Int.J.Curr.Microbiol.App.Sci (2020) *9*(9): 310-317

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 9 Number 9 (2020)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2020.909.039

Studies of Agrometeorological Indices on Hybrids Maize (*Zea mays* L.) under Different Weather Condition

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Keywords

Yield, GDD, HTU and PTU

Article Info

Accepted:
04 August 2020
Available Online:
10 September 2020

A B S T R A C T

An investigation was carried out during *kharif* 2017 at Department of Agricultural Meteorology, College of Agriculture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, entitled "Performance of maize hybrids (*Zea mays* L.) under different sowing windows" The experiment was laid out in a FRBD design where main plots were assigned to five sowing dates and sub-plots to two Cultivars of maize, with ten treatment combinations and replicated thrice. The treatment comprised the five date of sowing i.e. 25th MW, 26th MW, 27th MW, 28th MW and 29th MW and two cultivars, H_1 (Pioneer 3501), H_2 (Monsanto 9126). The results revealed that among the five different dates of sowing. D_1-25th MW sowing and hybrid H_1 (PIONEER-3501) resulted in crop sown with higher growth and yield parameters significantly *i.e.* Plant height, functional leaves, days to 50% tasseling, days to 50% silking, Number of cob per plant, length of cob, diameter of cob, Number of grain per cob and test weight also first date of sowing D_1 25th MW significantly highest grain yield (4969 kg/ha^{-1}) followed by D_2 (4816 kg/ha^{-1}), D_3 (4627 kg/ha^{-1}) D_4 (4424 kg/ha^{-1}) and D_5 (4131 kg/ha^{-1}) and among hybrid H_1 (PIONEER-3501) (4609 kg/ha^{-1}) and H_2 (MONSANTO-9126) (4578 kg/ha^{-1}) respectively. The highest total GDD was observed with D_3 27th MW sowing date i.e. 2498.7 ^{0}C day and hybrid H_2 (Monsanto 9126) i.e. 3008.9 ^{0}C day similarly the highest HTU was observed with D_3 27th MW sowing date i.e. 13521.2 ^{0}C day/hr and hybrid H_2 (Monsanto 9126) i.e. 16723.3 ^{0}C day/hr. PTU observed during total crop growth period was highest in D_4 28th MW i.e. 37321.2 ^{0}C day/hr as compare to remaining treatments. In case of hybrid PTU was highest in H_2 (Monsanto 9126) i.e. 38283.9 ^{0}C day/hr. The highest GDD, HTU and PTU was observed in hybrid H_2 (Monsanto 9126) as compare to H_1 (Pioneer 3501). In case of date of sowing the highest GDD and HTU in D_3 27th MW and PTU was highest in D_4 28 th MW.

Introduction

Maize is called as queen of cereal due to its great importance in human, animal diet and high yielding ability. It efficiently utilizes solar energy and has immense potential for higher yield and called as "Miracle Crop". Maize plays a vital role in ensuring food security as well as nutritional security through quality protein (Rawool, 2004). Maize is a

