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Influence of Weather Health indices on Growth and Yield of *Rabi* sorghum

Madhurya D.[1], Murthy V.R.K.[2] and Sree Rekha M.[3]*
[1]Ph.D. Scholar, Department of Agronomy,
Professor Jayashankar Telangana State Agricultural University (Andhra Pradesh), India.
[2] Professor (Rtd.), Department of Agronomy,
Acharya NG Ranga Agricultural University, Bapatla (Andhra Pradesh), India.
[3] Professor (AGRO) and Director (Polytechnics),
Acharya NG Ranga Agricultural University, LAM, Guntur (Andhra Pradesh), India.

(Corresponding author: Madhurya D.)*
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ABSTRACT: In the era of climate change crops are subjected to wide extremities of climate which ultimately effecting the growth and yield. Adoption of suitable sowing window and suitable hybrid helps preventing the exposure to the weather vagaries without compromise in yields. A field experiment was conducted at Bapatla, Acharya NG Ranga Agricultural University, India during *rabi* 2017-18. The experiment was laid in factorial RBD replicated thrice with four dates of sowing (2nd fortnight of September, 1st fortnight of October, 2nd fortnight of October & 1st fortnight of November) and three hybrids of sorghum (CSH-14, MAHALAKSHMI and CSH-25). The results showed that 2nd fortnight of September (D1) recorded the higher grain yield (5198 kg ha^{-1}), straw yield (9432kg ha^{-1}), GDD, HTU, PTU and TPR. Among the hybrids MAHALAKSHMI reported higher grain yield (5162 kg ha^{-1}), straw yield (9109 kg ha^{-1}) and recorded higher GDD, HTU, PTU and TPR. Significant linear relationship was observed for grain yield of all the three hybrids with agroclimatic/weather health indices.

Keywords: Sorghum, GDD, HTU, PTU, TPR.

INTRODUCTION

Sorghum is the third most important cereal crop in area and seventh in production around the world, and the most important millet crop in India with an area of 11.86 lakh ha with a production of 4.60 million tonnes during 2021-22. India contributes to 16% of worlds sorghum production. Several physical and biotic factors limit plant growth and development at various stages of crop development, and they are largely determined by weather factors. Adverse weather conditions, such as extreme temperature and rainfall, limit growth (Subramanyam *et al*. 2020). Change in weather conditions lead to climate change, which has a direct impact on global food security (Ainsworth and Ort 2010). Planting time is the most important nonmonetary input among the various agronomic practises, having a significant impact on crop growth, phenological development, pest occurrence, and crop productivity (Yadav *et al.* 2016). The optimal sowing time and the selection of improved cultivars play a significant role in maximising a crop's yield potential under specific agroclimatic conditions (Tyagi, 2014). Although sorghum is versatile in nature limited yield of the crop is majorly due to agro climatic conditions. The weather health indices are a potential tool for prediction of absolute relation between crop growth, phenological development and yield. Environmental factors have a strong influence on crop growth and yield. Selection of suitable sowing date is essential to produce higher yields and to withstand the changing weather. The present study is aimed to understand the relation between climate and yield of *rabi* sorghum in Krishna-Godavari zone of Andhra Pradesh using weather health indices.

MATERIALS AND METHODS

A field experiment entitled “Crop weather relationship studies in *Rabi* sorghum” was conducted during *rabi* 2017 in sandy loam soils of Bapatla, Andhra Pradesh. The treatments consisted of three hybrids of sorghum *viz.*, CSH-14 (V_1), MAHALAKSHMI (V_2) and CSH-25 (V_3) as first factor and four dates of sowing *viz.*, 2nd fortnight of September (D_1), 1st fortnight of October (D_2), 2nd fortnight of October (D_3) and 1st fortnight of November (D_4) as second factor. The treatments were laid out in Factorial-RBD replicated thrice. The soil of the experimental plot is low in organic carbon, medium in phosphorus, nitrogen and high potassium and sandy in texture.

