RESEARCH ARTICLE

Influence of Agro Meteorological Indices on Different Sowing Time of Irrigated Maize in Western Agro-Climatic Zone of Tamil Nadu

Sowmiya R[1], Krishnan R[1], Karthikeyan R[1], Jeyarani S[2] and Chandrasekhar CN[3]
[1]Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore-641 003
[2]Department of Agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore-641 003
[3]Department of Crop Physiology, Tamil Nadu Agricultural University, Coimbatore-641 003

Received : 12th November, 2021
Revised : 29th November, 2021
Revised: 18th December, 2022
Accepted : 11th January, 2022

ABSTRACT

A field trial with different sowing windows of the maize crop was done in the Eastern Block Farm of Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India. The sowing windows we W*Kharif* and *Rabi* seasons were more suitable for maize cultivation and provided better yield than other seasons in the western agro-climatic zone of Tamil Nadu.

Keywords: *Agrometeorological indices; Sowing windows; Seasons; Maize; Climate change.*

INTRODUCTION

Maize (*Zea mays*), a C4 plant, requires a hot, dry subtropical climate with high sunshine hours, low wind speed, and occasional rains during growth and maturity (Andersen and Korn, 2000). It is the world's most- produced crop for both human and animal consumption (Giraldo *et al.,* 2019). In India, maize is the third most cultivated grain crop. India represents 4 % of the world maize area, 2 % of total production, and ranks 4th in the area; 7th in production among the maize growing countries. The area, production, and productivity of maize in India from 2019 to 2020 are 9569.06 thousand hectares, 28765.86 thousand tonnes, and 3006 kg ha^{-1}, respectively (https://www.indiastat.com). In Tamil Nadu, maize is grown for moneymaking purposes as it cannot serve the purpose of livelihood of the state's population, and the crop performs well on the climatic condition of the state (Saravanadurai *et al.,* 2010).

The major weather parameters that influence the life cycle and production potential of a crop are temperature, relative humidity, bright sunshine hours and solar radiation. Currently, the biggest challenge to the agricultural sector is climate change, which causes risk in cropping patterns and yields, ultimately resulting in food security threats (Bennetzen *et al.,* 2016). From 2000 to 2020, nineteen hottest years have occurred except 1998 because of very strong El Nino. IPCC report says that there will be a severe impact on crop yields if global warming exceeds 1.5 ^{o}C above pre-industrial levels (IPCC, 2018).

Temperature is the critical climatic factor that plays a major role in the growth, development and function of plants. Temperature modifies the enzymatic functions of plants and causes a change in phenology, which is coupled with yield (Zhu *et al.,* 2018). A report says that maize yield declines by a 7.4 % per ^{o}C increase in warming when no crop improvement strategies were adopted (Zhao *et al.,* 2017). The concept of heat unit or growing degree-day (GDD) plays a linear relationship in the growth of plants and is generally used to know the phenology and yield of crops (Kiniry *et al.,* 1983; Shukla and Vasuniya, 1998). The present investigation is designed to know the impact of the prevailing climate on the yield of maize by using various agro-meteorological indices.

MATERIAL AND METHODS

In Tamil Nadu, maize is cultivated throughout the year in the western agro-climatic zone and is the most efficient cropping zone for maize. The research was conducted in different locations of Eastern Block Farm at Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu. The experimental site is

Corresponding author: sowmiagro94@gmail.com

situated in the Western Agro-Climatic Zone of Tamil Nadu at 11°N and 76°57´E longitude and an altitude of 426.7 m above MSL. The climatic condition of the site was hot semi-arid under the Koppen climate classification. The wet season of the site lasts from June to November.

