Original Research Paper
Forecast Maize Phenology by Utilizing Thermal Indices under Foot Hills of Shivalik Conditions of Jammu and kashmir

ABSTRACT

Field experiments were conducted at Farmer fields at different locations of Reasi district, of Jammu region during*kharif* seasons of 2017, 2018 and 2019 to predict the phenology based on thermal indices in maize crop. The maize crop sown under irrigated conditions matured about one week late as compared to rainfed conditions and took more accumulated thermal time and Heliothermal units in all the three years of study. The accumulated growing degree days (GDD) and Heliothermal units (HTU) were significantly differed among dates; whereas in case of spacings it differed non-significantly except at physiological maturity in rainfed conditions. Mean accumulated growing degree days and Heliothermal units taken by each phenophase were recorded and then used for prediction of phenological development of maize crop. Significant regression equations were observed between different phenological stages of maize and GDD & HTU with the accuracy in the range of 89 to 97 and 54 to 66 per cent, respectively.

Keywords: ***Maize, Irrigated, Rainfed, Spacing, Phenology, Growing degree days, Heliothermal units.***

INTRODUCTION

Precise calculations of growing degree days (GDD) are important in models simulating crop growth and for the management of field crops. GDD is also a climatic feature. The use of GDD has vastly improved the description and prediction of phenological events compared with other approaches, such as time of year or number of days, particularly for crop phenology and developmental stage (Cross and Zuber 1972).The heat unit or growing degree day (GDD) concept assumes that there is direct and linear relationship between growth of plants and temperature. Maize requirements in the developing world alone will surpass the demand for both wheat and rice and will increase from 282 million tons in 1995 to 504 million tons in 2020 (Baba and Mir, 2018). In Asia, maize demand is expected to rise from 138 million tonnes in 1993 to 243 million tonnes, accounting for 60 per cent of the global increase in maize consumption by 2020 (Baba and Mir, 2018). Asia contributes about one-third to the world's total maize production with China taking the lead both in terms of yield and harvested area. The rapid adoption of high-yielding/improved maize varieties in Asia has led to significant yield increases in the favourable rain-fed and irrigated maize growing areas.

Jammu and Kashmir, one of the Himalayan states of India, is the traditional maize growing region in the country. Augmentation of maize productivity is imperative for uplifting smallholder farmers in the state occupying the area of 9.2 mha with an average productivity of 88.90 q/ha in India (Anonymous, 2018). In J&K state maize is grown on 3.22 lakh hectares out of which 2.16 lakh hectares area is in Jammu region with total production of 49.22 and 39.58 lakh quintals, respectively (Anonymous, 2018a). In Jammu maize is mostly grown under rainfed conditions and its productivity is quite low (Jamwal, 2018). Various biotic and abiotic factors play important role in realizing the productivity. The duration, growth and yield are primarily decided by thermal and photoperiod conditions experienced by the crop during its life cycle (Singh *et al.*, 2003). The scientific way of assessing and quantifying the effect of temperature and photoperiod on plant growth, development and yield by applying GDD theory which advocates that the plants have a definite temperature requirement to pass through a certain growth portion or phenophase. The technique has widely been used to study the growth rate (Morrison and Agrawal, 1980), phenology (Kiniryet al., 1983) and yield (Shukla and Vasuniya, 1998). Keitzar and Singh (1981) also worked out the thermal requirement at different phenophases in maize crop.

The occurrence of different phenological events during crop growth period in relation to temperature can be estimated by using accumulated heat units or growing degree days (GDD). Knowledge of accumulated growing degree days can provide an estimate of harvest date as well as crop development stage (Ketring and Wheless, 1989). Heat units required for maize crop to progress from one phase to other phase has been reported earlier by Thavaprakash et al., (2007) and Girijesh et al., (2011).

Keeping above in view, the present study was carried at different locations of foot hills of Shivlik range in Reasi district under KrishiVigyan Kendra (Farm Science Center), Reasi, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu to predict the phenology of the maize crop with Agrometeorological indices.

