those indices against green cob and biological yield was carried out to forecast how those two variables will respond to agrometeorological indices.

Statistical analysis

A factorial randomised block design (RCBD) with three replications was employed to set up the experiment, and R software was utilised for the statistical analysis.

RESULT AND DISCUSSION

Effect of planting date and establishment method on phenology

When specific phenological stages are attained depends much on the sowing period. The plant had reached Knee High, 50% Tassling, 50% Silking, and Milking phases on the initial date of planting, whether through transplanting or direct sowing, whereas

Table 1: Accumulated GDD, HTU, PTU and HyTU at different growth stages of sweet corn

Treatments		Phenological stages				Phenological stages			
		Knee height	Tasseling	Silking	Milking	Knee height	Tasseling	Silking	Milking
			GDD				HTU		
E1	D1	498.4[a]	917.6[a]	992.8[a]	1415.1[a]	4136[a]	7570[a]	8680[a]	11190[a]
	D2	436.2[b]	866.6[b]	955.4[b]	1370.1[b]	3770[a]	7074[b]	8270[b]	10116[a]
	D3	359.9[c]	866.6[c]	894.7[c]	1287.1[c]	3575[a]	6774[c]	7868[c]	9240[a]
E2	D1	468.6[a]	904.2[a]	982.9[a]	1393.1[a]	4035[a]	7492[a]	8574[a]	11106[a]
	D2	370.0[b]	816.4[b]	917.9[b]	1357.1[b]	3739[a]	6992[b]	8180[b]	9993[a]
	D3	318.3[c]	766.4[c]	881.3[c]	1264.1[c]	3520a	6692[c]	7792[c]	9150[a]
			PTU				HyTU		
E1	D1	5961[a]	12170[a]	13681a	17870[a]	27617[a]	56570[a]	63245[a]	91234[a]
	D2	5220[b]	11770[b]	13107[b]	17111[b]	24459[b]	52370[b]	59676[b]	88567[b]
	D3	4315[c]	10792[c]	12270[c]	16490[c]	21236[c]	46679[c]	54234[c]	83898[c]
E2	D1	5788[a]	12017[a]	13440[a]	17659[a]	27370[a]	56234[a]	63043[a]	90876[a]
	D2	5136[b]	11636[b]	12991[b]	16940[b]	24120[b]	52110[b]	59433[b]	88102[b]
	D3	4270[c]	10590[c]	12110[c]	16237[c]	21024[c]	46517[c]	54023[c]	63245[c]

late planting had more swiftly reached distinct phenological stages. The accumulated GDD by sweet corn at various phases and planting dates using two different establishing methods are presented in Table 1. Growing degree days (GDD), a measurement of the total amount of warmth needed to reach maturity, varied greatly between planting dates. The degree day accumulation with direct sowing was found to be considerably greater, Knee-high stages range from 359.9 to 498.4°C, and milking stages range from 1264.1 to 1415.1°C, respectively. From knee height through physiological maturity (the milking phases), the degree day accumulation under transplanting methods ranged from 318.3 to 468.6°C, and it was found to be considerably higher. However, a declining trend in the cumulative GDD for completing all phenological stages was observed in both establishment procedures with each additional delay in sowings. Due to higher ambient temperatures and longer sunshine hours, crops that were sown earlier gathered more degree days over a longer period of time. With delayed sowing, a similar decreasing trend in accumulated GDD was observed. (Garcia *et al*., 2009) Ahmed *et al*., 2020; Rahman *et al*., 2004; Sarvari and Zsuzsa, 2007). As each day since seeding passed, the amount of time needed to reach physiological maturity decreased. Direct sowing exhibited the longest physiological maturity duration among the establishment procedures. The milking stages took (117.4) days relative to the first date of sowing, which is stated in the material and procedure, and were followed by transplantation, which needed (114.4) days. The maximum GDD was accumulated on April 25th with direct sowing. However, under the transplanting method, the first DOS, i.e. April 25th, produced the highest GDD. This could be because the plant expresses its full potential. As the sowings were delayed, the number of heat units accumulated for various phenological growth stages decreased. (Khavse *et al*., 2015) reported similar variability.