The maize hybrid CO 6 was cultivated in four seasons with three sowing windows in each season *viz., Kharif*, 2019 (D_1 - June 15th, D_2 - July 15th and D_3 - August 15th), *Rabi*, 2019 (D_1 - September 15th, D_2 - October 15th and D_3 - November 15th), Late *Rabi*, 2020-2021 (D_1 - December 15th, D_2 - January 15th and D_3 - February 15th) and Summer, 2021 (D_1 - March 15th, D_2 - April 15th and D_3 - May 15th). The daily weather data that prevailed during the cropping period was collected from the Agrometeorological Observatory, TNAU, Coimbatore. The weather data recorded during the entire cropping period are presented in Figures 1 and 2. The phenological observations noted were 50 percent tasseling, 50 percent silking and harvest maturity. The data were not statistically analyzed.

The agrometeorological indices *viz.,* GDD, HTU, PTU, RTD and seasonal efficiency were calculated. For GDD, HTU and PTU calculation, the base temperature was taken as 10 °C. The formulas are as follows:

1. Growing Degree Days (GDD): (Nuttonson, 1995)

$$GDD = \frac{(Tmax + Tmin)}{2} - Tb$$

T_{max} – Maximum temperature (°C)

T_{min} – Minimum temperature (°C)

T_b – Base temperature (°C)

2. Helio Thermal Unit (HTU): (Rajput, 1980)

$$HTU = GDD \times SSH$$

SSH – Bright sunshine hours

3. Photo Thermal Unit (PTU): (Chakravarthy and Sastry, 1985)

$$PTU = GDD \times N$$

N – Maximum possible day length (hrs)

4. Relative Temperature Disparity (RTD): (Rajput, 1980)

$$RTD = \frac{(Tmax - Tmin)}{Tmax} \times 100$$

T_{max} – Maximum temperature (°C)

T_{min} – Minimum temperature (°C)

5. Seasonal efficiency

$$\text{Seasonal efficiency} = \frac{\text{Yield of crops in a season}}{\text{Mean yield of all seasons}} \times 100$$

RESULTS AND DISCUSSION

Days taken for different phenophases

The data on the influence of seasons on the phenological stages were presented in Table 1. Amongthe different sowing windows taken, the maize crop cultivated in March (summer) took lesser days to attain tasseling (47), silking (50.5) and maturity (94). Among the seasons, the crop sown during summer has reached tasseling (47.8) and silking (51.60) stages earlier and the crop sown in *Rabi* season took more days to reach tasseling (56.3) and silking (60.03) stages. This might be due to the prevalence of higher temperature and solar radiation during the summer season. The prevalence of higher temperature, solar radiation and longer day length during the summer season has provided an improved crop growth resulting in earlier tasseling and silking, while in *Rabi* due to lower temperature, solar radiation and shorter day length delayed the tasseling and silking process. The results were substantiated by Thavaprakaash *et al.* (2007), who observed in the study that higher amount of solar radiation and daily mean temperature during summer months might have encouraged the early attainment of phenophases of baby corn which supports the results of the present study.

Table 1. Influence of seasons on the phenological stages (days)

Seasons	Dates of sowing	50 % tasseling	50 % silking	Maturity
Kharif, 2019	D_1 (June 15th)	51.0	53.6	104
	D_2 (July 15th)	53.4	57.0	108
	D_3(August15th)	53.0	56.0	110
	MEAN	52.5	55.53	107.3
Rabi, 2019	D_1 (September 15th)	55.0	58.0	110
	D_2 (October 15th)	56.6	59.9	112
	D_3 (November 15th)	57.3	62.2	115
	MEAN	56.3	60.03	112.3
Late *Rabi*, 2020-2021	D_1 (December 15th)	57.0	61.5	104
	D_2 (January 15th)	53.0	57.0	103
	D_3 (February 15th)	49.0	52.0	100
	MEAN	53.2	56.83	102.3
Summer, 2021	D_1 (March 15th)	47.0	50.5	94
	D_2 (April 15th)	47.5	51.3	97
	D_3(May 15th)	49.0	53.0	100
	MEAN	47.8	51.60	97

(*Data were not statistically analyzed)

The data on the accumulated agro-meteorological indices as influenced by the sowing windows at various phenological stages are presented in Tables 2 to 5.