versatile crop grown over a range of agro climatic zones. In fact the suitability of maize to diverse environments is unmatched by any other crop. It is grown from 58oN to 40oS, from below sea level to altitudes higher than 3000 m, and in areas with 250 mm to more than 5000 mm of rainfall per year (Shaw, 1988 and Dowswell *et al.,* 1996) and with a growing cycle ranging from 3 to 13 months (CIMMYT 2000). However, the major maize production areas are located in temperate regions of the globe. The United States, China, Brazil and Mexico account for 70% of global production. India has 5% of corn acreage and contributes 2% of world production. Maize is principally a rainy season crop and requires a minimum soil temperature of 13ºC for germination and root development (optimum range 21ºC- 27ºC). It response well to warm conditions (optimum of 21ºC- 30ºC) as growth increases with temperature up to 30ºC. In India, area and production of maize are about 9.23 million hectares and 23.73 million tonnes respectively, having average productivity about 2564 kg ha-1. In Maharashtra, the area and production of maize is about 1.05 million hectares and 2.20 million tonnes production with the productivity of 2080 kg ha^{-1}, The productivity of maize in Marathwada is low (1983 kg ha^{-1}) as compared to Maharashtra (Anonymous, 2015). It ranked next to rice, wheat and sorghum in respect of area and production. Though it is consumed all over the country but it is a staple food of people in hilly and sub mountain area of North India. It is extensively grown in Uttar Pradesh, Bihar, Rajasthan, Madhya Pradesh etc. (Dayanand and Jain, 1994). Negative effect of some abiotic and biotic stresson plant, sowing date can play a major role in determining the seed yield, quality, seed germination and understanding whole phenological stages in many regions. Some researchers pointed out that especially, the effect of sowing date and plant density on corn expressed that delay in sowing reduces the number of kernels in corn (Cantarero *et al.,* (2000). Shumway *et al.,* (1992) found that delay in sowing reduce quality performance and performance components of maize. Early and intermediate sowings tend to best utilize solar radiation for grain production.

Materials and Methods

The field experiment was conducted during the *Kharif* 2017 at Research farm of Department of Agricultural Meteorology, college of Agriculture Parbhani to study the performance of maize hybrids (*Zea mays L.)* under different sowing windows. The experiment was laid out in Factorial Randomized Block Design replicated three times. The treatments comprised of five dates of sowing i.e., 25^{th} MW, 26^{th} MW, 27^{th} MW, 28^{th} MW and 29^{th} MW in main plots and two maize hybrid H_1 (PIONEER-3501) and H_2 (MONSANTO-9126) in sub plots. Gross and net plot sizes were 6.0 x 5.0 m^2 and 4.8 x 4.2 m^2, respectively. Sowing was done by dibbling method with spacing of 60 x 30 cm. The entire recommended packages of practices were adopted. The crop was harvested at physiological maturity. Data on growth, yields and, micrometeorological parameters were recorded as per procedure. The observations pertaining to all biometric observation 15 days interval and post-harvest yield attributes observations were recorded at harvest. Agro-meteorological indices were computed for different phenophases of crop.

Growing degree days (^{0}C day)

Growing Degree Days is defined as "the sum over the growing season of a crop of the difference between the daily temperature and a reference temperature". GDD was expressed in terms of ^{o}C day. The growing degree days (GDD) was worked out by considering the base temperature of 10 ^{o}C (Patel *et al.,* 1999).

The total growing degree days (GDD) for different phenophases were determined by the following formula-

$$GDD\ (^{o}C\ day/hr) = \sum_{i=1}^{n} [(T_{max} + T_{min}) / 2] - T_b$$

Where,

GDD = Growing degree days
T_{max} = Daily maximum temperature (^{0}C)
T_{min} = Daily minimum temperature (^{0}C)
T_b = Base temperature (10 ^{0}C)

Helio-thermal Units (HTU) (^{0}C day hrs)

The HTU may be defined as "the accumulated product of GDD and Bright sun shine hours between the developmental thresholds for each day" and HTU was expressed in terms of ^{o}C day hrs.

The HTU is the product of GDD and mean daily hours of bright sun shine. The sum of HTU for each phenophase was worked out by following equation which was given by Nagamani *et.al* (2015).

HTU (^{o}C day/ hrs) = GDD×BSS

Where,

HTU = Helio Thermal Units
GDD = Growing Degree days
BSS = Bright Sun Shine Hours

Photo Thermal Unit (PTU) (^{0}C day hrs)

PTU may be defined as "the product of growing degree days and the day length" expressed in terms of ^{o}C day hrs. PTU was computed by using following formula. This was proposed by Gudadhe *et al.,* (2013).