Analysis of the data showed that delayed planting from 25[th] April to 5[th] of June, days taken to reach different phenological stages decreased at all growth stages. In respect of 25[th] April of sowing with direct seeded Crop reached knee high stage within 37.3 days after sowing, tasseling within 68.2 days after sowing, silking within 75.1 days after sowing and harvesting within 117.5 days after sowing. 15[th] May accumulated less heat units compare to 1[st] date of sowing as the crop reached knee high stage within 35.4 days after sowing, tasseling within 66.4 days after sowing, silking within 72.4 days after sowing and harvesting within 107.6 days after sowing. In case of 3[rd] sowing i.e 5[th] of june it took 33.5 days to knee heigh, 63.2 days to tasseling , 69.5 days to silking and 101.1 days to maturity stages. However, to achieve various phenophases such as knee height, tasseling, silking, and milking, early Planting on April 25th with direct sowing yielded maximum GDD of 498.4, 917.6, 992.8, and 1415.1 respectively. However, under the transplanting method, the first DOS, i.e. April 25[th], recorded the highest GDD. The number of days' sweet corn took to reach various phenological stages was reduced when sowing was delayed. This is due to the fact that early sowing resulted in delayed germination and emergence, as well as a longer time to reach silking, tasseling, and harvesting, due to lower temperatures and the accumulation of more heat units.

Heliothermal unit (HTU)

Sweet corn accumulated a total of heliothermal units that ranged from 3520 to 4136 °C day hour for the knee high stage, 6692 to 7570°C day hour for the tasseling stage, 7792 to 8680°C day hour for the silking stage, and 9150 to 11190°C day hour for the maturity stage in order to reach various phenological stages in the years 2020 and 2021 (Table 1). However, the maximum HTU had been noted by the time planting with direct seeding to knee height, tasseling, and harvesting had taken place on April 25. Crop growth duration was cited as the most important factor, with silking and maturity after sowing measured at 4136, 7570, 8680, and 11190°C, respectively, per day and hour. In comparison to late planting, early planting with direct sowing was more active in terms of growth and crop longevity, which produces a greater build-up of heat units.

Table 2: Thermal use efficiency (GDDE, HTUE, PTUE and HyTUE) at different growth stages of sweet corn.

Treatments		Phenological stages				Phenological stages			
		Knee height	Tasseling	Silking	Milking	Knee height	Tasseling	Silking	Milking
		GDDE				HTUE			
E1	D1	11.2	14.9	11.4	8.8	89	118	98	70
	D2	10.8	14.6	11.3	8.5	97	119	98	69
	D3	10.5	13.8	11.1	9.8	104	123	98	70
E2	D1	9.9	13.5	10.7	8.1	85	108	93	65
	D2	8.5	12.6	10.9	9.1	86	110	94	65
	D3	8.4	12.6	10.5	9.1	93	112	95	67
		PTUE				HyTUE			
E1	D1	125	188	153	111	599	813	709	571
	D2	129	198	154	115	620	883	715	605
	D3	134	198	155	125	632	921	767	638
E2	D1	114	174	147	103	557	766	691	533
	D2	118	179	147	114	558	805	706	593
	D3	122	180	148	117	578	843	674	603

The number of days' sweet corn took to reach various phenological stages was reduced when sowing was delayed. This is due to the fact that early sowing resulted in delayed germination and emergence, as well as a longer time to reach silking, tasseling, and harvesting, due to lower temperatures and the accumulation of more heat units. Significant variation in sowing dates was observed throughout the growth stages. Early planting with direct sowing resulted in more strong development and longer crop lifetime, which increased the number of heat units that accumulated. Throughout the entire growing season, PTU accumulation varied significantly depending on the sowing dates and establishing methods used. The outcomes of research like this one support these results (Khavse *et al.*, 2015, Gowda *et al*., 2013).

Photothermal units (PTU)

PTUs accumulated during various phenological phases, as shown in (Table 1), with the highest values recorded on the first date of sowing with direct sowing and decreasing with subsequent days, according to the pooled data for both years. Early sowing with a longer duration was also linked to early maturation of late sowing. Direct sowing on 25th of April (first date of sowing) accumulated PTUs of 5961°C per hour for knee high stage, 12170°C per hour for tasseling stage, 13681°C per hour for silking stage, and 17870°C per hour for milking stage. Similar to this, under transplanting sweet corn with the first date of sowing, accumulated 5788 °C day hour to reach the knee high stage, 12017 °C day hour to reach the tasseling stage, 13440 °C day hour to reach the silking stage, and 17659 °C day hour to reach the milking stage. Which required more days to reach different phenophases, same like direct sowing on the first sowing date. This could be because early sowing during a favourable period accumulated more heat units at different phenophases, resulting in higher PTU values. When alternative sowing dates and establishing techniques were applied, PTU accumulation varied dramatically throughout the course of the growth season. It took more time for direct seeding with the first date of sowing to attain different phenophases. This might be the case because early sowing at a favourable time period led to increased PTU readings since more heat units were accumulated at various phenophases. PTU accumulation varied greatly throughout the growth season as a result of various sowing dates and establishing techniques. Significant variation in sowing dates was observed throughout the growth stages. Early planting with direct sowing resulted in more strong development and longer crop lifetime, which increased the number of heat units that accumulated.