METHODOLOGY

The field experiments were conducted under rainfed as well as irrigated conditions with the same treatment combinations under sub-tropical condition ofShivalik Foot hills district Reasi of Jammu region during three *kharif* seasons (2016, 2017 and 2018). The experiment was conducted under the full supervision and internetion of KrishiVigyan Kendra scinetists. The location of the area is at $32^{o}97^{/}$North latitude and a longitude of $74^{o}91^{/}$ at an elevation of 790 meters above mean sea level. The treatment combinations in main plots were (a) two dates of sowing, *viz.*, D_1 (June 10) and D_2 (June 25) and in subplots (b) three spacings*i.e.*, 60 x 20 cm (S_1), 60 x 25 cm (S_2) and Broadcasting (S_3) laid out in split plot design, with four replications. The total number of treatment combinations was 12. Net plot size was 5m x 2m. All recommended practices were followed as per package and practices for SKUAST-Jammu for the region. In case of broadcasting (farmer practice) treatment, the plant density was recorded about 8-10 plants/m^2 in different years. Daily weather data were recorded from the IMD weather station situated at about 200 meters away from the experimental site. The normal annual rainfall of region is 1100 mm out of which rainfall received in the crop growing season was 536.4, 464.3 and 723 mm during 2016, 2017 and 2018, respectively. In the month of June 102.7, 56.6, 29.2 mm; while in July 226.8, 268.5 and 212.4 mm rainfall received 2016, 2017 and 2018, respectively during the early phase of the maize crop. In the later phase *i.e.,* in the months of August and September the rainfall received was 138.2, 110.2 & 208.0 mm and 38.7, 33.0 & 256.3 mm, respectively during the study years. The crop sown under rainfed condition was not supplied any irrigation; while in case of irrigated condition; one surface irrigation was applied in the year 2016 at 6th leaf stage. However, two irrigations were supplied; one at 6thleaf in 2017 & 2018 and another at soft dough stage during 2017 and tassel emergence stage in 2018 to the maize crop. The different phenophases*i.e.,* 50% plants with 6th leaf emergence (P_1), 50% plants with tassel (P_2), 50% plants with silking (P_3), dough stage (P_4) and physiological maturity (P_5) in both the moisture regimes were recorded by visual inspecting the five tagged sample plants from each plot at an interval of 3-4 days. Based on the weather data, the agro-meteorological indices were calculated using following expressions.

The Growing degree days (GDD) were determined as per Nuttonson (1955) using base temperature of 8.0 °C (Tojo Solar *et al.,* 2005).

$$\text{GDD } (^{o}\text{C day}) = \sum_{a}^{b} \frac{[T_{max} + T_{min}]}{\ldots\ldots\ldots\ldots\ldots\ldots} - Tb$$

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$$\text{HTU } (^{o}\text{C day hours}) = \sum_{a}^{b} [\text{GDD*N}]$$

where, GDD= Growing degree days (^{o}C day)

T_{max}=Maximum temperature during a day

T_{min}=Minimum temperature during a day

T_b =Base temperature (8^{o}C)

a is the starting date of phenophase of interest whereas b is the ending date of phenophase of interest.

HTU= Heliothermal units (^{o}C day hours) and N=Actual sunshine hours (hrs).

The statistical analysis was carried out using the MS Excel and OP stat.

RESULTS AND DISCUSSIONS

Phenological studies

The duration (days) taken for different phenological events *i.e.,* P_1 to P_5 under different treatments are summarized in Table 1. The different days taken by various phenophases (P_1 to P_5) under different years differed significantly in both rainfed and irrigated conditions except the phenophase P_4 under irrigated conditions during the year 2017 (Table 1).The crop sown on normal sowing date 25th June (D_2) matured earlier and differed significantly as compared to the early sown crop 10thJune (D_1) under both rainfed and rainfed conditions, in different years. Similar results were also reported by Tyagi*et al.,* (1996) and Dhaliwal*et al.,* (2006) in mustard crop. Among the plant densities, tassel and silking stages were non-significant during 2017 and 2018 under rainfed conditions; while during the year 2019, the different phonological stages differed non-significantly except the dough stage (P_4) under rainfed conditions. Singh *et al.,* (2004) had found no significant effect on days to be taken to various phenophases in mustard crop under rainfed conditions. Under irrigated conditions, the various phenological events among different spacing differed non-significantly, except 1-2 stages in each year. But the narrow spacing (S_1) is statistically at par with broadcasting (S_3) during 2016 & 2017. However, during 2018, 6th leaf and dough stages differed significantly among the spacings.

Growing degree days (GDD)

The growing degree days were accumulated to attain different phenological stages in various treatments, the values of which are presented in Table 2. The data revealed that the early sown (D_1) maize crop attained 1871.5^{0}C days; while the normal/timely sown (D_2) crop took 1676.3^{0}C days for maturity under rainfed conditions. However, D_1 and D_2 maize crops took 1954.2 and 1772.9^{0}C days for maturity under irrigated conditions, respectively which shows that the crop sown under irrigated conditions accumulated more heat units as compared to rainfed conditions for attaining maturity. Singh *et al.*, (2003) observed similar results in wheat crop. The thermal time required for attaining each phenophase differed significantly between the two dates of sowing under both conditions (Table 2). However, a non-significant effect was noticed among three spacings at all the phenophases under both rainfed and irrigated conditions except the physiological maturity stage (P_5) under rainfed conditions. The standard error of mean (SEm) varies from 2.9 to 17.2 among dates; while it varies from 3.7 to 21.0 in different spacings, under both conditions. The phenophase 6th leaf to tassel emergence (P_2) took more thermal time whereas, phenophase tassel emergence to silking stage (P_3) took less growing degree days (GDD) in both dates of sowing under rainfed and irrigated conditions. Kestner and Kestner (1977) also reported direct impact of heat units on phenology.