PTU (^{o}C day hrs) = GDD x Day length

Where,
PTU = Photo Thermal Units
GDD = Growing Degree days

Results and Discussion

Yields

The data on mean grain, straw and biological yield of maize as influenced by different sowing dates and hybrids are given in Table 1. the data indicated that mean grain, straw and biological yield was 4593 kg ha^{-1}, 9443 kg ha^{-1} and 14036 kg ha^{-1} respectively. Different date of sowing significantly influenced the grains and straw yields. The maize sown in D_1 25th MW produced significantly higher grain yield (4969 kg/ha^{-1}) and followed by D_2 (4816 kg/ha^{-1}), D_3 (4627 kg/ha^{-1}), D_4 (4424 kg/ha^{-1}) and D_5 (4131 kg/ha^{-1}). There was 7%, 11% and 17% reduction in the grain yield in 27th MW, 28th MW and 29th MW. This might be due to delayed sowing as compared to first date of sowing i.e. 25th MW. However among hybrid H_1 (PIONEER 3501) was (4609 kg/ha^{-1}) and H_2 (MONSANTO 9126) (4578 kg/ha^{-1}) respectively. These results were in conformity by Rahman *et al.,* (2001) and Sulochana *et al.,* (2015).

The straw and biological yield was produced significantly higher in 25th MW as compare to rest of sowing dates and first hybrid H_1 (PIONEER 3501) was more yield as compare to H_2 (MONSANTO 9126) respectively. Sowing of maize during different sowing dates significantly influenced growth and yield characters. Plant height, functional leaves, days to 50% tasseling, days to 50% silking, Number of cob per plant, length of cob, diameter of cob, Number of grain per cob and test weight were significantly more when maize sown during 25th MW and hybrid H_1 (PIONEER 3501) was most favoured of the growth and yield contributing characters.

Agro-meteorological indices

Growing degree days (GDD)

Growing degree days (GDD) for hybrids maize crop under different sowing dates from sowing to maturity are presented in Table 2. Data Revealed that the mean total heat requirement during crop life cycle *i.e.* Sowing to seedling/sprouting to Milk to physiological maturity (P_1 to P_6) was 2483.3 ^{0}C. The total heat load was reported during D_1 25th MW was 2484.0 ^{0}C day and it was followed by D_2 26th MW (2492.7 ^{0}C), D_3 27th MW (2498.7 ^{0}C), D_4 28th MW (2478.1 ^{0}C) and D_5 29th MW (2463.2 ^{0}C) day. It indicated that the total heat load was increased from D_1 to D_3 and again decreased at D_4 28th MW it may be due to delayed sowing occurred during crop life cycle. Whereas, Date of sowing D_3 27th MW indicated more heat load (i.e. 2498.7 ^{0}C day) than rest of the treatments it may be due to maximum air temperature prevailed at sowing time. Date of sowing D_5 29th MW lowest heat load (i.e. 2463.2 ^{0}C day). Heat unit required for attaining various phenophases in D_4 27th MW date of sowing due to effect of temperature and delayed sowing during the crop growing season. It will definitely affect GDD of hybrids maize crop. The data presented in Table 2 revealed that the mean heat requirement of hybrid during crop life cycle from 2967.8 ^{0}C. The total heat load reported in hybrids during crop life cycle was H_1 (Pioneer 3501) 2926.7 ^{0}C and H_2 (Monsanto 9126) 3008.9 ^{0}C. It may be occurred due to different crop duration, from emergence to maturity of such Cultivars Similar results were reported by Majumder *et al* (2016).

Table.1 Yield of hybrids maize under different treatments

Treatments	Post-harvest Observation			
	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Biological Yield (kg ha^{-1})	Harvest Index (%)
Date of Sowing				
D_1 (25th SMW)	4969	10825	15794	31.46
D_2 (26th SMW)	4816	10302	15118	31.85
D_3 (27th SMW)	4627	9658	14285	32.39
D_4 (28th SMW)	4424	9597	13885	31.86
D_5 (29th SMW)	4131	9337	14021	29.46
S.E. ±	57.39	51.17	108.56	0.52
CD at 5 %	170.27	151.81	322.08	NS
Hybrids				
H_1 (PIONEER 3501)	4609	10047	14656	31.44
H_2 (MONSANTO 9126)	4578	9840	14418	31.75
S.E ±	36.30	32.36	68.66	0.52
CD at 5 %	107.69	96.00	203.69	NS
Interaction (D x V)				
S.E ±	81.16	92.36	173.52	0.46
CD at 5 %	NS	NS	NS	NS
General Mean	4593	9443	14036	32.72