All the agronomic practices were followed as per the recommendation. During the crop growth period, the weekly mean maximum temperatures ranged from 35.02°C to 25.6°C and weekly mean temperatures ranged from 14.2°C to 25.8°C. The weekly mean relative humidity ranged from 90.2 to 60.8%. A total rainfall of 220.2 mm was received in 11 rainy days during the crop growth period. The mean weekly sunshine hours ranged from 3 to 8 hours day^{-1} with an average of 5 hours per day. The mean weekly day length ranged from 10.54 to 11.7 hours day^{-1}. The formula adopted for thermal indices were given below

Growing degree days: Iwata (1984)

$$GDD = \frac{T_{max} + T_{min}}{T_b}$$

Where, T_{max} = Maximum temperature,

T_{min} = Minimum temperature, T_b = Base temperature

Heliothermal units: Rajput (1980)

HTU = (GDD) × (Bright sunshine hours)

Photothermal units: Nuttonson (1956)

PTU = GDD × Day length

RESULTS AND DISCUSSION

Grain yield and straw yield: Significantly, higher grain yield of 5162 kg ha^{-1} was recorded with 2nd fortnight of September (D_1) and was on par with 1st fortnight of October sown crop (5082 kg ha^{-1}) and 2nd fortnight of October (4839 kg ha^{-1}) sown crop (Table 1). However, lowest grain yield was recorded when the crop was sown during 1st fortnight of November (4526 kg ha^{-1}). Among the hybrids, MAHALAKSHMI hybrid produced significantly higher grain yield of 5198 kg ha^{-1} and was on par with CSH-25 which yielded 4903 kg ha^{-1} and lowest yield was recorded with CSH-14 which yielded 4607 kg ha^{-1}. The role of light part of solar spectrum in photosynthesis with MAHALAKSHMI hybrid is more predominant which might be due to excitation of chlorophyll by light which culminated in better synthesis of ATP and NADPH by this hybrid. In addition, the chloroplasts which contain the specialized light absorbing green pigments in chlorophyll of this hybrid may have responded to light intensities during the vegetative and reproductive growth of the hybrid. This process ultimately resulted in higher seed yield of this hybrid when sown on 2nd fortnight of September (Taiz and Zeiger 2003). Similar findings were reported by Karhale *et al.* (2014); Rao *et al.* (2008); Maurya *et al*. (2012); Dera *et al*. (2016); Borker *et al*. (2019). Stover yield followed similar trend with 9109 kg ha^{-1} recorded with 2nd fortnight of September (D_1) and was on par with 1st fortnight of October sown crop (8454 kg ha^{-1}) and significantly superior to 2nd fortnight of October (7574 kg ha^{-1}) sown crop. However, lowest stover yield was recorded when sorghum was sown during 1st fortnight of November (7544 kg ha^{-1}).

Growing Degree Days (GDD): GDD required by the crop to attain the growth stages were given in Table 2. The highest GDD was accumulated with 2nd fortnight of September (D_1) (2566 °C day) sown crop followed by 1st fortnight of October (D_2) (2496°C day) sown crop which might be due to longer crop duration and higher temperatures (Murthy 1999, 2015; Agarwal and Upadhyay 2009). Among the hybrids of sorghum, MAHALAKSHMI accumulated higher GDD for vegetative (624°C day), reproductive (1208°C day) and maturity (1143°C day) stages which may be due to higher number of growth days. The use of Growing Degree Days (GDD) to predict crop development because of variation in daily minimum and maximum temperature. The time period necessary to reach that GDD is function of variation in daily maximum and minimum temperature throughout the growing season, therefore may depend on planting date. Decrease in GDD in later sowings was observed due to increase in temperatures at the stages of crop. The results are in line with Praveen *et al*. (2020); Haider *et al.* (2003); Poornima *et al.* (2008); Poornima *et al.* (2010); Bhaviskar *et al*. (2017); Subramanyam *et al.* (2018).

Helio Thermal Units (HTU): Accumilated Helio thermal units are presented in Table 3. The accumulated mean HTU at vegetative stage ranged from 1195 to 2502°C day hr and at maturity phases ranged from 9950 to 14360°C day hr for different dates of sowing. Among the dates of sowing the highest HTU was recorded with 2nd fortnight of September (D_1) (14360 °C day hr) in all hybrids under study. The values of total HTU gradually decreased under delayed sowing. Among the hybrid CSH-25 and MAHALAKSHMI accumulated highest HTU. Delay in sowing reduced the accumulated healiothermal units in the later stages of crop growth. The similar findings were reported by Baviskar *et al*., (2017); Subramanyam *et al*. (2018); Poornima *et al.* (2010); Praveen *et al*. (2020).