Heliothermal Units (HTU)

The bright sunshine hours plays an important role in development of different phenophases in maize crop sown under different moisture regimes. The heliothermal units required by the maize crop during different phenological stages of maize crop sown on 10th June and 25th June in three spacings under rainfed and irrigated conditions are summarized in Table 3. The accumulated heliothermal units were significantly differed among different dates of sowing in both rainfed and irrigated conditions; however among spacing, it differed non-significantly (Table 3). More HTU were accumulated in early sown (D_1) maize crop under irrigated conditions as compared to timely sown crop (D_2). Under irrigated conditions, HTU was more because of more heat units required by the maize crop. Kour and Hundal(2006) found more accumulated HTU in *Brassica* spp. under irrigated conditions. However, in various spacings wider spacing (S_2) acquire more HTU from sowing to dough stage (P_4), however from dough stage to physiological maturity (P_5); broadcasting (S_3) took more accumulated HTU under both the conditions. And standard error of mean (SEm) varied from 178.4 to 251.1 under rainfed conditions and in irrigated conditions it varied from 163.0 to 334.4 (Table 3). Similar results have been reported by Agarwal*et al.*, (1999).

Prediction of phenological events based on meteorological indices

Simple linear regression models were developed for prediction of each phenological stage of the maize crop using three years data for occurrence of each phenophase (days to be taken) with accumulated growing degree days (AGDD) and heliothermal units (HTU), which are presented in Table 4. The results revealed that the accumulated growing degree days predict the phenology of the maize crop more accurately as compared to Heliothermal units and could thus be best used for predicting phenology of maize under subtropical conditions of Jammu. The occurrence of different phenological stages (days to be taken) in maize crop with accumulated growing degree days (AGDD) can be predicted with an accuracy of 89 to 97%; whereas in case of heliothermal units it could be predicted within the range of 54 to 66% (Table 4). Hundal*et al.,* (1997) also reported that accumulated growing degree days could be used as an index to predict phenological development of crop.

Conclusion

The crop sown on date 25th June (D2) matured earlier and differed significantly as compared to the early sown crop 10th June (D1) under both rainfed and rainfed conditions, in different years. Likewise, early sown (D1) maize crop attained 1871.50C days; while the normal/timely sown (D2) crop took 1676.30C days for maturity under rainfed conditions. However, D1 and D2 maize crops took 1954.2 and 1772.90C days for maturity under irrigated conditions, respectively which shows that the crop sown under irrigated conditions Lastly, more HTU were accumulated in early sown (D1) maize crop under irrigated conditions as compared to timely sown crop (D2).

Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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Table 1.Effect of various treatments on occurrence of different phenophases (days) in maize during *kharif* season of 2017, 2018 and 2019.

Kharif 2017										
Treatments	**Rainfed**					**Irrigated**				
	P_1	P_2	P_3	P_4	P_5	P_1	P_2	P_3	P_4	P_5
D_1	18	53	59	69	80	19	55	61	71	83
D_2	15	45	55	66	72	17	53	59	70	78
CD	0.79	0.96	0.92	0.98	1.48	0.94	0.77	1.34	0.67	0.73
SEm	0.26	0.32	0.31	0.32	0.49	0.31	0.26	0.44	0.22	0.24
S_1	17	49	57	67	76	17	54	61	71	81
S_2	16	50	56	67	75	19	54	59	69	80
S_3	17	49	57	69	77	18	54	60	72	81
CD	N S	N S	1.13	1.19	N S	1.15	N S	N S	0.82	0.89
SEm	0.32	0.40	0.37	0.39	0.60	0.38	0.31	0.54	0.27	0.30
Kharif 2018										
Treatments	**Rainfed**					**Irrigated**				
	P_1	P_2	P_3	P_4	P_5	P_1	P_2	P_3	P_4	P_5
D_1	14	47	59	75	87	15	51	63	79	90
D_2	10	45	55	70	81	12	49	59	79	85
CD	0.76	0.85	1.55	1.12	1.49	1.08	1.24	1.00	NS	0.82
SEm	0.25	0.28	0.51	0.37	0.49	0.36	0.41	0.33	0.51	0.27
S_1	13	47	57	73	85	14	50	62	79	87
S_2	12	46	56	72	82	14	49	60	77	87
S_3	12	45	58	74	85	13	50	61	80	88
CD	0.93	NS	NS	1.37	1.83	NS	NS	1.22	1.87	NS
SEm	0.31	0.35	0.63	0.46	0.61	0.44	0.51	0.41	0.62	0.33
Kharif 2019										
Treatments	**Rainfed**					**Irrigated**				
	P_1	P_2	P_3	P_4	P_5	P_1	P_2	P_3	P_4	P_5
D_1	17	51	62	76	90	19	54	64	79	96
D_2	12	47	51	70	83	15	50	60	75	86
CD	0.59	1.01	0.90	0.77	0.84	0.42	2.02	1.97	0.75	1.10
SEm	0.19	0.34	0.30	0.25	0.28	0.14	0.67	0.65	0.25	0.37
S_1	15	50	57	73	86	18	53	62	78	91
S_2	14	48	56	72	85	16	51	61	76	91
S_3	15	49	57	74	87	17	52	63	77	91
CD	0.72	NS	NS	0.94	1.03	0.51	NS	NS	0.91	NS
SEm	0.24	0.41	0.37	0.31	0.34	0.17	0.82	0.80	0.30	0.45