Growing degree days (GDD)

The summer season required more heat units to attain tasseling stage (913.72) and late *Rabi* required more heat units from tasseling to silking

(66.13), silking to maturity (873.17) and sowing to maturity (1820.63) comparing the four seasons. This might be due to the higher temperature which prevailed during the cropping period. Whereas, late *Rabi* season provided lower heat units to reach tasseling (881.33); *Rabi* season was having minimum heat units for attaining silking stage from tasseling (50) and also to attain maturity from sowing (1768.10) while summer season required lower heat units from silking to maturity (800.53). This might be due to the optimum temperature prevailed during those phenological stages.

Table 2. Accumulated agro meteorological indices influenced by different sowing windows at tasseling stage

Season	Sowing windows	GDD	HTU	PTU	RTD
Kharif, 2019	D_1 (June 15th)	923.80	5280.36	11645.00	1300.04
	D_2 (July 15th)	891.70	3678.89	11091.80	1261.89
	D_3(August15th)	906.55	4832.49	11001.80	1299.32
	MEAN	907.35	4597.25	11246.20	1287.08
Rabi, 2019	D_1 (September 15th)	920.05	5632.68	10904.95	1448.44
	D_2 (October 15th)	893.75	4868.38	10407.00	1357.59
	D_3 (November 15th)	878.95	4348.68	10150.75	1392.66
	MEAN	897.58	4949.91	10487.57	1399.56
Late *Rabi*, 2020-2021	D_1 (December 15th)	850.75	5067.62	9905.54	1683.33
	D_2 (January 15th)	864.90	7580.05	10229.33	1870.59
	D_3 (February 15th)	928.35	8397.11	11191.87	1693.92
	MEAN	881.33	7014.93	10442.24	1749.28
Summer, 2021	D_1 (March 15th)	935.40	7243.74	11572.30	1385.84
	D_2 (April 15th)	919.60	7306.36	11579.59	1300.18
	D_3(May 15th)	886.15	6170.48	11219.67	1305.09
	MEAN	913.72	6906.86	11457.19	1330.37

(*Data were not statistically analyzed)

Helio thermal unit (HTU)

The late *Rabi* season recorded maximum HTU which helped the maize crop to reach tasseling (7014.93), tasseling to silking (521.44), silking to maturity (7203.26) and sowing to maturity stages (14739.64) compared among the four seasons. This might be due to the maximum sunshine hours prevailed during the cropping period. Though the sowings were taken in late *Rabi* season, the later growing days of this season crop falls on summer where greater sunshine hours prevailed. The *Kharif* season took minimum heliothermal unit to attain tasseling (4597.25) and from silking to maturity (4649.45) and sowing to maturity stages (9553.08), while summer season acquired lower HTU from tasseling to silking stage (199.60) which might be due to the ideal sunshine hours prevailed during those stages.

Table 3. Accumulated agro meteorological indices influenced by different sowing windows at tasseling to silking stage

Season	Sowing windows	GDD	HTU	PTU	RTD
Kharif, 2019	D_1 (June 15th)	43.85	0	543.74	47.35
	D_2 (July 15th)	70.65	507.75	854.86	71.42
	D_3(August15th)	53.15	411.41	627.17	92.47
	MEAN	55.88	306.39	675.26	70.41
Rabi, 2019	D_1 (September 15th)	49.50	287.55	574.20	75.50
	D_2 (October 15th)	44.50	339.40	511.75	92.05
	D_3 (November 15th)	56.00	441.51	649.60	159.98
	MEAN	50.00	356.15	578.52	109.18
Late *Rabi*, 2020-2021	D_1 (December 15th)	65.90	411.03	777.62	115.18
	D_2 (January 15th)	73.50	737.82	882.00	156.15
	D_3 (February 15th)	59.00	415.47	725.70	93.98
	MEAN	66.13	521.44	795.11	121.77
Summer, 2021	D_1 (March 15th)	65.75	308.32	828.45	84.06
	D_2 (April 15th)	49.00	133.12	622.30	57.33
	D_3(May 15th)	64.00	157.35	806.40	94.09
	MEAN	59.58	199.60	752.38	78.49