Photo thermal units (PTU): The photo thermal units for different phenophases are presented in Table 4 and revealed that the accumulated photo thermal units (PTU) from vegetative to maturity ranged from 7029 to 11939°C day hr for different hybrids at different dates of sowing. With reference to total PTU accumulation, 2nd fortnight of September (D_1) (28232°C day hr) and among the hybrids MAHALAKSHMI recorded highest PTU values at all growth stages (8824, 9212 and 12712°C day hr), which might be due to the higher crop duration along with the higher day length and GDD. These results are in conformity with the findings of Padma and Subbaiah (2008); Murthy (2016); Prajapat *et al*. (2018); Akhter *et al*. (2015). Mostly sorghum crop was sensitive to photoperiod and are classified as short day plants in other words, the night must be longer than a critical minimum. Photoperiod sensitive cultivars have a terminal vegetative bud that remains vegetative until days shorten enough to initiate its differentiation into a floral bud. This initiation happens at a critical photoperiod, namely, when the day length is short enough to initiate flowering, but not long enough to prevent it. These are the reasons for differentiations in accumulated PTUs (Murthy, 2016). The results are in line with Praveen *et al.* (2020).

Thermo photo ratio (TPR): The calculated TPR from vegetative to maturity ranged from 54 to 224 for different dates of sowing in different hybrids (Table 5). Among the sowing dates, 2nd fortnight of September (D_1) recorded the highest (224) TPR with MAHALAKSHMI followed by CSH-25 (217) when sown on 1st fortnight of November (D_4). The lowest TPR of 200 were accumulated with the CSH-14 hybrid on 1st fortnight of November (D_4). With regard to hybrids, CSH-25 recorded the highest TPR (224) values compared to other hybrids. The results are in line with Borkar *et al.* (2019).

Relationship between Total Drymatter/Seed Yield and Weather Health Indices for different Sorghum Hybrids. Linear regression equations were obtained between agroclimatic indices/weather health indices *viz.,* GDD, HTU, PTU and TPR (Table 6 and Fig. 1-4) as independent variables and seed yield as dependent variables for three sorghum hybrids at four dates of sowing and presented in Table 6. The results were drawn by taking yield and dry matter as the independent variable and weather parameters as dependent variable. The results are in line with Raghuvanshi *et al.* (2021); Al-Salim *et al.* (2017).

Table 1: Grain yield (kg ha^{-1}) and Stover yield (kg ha^{-1}) of sorghum as influenced by dates of sowing and hybrids.

Treatments	Grain yield	Stover yield
Hybrids (V)		
(V_1) CSH-14	4607	6967
(V_2) MAHALAKSHMI	5198	9432
(V_3) CSH-25	4903	8112
SEm±	141.0	480
CD (0.05)	413.5	1406
Dates of sowing (D)		
(D_1) 2nd fortnight of September	5162	9109
(D_2) 1st fortnight of October	5082	8454
(D_3) 2nd fortnight of October	4839	7574
(D_4) 1st fortnight of November	4526	7544
SEm±	162.8	415
CD (P=0.05)	477.5	1218
Interaction (D x V)		
SEm±	141.0	830.7
CD (P=0.05)	NS	NS
CV (%)	9.9	17.6

Table 2: Accumulated Growing degree days (GDD) during different phenophases of sorghum hybrids at different dates of sowing (data statistically not analyzed).