Table.2 Accumulated Growing Degree Day (GDD ^{o}C day) to attain various phenophases in maize under different date of sowing

Treatment	Phenophases of maize							
	P_1	P_2	P_3	P_4	P_5	P_6	Total	Mean
Dates of sowing								
D_1 (SMW 25)	230.2	978.6	296.0	124.0	271.3	583.9	2484.0	414.0
D_2 (SMW 26)	215.2	976.6	281.1	118.5	312.8	588.5	2492.7	415.4
D_3 (SMW 27)	219.3	995.4	271.5	121.7	293.7	596.6	2498.7	416.3
D_4 (SMW 28)	230.6	957.2	285.2	127.2	284.8	593.1	2478.1	413.0
D_5 (SMW 29)	256.0	979.8	268.8	103.3	245.7	609.7	2463.2	410.5
Mean	230.3	977.5	280.5	118.9	281.7	594.4	2483.3	413.8
Hybrids								
H_1(PIONEER 3501)	312.5	840.0	352.3	197.4	413.3	811.2	2926.7	487.8
H_2(MONSANTO 9126)	257.5	867.5	407.4	324.8	424.6	727.1	3008.9	501.5
Mean	285.0	853.8	379.9	261.1	419.0	769.2	2967.8	494.7

P_1: Sowing to seedling/sprouting. P_2: Seedling /sprouting to grand growth. P_3: Grand growth to tasseling. P_4: Tasseling to silking. P_5: Silking to milk. P_6: Milk to physiological maturity

Table.3 Accumulated Helio Thermal Unit (HTU ^{o}C day hrs) to attain various phenophases in maize under different date of sowing

Treatment	Phenophases of maize							
	P_1	P_2	P_3	P_4	P_5	P_6	Total	Mean
Dates of sowing								
D_1 (SMW 25)	2140.8	4305.8	1480.0	607.6	949.5	3561.8	13045.6	2174.3
D_2 (SMW 26)	774.7	4587.7	1208.7	379.2	2001.9	3589.8	12542.1	2090.3
D_3 (SMW 27)	1622.5	4081.1	977.4	547.6	2204.2	3818.2	13521.2	2208.5
D_4 (SMW 28)	530.6	4211.7	1311.9	1144.8	1509.4	4092.4	12800.8	2133.7
D_5 (SMW 29)	716.8	4507.1	2016.0	630.1	1253.1	4206.9	13330.1	2221.7
Mean	1157.1	4338.7	1398.8	661.9	1583.6	3853.8	13048.0	2165.7
Hybrids								
H_1(PIONEER 3501)	2500.0	3444.0	1937.6	1085.7	1735.9	5435.1	13138.2	2689.7
H_2(MONSANTO 9126)	2394.7	3470.0	2403.7	1071.9	2802.4	4580.7	16723.3	2787.2
Mean	2447.4	3457.0	2170.7	1078.8	2269.2	5007.9	14930.8	2738.5

Table.4 Accumulated Photo Thermal Unit (PTU ^{o}C day hrs) to attain various phenophases in maize under different date of sowing