Hydrothermal units (HyTU)

Depending on the establishment method and planting date, at various phenological stages of the sweet corn growth cycle, there are considerable differences in the accumulation of hydrothermal units. (Table 1). The number of HyTUs accumulated to reach knee height, tasseling, silking, and maturity stage varied from 27617 to 27370, 56234 to 56570 °C day percent, 63043 to 63245-day percent, and 90876 to 91234-day percent, respectively, for both direct and transplanting methods with the same sowing date. Data show that sowing on the first date with different establishment techniques performed better than sowing on later dates, such as the 15th of May and the 5th of June, when HyTUs were accumulated at knee height, tasseling, silking, and maturity stage ranged from 24120 to 24459 °C day percent, and 52110 to 52110 °C day%, respectively. Depending on the establishment method and planting date, the accumulation of hydrothermal units during the sweet corn growth period at different phenological phases varies affectedly. The sowing dates and establishment procedures increase grain and stover yield, as well as the harvest index, provide a comprehensive picture of a plant's relative biomass production, with component analysis assisting in estimating the relative harvest index. Transplanting with 1st date of sowing increased dry matter accumulation, light interception, radiation use efficiency, harvest index and yield, according to Benedetto and Rattin (2008).

Thermal use efficiencies

The crop does not fully utilise the heat energy available to it or convert it to dry matter. However, a number of aspects such as genetic makeup, better management practices, and so on influence the crop yield potential, which can be measured in terms of thermal use efficiency as shown Table 2. Transplanting sweet corn with first date of planting resulted in higher biological yields of GDDE, HTUE, PTUE, and HyTUE. The increased values for GDDE, HTUE, PTUE, and HyTUE were due to a significant increase in sweet corn yield under transplanting on the first planting date. The shorter crop growth period resulted in forced maturity, which had a negative impact on crop productivity, as evidenced by lower thermal use efficiencies. However, in terms of grain yield and biological yield, the highest value was recorded with the transplanting method with the 1st date of sowing, which has more functional leaves, more LAI, and more dry matter accumulation than direct sowing, which has poor germination, more bird damage, and less dry matter accumulation than transplanting leads to lesser grain and straw yield compare to transplanting. Overall highest number of thermal efficiency used by tasseling stages which harvest the optimum unit of thermal use efficiency under various phenophase are tasseling stages which contribute almost 38 percent of total GDDE, followed by Silking which took 27 percent and knee high 25 percent and Milking stages which utilize almost 20 percent of thermal use efficiency respectively.

The increased value for GDDE, HTUE, PTUE, and HyTUE were due to a significant increase in yield of sweet corn under transplanting on the first planting date. in chilly, humid regions, the thermophilic plant of maize yields little. Crops of maize that are subjected to cold stress have slower growth rates and longer growth times. In hilly and temperate regions, low temperatures weaken the seedling and may cause grain filling to cease early towards the conclusion of the growth cycle, leading to decreased and uneven grain output. (Thakur *et al*., 2010) (Wijewardana *et al.*, 2016). In maize, chilling stress at the early seedling stage or low temperatures throughout the reproductive stage may harm plant cells or tissue, depending on the length and severity of the stress. (Tampus and Escasinas, 2019).

The shorter crop growth period resulted in forced maturity, which had a negative impact on productivity of crop, as evidenced by lower the thermal use efficiencies. However, in terms of grain yield and biological yield, the highest value was recorded with the transplanting method with the 1st date of sowing, which has more functional leaves, more LAI, and more dry matter accumulation than direct sowing, which has poor germination, more bird damage, and less dry matter accumulation than transplanting leads to lesser grain and straw yield compare to transplanting the findings was in conformity with (Mehdi *et al*., 2018, Gavric and Omerbegovic, 2021)**.**

CONCLUSION

The outcomes demonstrate that the planting date and establishment method both significantly influenced the productivity and phasic development of the crop. The length of the growth cycle affects how much assimilates the crop accumulates. Since the first planting date impacts both the crop's growth period and the effectiveness of consuming heat, as demonstrated by thermal use efficiencies, it is advocated. Thermal use efficiencies, such as heat use efficiency, heliothermal use efficiency, photothermal use efficiency, and hydrothermal use efficiency, demonstrate that the crop plant may successfully utilise the current weather conditions when the establishing method, or transplanting the crop, is appropriate.

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