Growing degree days (°C day)					
Growth stages	**Dates of sowing**				**Mean**
	(D_1) 2nd fortnight of September	**(D_2) 1st fortnight of October**	**(D_3) 2nd fortnight of October**	**(D_4) 1st fortnight of November**	
CSH-14 (V_1)					
Vegetative phase	330	559	328	331	387.83
Reproductive phase	1155	974	902	836	967.16
Maturity	975	948	937	918	944.50
Total	2424	2314	2251	2206	
MAHALAKSHMI (V_2)					
Vegetative phase	624	355	435	487	475.71
Reproductive phase	1208	901	850	764	930.77
Maturity	1143	1074	1017	1002	1059
Total	2566	2492	2410	2395	
CSH-25 (V_3)					
Vegetative phase	646	379	371	371	442.41
Reproductive phase	1165	983	918	809	968.75
Maturity	997	977	932	952	964.5
Total	2496	2388	2331	2288	

Table 3: Accumulated Helio thermal units (HTU) during different phenophases of sorghum hybrids at different dates of sowing (data statistically not analyzed).

Helio thermal units (°C day hour)					
Growth stages	Dates of sowing				Mean
	(D_1) 2nd fortnight of September	(D_2) 1st fortnight of October	(D_3) 2nd fortnight of October	(D_4) 1st fortnight of November	
CSH-14					
Vegetative phase	1637	1614	1369	1195	1454.3
Reproductive phase	4828	4683	4591	4458	4640.4
Maturity	6073	5328	4826	4529	5189.2
Total	13493	12419	1002	9950	
MAHALAKSHMI					
Vegetative phase	2502	2171	1603	1267	1885.7
Reproductive phase	5059	4847	4325	3726	3224.5
Maturity	7613	6397	5393	5012	6103.7
Total	14360	12576	10710	10217	
CSH-25					
Vegetative phase	2347	1781	1530	1508	1791.5
Reproductive phase	5045	4055	4703	4529	4583.1
Maturity	6669	5672	5122	4640	5525
Total	14360	13042	11760	10852	

Table 4: Accumulated Photothermal units (PTU) during different phenophases of sorghum hybrids at different dates of sowing (data statistically not analyzed).

Photo thermal units (°C day hour)					
Growth stages	Dates of sowing				Mean
	(D_1) 2nd fortnight of September	(D_2) 1st fortnight of October	(D_3) 2nd fortnight of October	(D_4) 1st fortnight of November	
CSH-14(V_1)					
Vegetative phase	8052	7585	7029	7029	7421
Reproductive phase	8440	7549	7095	6060	7286
Maturity	1118	10637	10329	10174	10580
Total	26668	25463	24762	24273	
MAHALAKSHMI(V_2)					
Vegetative phase	8824	7817	7519	7280	7860
Reproductive phase	9212	7468	7002	6883	7641
Maturity	12712	11993	11939	9855	11624
Total	28232	27412	26514	26349	
CSH-25(V_3)					
Vegetative phase	8319	7817	7280	7280	7672
Reproductive phase	8174	7772	7240	6262	7362
Maturity	11629	11128	10971	10685	11103
Total	27465	26274	25649	25172	

Table 5: Accumulated Thermo photo ratio (TPR) during different phenophases of sorghum hybrid at different dates of sowing (data statistically not analyzed).

Thermo photo ratio (°C day $hour^{-1}$)					
Growth stages	Dates of sowing				Mean
	(D_1) 2nd fortnight of September	(D_2) 1st fortnight of October	(D_3) 2nd fortnight of October	(D_4)) 1st fortnight of November	
CSH-14 (V_1)					
Vegetative phase	64.29	62.68	58.09	54.91	59.9
Reproductive phase	69.76	62.39	58.64	53.27	61.0
Maturity	105.72	97.04	75.06	72.39	87.2
Total	213.90	213.77	206.44	200.13	
MAHALAKSHMI (V_2)					
Vegetative phase	66.49	64.60	60.17	56.79	63.5
Reproductive phase	65.27	64.23	60.66	55.13	61.0
Maturity	111.48	103.61	92.53	91.17	88.4
Total	224.44	224.29	223.40	220.82	
CSH-25 (V_3)					
Vegetative phase	70.67	62.14	64.60	56.79	62.1
Reproductive phase	66.99	64.23	57.87	55.13	61.3
Maturity	105.67	95.48	79.88	72.65	99.6
Total	217.59	215.49	210.31	208.71	

Table 6: Relationship between grain yield and GDD, HTU, PTU and TPR for different sorghum hybrids.