(*Data were not statistically analyzed)

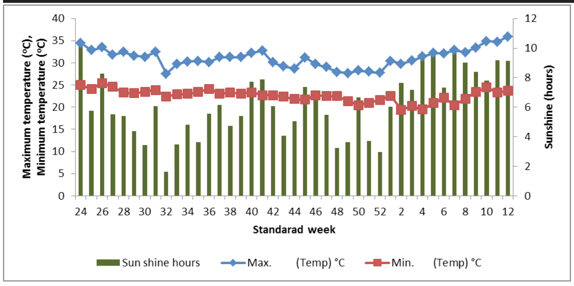

Fig 1. Weather prevailed during *Kharif* and *Rabi* season, 2019-2020

Photo thermal unit (PTU)

The summer season has taken maximum PTU to attain tasseling (11457.19) and maturity stages (22278.59), while late *Rabi* season took maximum PTU from tasseling to silking (795.11) and from silking to maturity stage (10710.32) comparing the four seasons. This is due to the longer day length prevailed during the cropping period. However, the late *Rabi* season took low PTU to reach tasseling stage (10442.24) and *rabi* season acquired low PTU from tasseling to silking (578.52), silking to maturity (9537.88) and from sowing to maturity (20603.95). This is because of the optimum day length existed during those months of cultivation.

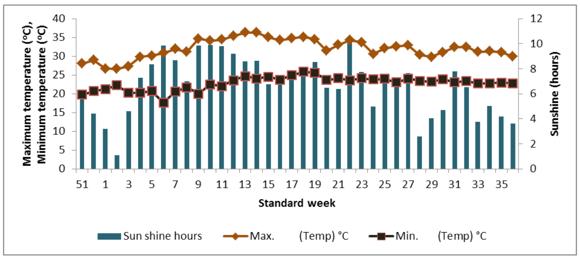

Fig 2. Weather prevailed during Late *rabi* and Summer season, 2020-2021

Table 4. Accumulated agro meteorological indices influenced by different sowing windows at silking stage to maturity

Season	Sowing windows	GDD	HTU	PTU	RTD
	D_1 (June 15^{th})	840.00	3944.39	10272.40	1185.11
Kharif, 2019	D_2 (July 15^{th})	865.05	5182.81	10315.94	1327.58
	D_3(August15^{th})	859.55	4821.14	10029.60	1295.11
	MEAN	854.87	4649.45	10205.98	1269.27
	D_1 (September 15^{th})	783.45	3756.32	9042.95	1200.27
Rabi, 2019	D_2 (October 15^{th})	793.50	5144.93	9188.35	1551.71
	D_3 (November 15^{th})	900.35	7757.33	10604.80	1762.74
	MEAN	825.77	5492.36	9537.88	1504.36
	D_1 (December 15^{th})	783.65	7248.95	9404.30	1471.55
Late *Rabi*, 2020-2021	D_2 (January 15^{th})	914.90	7220.99	11206.58	1412.09
	D_3 (February 15^{th})	920.95	7139.85	11520.09	1323.48
	MEAN	873.17	7203.26	10710.32	1402.37
	D_1 (March 15^{th})	784.80	5805.85	9942.66	1167.28
Summer, 2021	D_2 (April 15^{th})	803.85	4576.91	10155.02	1146.18
	D_3 (May 15^{th})	812.95	4387.04	10109.42	1225.97
	MEAN	800.53	4923.27	10069.03	1179.81

(*Data were not statistically analyzed)

Relative temperature disparity (RTD)

The late *Rabi* season took more RTD to attain tasseling (1749.28), tasseling to silking (121.77) and maturity stage (3273.43), while *Rabi* season has taken more RTD from silking to maturity (1504.36) within the four seasons. This might be due to the maximum and minimum temperature differences that prevailed during the cropping period that increased the RTD values and so it took more days to achieve those stages. The lower RTD was acquired by *Kharif* season to reach tasseling (1287.08) and tasseling to silking (70.41) stage, while summer took less RTD from silking to maturity (1179.81) and from sowing to maturity (2588.68).