Treatment	Phenophases of maize							
	P_1	P_2	P_3	P_4	P_5	P_6	Total	Mean
Dates of sowing								
D_1 (SMW 25)	2688.3	12956.6	3904.2	1556.2	3388.5	7211.7	31705.1	5284.2
D_2 (SMW 26)	2847.1	12969.2	3541.9	1480.1	3878.7	7209.1	31926.1	5321.0
D_3 (SMW 27)	2894.8	13099.9	3391.1	1511.5	3915.0	7272.6	32084.8	5347.5
D_4 (SMW 28)	3039.3	12472.2	9542.2	1569.6	3491.6	7206.2	37321.2	6220.2
D_5 (SMW 29)	3363.8	12649.2	3319.7	1268.5	3009.8	7377.4	30988.4	5164.7
Mean	2966.7	12829.4	4739.8	1477.2	3536.7	7255.4	32805.1	5467.5
Hybrids								
H_1 (PIONEER 3501)	4134.4	11079.1	4692.6	2475.4	5137.3	9880.4	37399.2	6233.2
H_2 (MONSANTO 9126)	3406.7	11451.0	5320.6	4053.5	5239.6	8812.4	38283.9	6380.6
Mean	3770.6	11265.1	5006.6	3264.5	5188.5	9346.4	37841.6	6306.9

Helio-thermal units (HTU)

The Helio-thermal units (HTU) for hybrids maize crop under different sowing dates from sowing to maturity are presented in Table 3. revealed that the mean total helio-thermal units (HTU) observed during crop life cycle i.e. Sowing to seedling/sprouting to Milk to physiological maturity (P_1 to P_6) in date of sowing (D_1 to D_5) 13048.0 ^{0}C day hrs. The helio-thermal units were higher in first date of sowing D_3 27th MW i.e. 13521.2 0C day hrs.

The lowest HTU were observed in D_2 26th MW i.e. 12542.1 ^{0}C day hrs than rest of the treatments due to variation of temperature and bright sunshine hours during the crop growing season. The data depicted in Table 3 revealed that the total mean helio-thermal unit (HTU) requirement for Two hybrids during crop life cycle was 14930.8 ^{0}C day hrs. The helio-thermal units (HTU) were higher in H_2 (Monsanto 9126) i.e. 16723.3 ^{0}C day hrs and the lowest HTU were observed in H_1 (Pioneer 3501) 13138.2 ^{0}C day hrs. It may be due to different growth period. Similar results were reported by Singh *et al.,* (2013).

Photo-thermal Units (PTU)

The data presented in Table 4 revealed that mean total Photo-thermal Units (PTU) required in the life cycle i.e. Sowing to seedling/sprouting to Milk to physiological maturity (P_1 to P_6) stage was 32805.1 ^{0}C day hrs for sowing date. Date of sowing D_4 28th MW required more PTU i.e. 37321.2 ^{0}C day hrs than rest of the treatments, it may be due to maximum air temperature prevailed at sowing time. Date of sowing D_5 29th MW required lowest heat load i.e. 30988.4 ^{0}C day hrs heat unit for attaining various phenophases due to effect of temperature during the crop growing season. The data depicted in Table 3 revealed that the total mean Photo thermal unit (PTU) requirement for Two hybrids during crop life cycle was 37841.6 ^{0}C day hrs. The Photo thermal units (PTU) were higher in H_2 (Monsanto 9126) i.e. 38283.9 ^{0}C day hrs and the lowest PTU were observed in H_1 (Pioneer 3501) 37399.2 ^{0}C day hrs. It might be due to the different crop duration in above Varieties. Similar results were reported by Thavaprakaash *et al.,* (2007).

In conclusion based on the above findings, it may be concluded that Sowing dates in June D_1 25th MW and maize hybrid H_1 (PIONEER 3501) superior and better as compare to other treatments is appropriate in terms higher physiological maturity and yield. Build up of GDD, HTU and PTU are good estimators to study maize phenology and can be used as a reliable tool to optimize the sowing period for different maize cultivars. It is also useful for the appraisal of yield potential of maize in different dates of sowing.

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How to cite this article:

Shingne, S. V., B. V. Asewar and Raut, G. B. 2020. Studies of Agrometeorological Indices on Hybrids Maize (*Zea mays* L.) under Different Weather Condition. *Int.J.Curr.Microbiol.App.Sci.* 9(09): 310-317. doi: https://doi.org/10.20546/ijcmas.2020.909.039