Hybrids	Regression equation	Coefficient of determination (R^2)
	GY and GDD	
CSH-14	TDM=-40132.7+21.8GDD	0.83*
MAHALAKSHMI	TDM=-40329.6+21.81GDD	0.92*
CSH-25	TDM = -3404.8+ 7.07GDD	0.87*
	GY and HTU	
CSH-14	GY =9372.02-0.422HTU	0.54*
MAHALAKSHMI	GY = 6401.56-0.11HTU	0.91*
CSH-25	GY =11448.89-0.50HTU	0.75*
	GY and PTU	
CSH-14	GY = 12631+0.6607PTU	0.66*
MAHALAKSHMI	GY = 2098.36+0.111PTU	0.94*
CSH-25	GY = -5681.13+0.40PTU	0.81*
	GY and TPR	
CSH-14	GY= -12927+81.28TPR	0.67*
MAHALAKSHMI	GY =2098.36+13.45TPR	0.94*
CSH-25	GY = -9126.9+65.201TPR	0.92*

* Significant

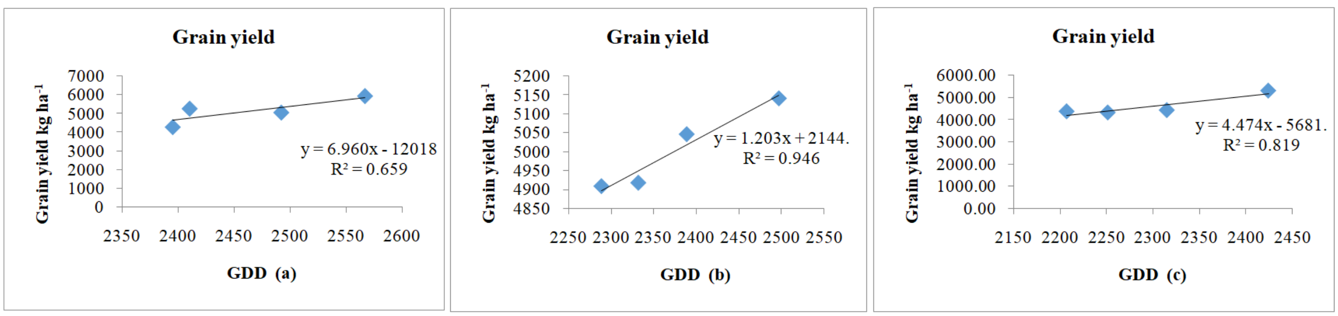

Fig. 1. Relationship between Grain yield (kg ha^{-1}) and growing degree days (a) CSH-14 (b) Mahalakshmi (c) CSH-25.

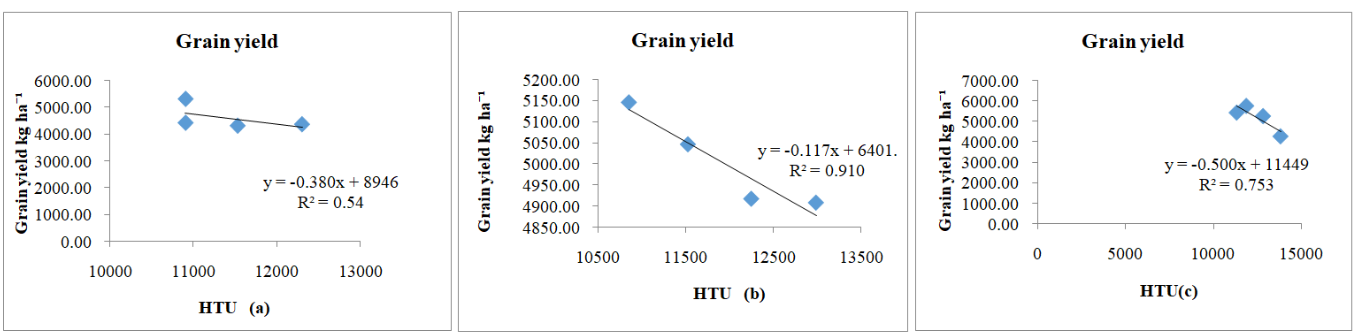

Fig. 2. Relationship between Grain yield (kg ha^{-1}) and heliothermal units (a) CSH-14 (b) Mahalakshmi (c) CSH-25.