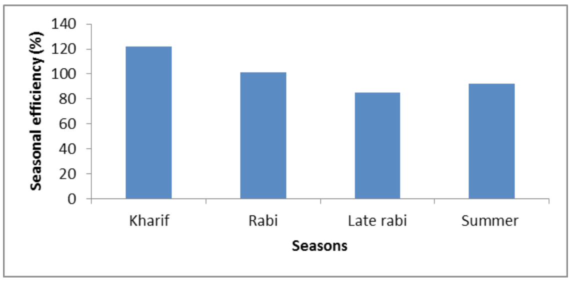

Fig 3. Seasonal efficiency of four seasons

Seasonal efficiency

The seasonal efficiency was higher in the *Kharif* season followed by *Rabi*, summer and late *Rabi* (Fig 3). The efficiency values of the *Kharif* and *Rabi* seasons were higher than 100, which shows that these seasons are more suitable for growing maize than the late *rabi* and summer seasons. This was similar to the outcomes of Thavaprakaash *et al.* (2007), who reported that the seasonal efficiency was higher than 100 in *Kharif, Rabi* and summer seasons while it was less than 100 in late *rabi* season, which expressed the non-suitability of the season.

Table 5. Accumulated agro meteorological indices influenced by different sowing windows from sowing to maturity

Season	Sowing windows	GDD	HTU	PTU	RTD
Kharif, 2019	D_1 (June 15th)	1807.65	9224.74	22461.14	2532.50
	D_2 (July 15th)	1827.40	9369.44	22262.64	2660.89
	D_3(August15th)	1819.25	10065.05	21658.62	2686.90
	MEAN	1818.10	9553.08	22127.47	2626.76
Rabi, 2019	D_1 (September 15th)	1836.65	10266.44	21492.44	2866.41
	D_2 (October 15th)	1731.75	10352.70	20107.07	3001.34
	D_3 (November 15th)	1735.90	11776.15	20212.35	3171.53
	MEAN	1768.10	10798.43	20603.95	3013.09
Late *Rabi*, 2020-2021	D_1 (December 15th)	1700.30	12727.61	20087.47	3270.06
	D_2 (January 15th)	1853.30	15538.87	22317.91	3438.84
	D_3 (February 15th)	1908.30	15952.44	23437.66	3111.38
	MEAN	1820.63	14739.64	21947.68	3273.43
Summer, 2021	D_1 (March 15th)	1785.95	13357.92	22343.39	2637.18
	D_2 (April 15th)	1772.45	12016.40	22356.90	2503.70
	D_3 (May 15th)	1763.10	10714.88	22135.49	2625.15
	MEAN	1773.83	12029.73	22278.59	2588.68

(*Data were not statistically analyzed)

CONCLUSION

The differences in the GDD, HTU, PTU and RTD at four seasons were based on the temperature, sunshine and day length that existed during the months of cropping. Comparing the four seasons, the seasonal efficiency was higher in *Kharif* and *Rabi* seasons, which makes these two seasons highly suitable for cultivating maize in the western agro-climatic zone of Tamil Nadu.

Funding and Acknowledgment

No funding has been received. The authors acknowledge the support provided by the Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore.

Ethics statement

No specific permits were required for the described field studies because no human or animal subjects were involved in this research.

Originality and plagiarism

The authors assure that the research work submitted here is original and not subjected to any plagiarized content.

Consent for publication

All the authors agreed to publish the content.