Table 2. Effect of various treatments on cumulative heat units (^{o}C day) at different phenophases in maize (mean of three years).

Treatments	**Rainfed**					**Irrigated**				
	P_1	**P_2**	**P_3**	**P_4**	**P_5**	**P_1**	**P_2**	**P_3**	**P_4**	**P_5**
D_1	388.8	1133.2	1336.0	1626.2	1871.5	417.2	1192.2	1386.4	1664.2	1954.2
D_2	279.9	989.5	1162.4	1477.2	1676.3	333.7	1094.2	1280.6	1591.1	1772.9
CD	22.3	41.9	54.0	28.8	9.4	36.5	26.8	28.4	37.7	42.7
SEm	7.1	13.3	17.2	9.1	2.9	11.6	8.5	9.0	11.9	13.6
S_1	346.0	1065.5	1255.3	1551.3	1777.0	375.6	1151.1	1350.2	1623.1	1864.8
S_2	322.3	1061.5	1231.2	1531.1	1749.2	381.4	1129.7	1311.7	1610.3	1851.9
S_3	334.9	1057.1	1261.2	1572.7	1795.5	369.3	1148.8	1338.6	1649.7	1874.0
CD	N S	N S	N S	N S	11.5	N S	N S	N S	N S	N S
SEm	8.7	16.3	21.0	11.2	3.7	14.2	10.4	11.0	14.7	16.6

Table 3. Effect of various treatments on heliothermal units (^{o}C day hours) at different phenophases in maize (mean of three years).

Treatments	**Rainfed**					**Irrigated**				
	P_1	**P_2**	**P_3**	**P_4**	**P_5**	**P_1**	**P_2**	**P_3**	**P_4**	**P_5**
D_1	2716.5	6945.6	8032.2	9878.1	11152.9	2901.9	7333.0	8393.7	10148.1	11605.2
D_2	1588.5	5462.4	6604.3	8297.3	9371.4	1908.0	6158.1	7290.4	8801.7	10067.8
CD	645.7	533.8	622.7	458.7	562.3	757.8	784.3	486.3	419.2	859.8
SEm	205.0	169.5	197.7	145.6	178.5	240.6	249.0	154.4	133.1	273.0
S_1	2208.5	6217.7	7377.5	9088.4	10287.7	2400.2	6763.3	7923.7	9513.7	10846.2
S_2	2096.8	6249.4	7205.6	9000.7	10105.2	2442.7	6656.4	7727.9	9339.9	10784.7
S_3	2152.1	6145.0	7371.7	9173.9	10393.7	2371.8	6817.0	7874.6	9571.2	10878.8
CD	N S	N S	N S	N S	N S	N S	N S	N S	N S	N S
SEm	251.1	207.6	242.1	178.4	218.7	294.7	305.0	189.1	163.0	334.4

Table 4.Prediction of phenological stage of maize.

Phenophase	**Accumulated growing degree days**		**Heliothermal units**	
	Regression equation	**R^2**	**Regression equation**	**R^2**
P$_1$	$y = 22.894x + 4.99$	0.94	$y = 238.99x - 1187.7$	0.64
P$_2$	$y = 24.645x - 127.22$	0.94	$y = 285.28x - 8002.5$	0.66
P$_3$	$y = 24.875x - 172.81$	0.96	$y = 185.6x - 3344.6$	0.55
P$_4$	$y = 23.362x - 118.69$	0.89	$y = 179.15x - 3646.2$	0.62
P$_5$	$y = 23.336x - 147.88$	0.97	$y = 145.44x - 1707.2$	0.54
y= Days taken for occurrence of phenophase, x= Thermal units				