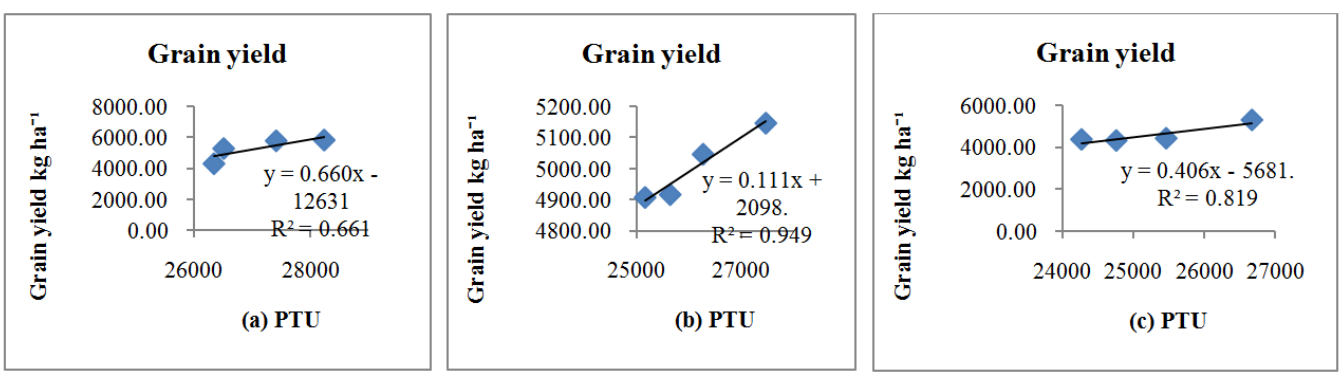

Fig. 3. Relationship between Grain yield (kg ha^{-1}) and Photothermal units (a) CSH-14 (b) Mahalakshmi (c) CSH-25.

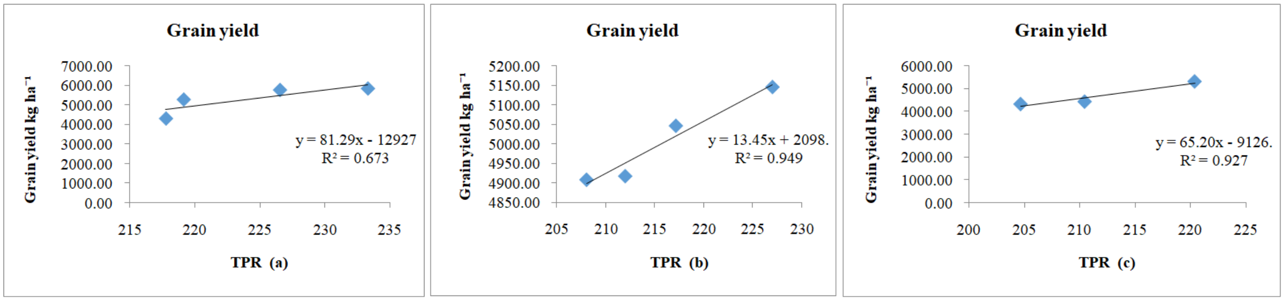

Fig. 4. Relationship between Grain yield (kg ha^{-1}) and ThermoPhoto Ratio (a) CSH-14 (b) Mahalakshmi (c) CSH-2.

CONCLUSION AND FUTURE SCOPE

From the study it can be concluded that time of sowing and selection of a hybrid suitable for the season play a critical role in accumulation of heat units to bring out quality produce. Identification of the sowing window by thermal approach helps in mitigating the impact of climate change. Early sown crop has an advantage of optimizing the climate stress, while late sown may succumb to environmental disturbances. Sowing of rabi sorghum hybrid MAHALAKSHMI during 2nd fortnight of September recorded better yields by accumulating higher GDD, HTU, PTU and TPR.

Future study can be made on influence of weather indices on crops by developing a suitable meterological model and also step down regression analysis of the data helps in identifying the major factors effecting the growth and yield of crop. Adoption of green house gas estimation during the crop period is a thought full idea towards studying the climate change.

Conflict of Interest. None.

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