Competing interests

There were no conflict of interest in the publication of this content

Data availability

All the data of this manuscript are included in the MS. No separate external data source is required. If anything is required from the MS, certainly, this will be extended by communicating with the corresponding author through corresponding official mail; sowmiagro94@gmail.com

Author contributions

Idea conceptualization - SR, KR, KR, Experiments - SR, Guidance – KR, KR, Writing original draft – SR, Writing - reviewing &editing - SR, KR.

REFERENCES

Andersen, S and D. A. Korn. 2000. In Andersen, S (Ed.), Landbrugsplanterne, second ed.; DSR Forlaget Inc., Frederiksberg, Denmark, 106–144.

Bennetzen, E. H., Smith, P and J. R. Porter. 2016. Agricultural Production and Greenhouse Gas Emissions from World Regions—The Major Trends over 40 Years. Global Environ Chang, 37: 43–55.

Chakravartty, N. V and P. N. Sastry. 1985. Some aspects of crop-weather interactions in wheat cultivars. Int. J. Ecol. Environ. Sci, 11: 139-144.

Giraldo, P., Benavente, E., Manzano-Agugliaro, F. and E. Gimenez. 2019. Worldwide Research Trends on Wheat and Barley: A Bibliometric Comparative Analysis. Agronomy. 9: 352.

IPCC, 2018. Summary for Policymakers In: Global Warming of 1.5 °C. An IPCC Special Report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., Zhai, P., Portner, H. O., Roberts, D., Skea, J., Shukla, P. R., Pirani, A., Moufouma-Okia, W., Pean, C., Pidcock, R., Connors, S., Matthews, J.B.R., Chen, Y., Zhou, X., Gomis, M.I, Lonnoy, E., Maycock, T., Tignor, M and T. Waterfield (eds.)]. In Press.

Kiniry, J. R., Ritchie, J. T and R. L. Musser. 1983. Dynamic nature of the photoperiod response in maize. Agron. J., 75(4).

Nuttonson, M. Y. 1995. Wheat climate relationship and use phenology in ascertaining the thermal and photothermal requirement of wheat. Am. Inst. Crop Ecol, Washington D.C.

Pal, R. K., Rao, M. N. N and N. S. Murty. 2013. Agro-meteorological indices to predict plant stages and yield of wheat for foot hills of Western Himalayas. Int. J. Food Sci. Technol., 4(9): 909–914.

Rajput, R. P. 1980. Response of soybean crop to climatic and soil environments. Ph. D Thesis, IARI, New Delhi, India.

Saravanadurai, A and M. Kalaivani. 2010. Growth actions of selected cereal crops in Tamil nadu State. Int. J. Appl., 1(3).

Shukla, A. K and S. S. Vasuniya. 1998. Yield performance of soybean genotypes. Indian J. Agrl. Sci., 68(9).

Thavaprakaash, N., Jagannathan, R., Velayudham, K and L. Gurusamy. 2007. Seasonal influence of phenology and accumulated heat units in relation to yield of baby corn. Int. J. Agric. Res, 2 (9): 826–831.

Zhao, C., Liu, B., Piao, S., Wang, X., Lobell, D. B., Huang, Y., Huang, M., Yao, Y., Bassu, S., Ciais, P., Durand, J. L., Elliott, J., Ewert, F., Janssens, I. A., Li, T., Lin, E., Liu, Q., Martre, P., Muller, C., Peng, S., Penuelas, J., Ruane, A. C. Wallach, D., Wang, T., Wu, D., Liu, Z., Zhu, Y., Zhu, Z and S. Asseng. 2017. Temperature increase reduces global yields of major crops in four independent estimates. Proceedings of the National Academy of Sciences., 114: 9326–9331.

Zhu, P., Jin, Z., Zhuang, Q., Ciais, P., Bernacchi, C., Wang, X., Makowski, D and D. Lobell. 2018. The important but weakening maize yield benefit of grain filling prolongation in the US Midwest. Glob. Change Biol.,24: 4718 – 4730.