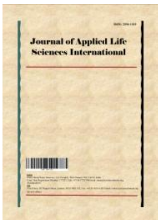

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Crop Weather Relationships of Fodder Sorghum Varieties under Different Sowing Times in Southern Agro Climatic Zone of Andhra Pradesh

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Field experiment was carried out during summer, 2018 at S. V. Agricultural College, Tirupati, Acharya N. G. Ranga Agricultural University to study the crop weather relationship of fodder sorghum varieties under different times of sowing. The experiment was in four dates of sowing (I Fortnight of January, II Fortnight of January, I Fortnight of February and II Fortnight of February) with varieties (CSV 21 F, CSV 30 F and CSV 32 F). Results are revealed that among the four times of sowing, different meteorological indices GDD, HTU, PTU, and TUE varied across the different growth stages. Early sowing (I Fortnight of January) had favorable agro-climatic conditions particularly temperature, day length and sunshine hours interms of required accumulation of GDD, PTU and HTU from sowing to harvest compared to other dates of sowing. Total requirement of accumulated GDD, HTU and PTU showed increasing trend with extension of sowing time from I Fortnight of January to II Fortnight of February. The CSV 32 F variety accumulated maximum GDD from sowing to until harvest.

Keywords: Times of sowing; GDD; PTU; HTU.

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1. INTRODUCTION

In India, animal husbandry is closely associated with crop production as a complementary enterprise, possessing the largest livestock population of 512 million heads [1]. The availability of quality feed and fodder has been considered as the major bottleneck in harnessing the potential of the livestock sector in India. Further increasing area under fodder crops is not possible in the country due to lot of demand for food grain to meet the facing hardship for feeding the burgeoning human population. Increasing the fodder yield per unit area is with introduction of high yielding, better quality fodder varieties with suitable location specific agronomic practices. The only way to enhance the fodder production under the existing situation.

Sorghum is an important widely grown forage crop for dairy animals. It is fast growing, quick in recovery after cutting, palatable, nutritious and utilized as silage and hay besides fresh feeding. Sorghum crop is adaptive to vast environmental conditions in India and as well as in Chittoor district. Seasonal variation in production of fodder results in large gap between demand and supply of green fodder during crucial periods of the year such as summer. Development of location specific agrotechniques and identification of good quality genotypes of sorghum offer an excellent opportunity to provide good quality fodder for better nutrition to bovine population.

Among agronomic manipulations, sowing time and suitable cultivars are considered to be important for increased production potentials of fodder sorghum. The sowing time of the sorghum affects the fodder supply to considerable extent and hence, proper sequencing of the sowing time should be done in order to achieve maximum fodder yield along with maintaining the regular supply of the green fodder. The identification of genotype for enhanced productivity and quality during summer to mitigate the present shortage of fodder requirement in summer season.

The critical agrometeorological variables associated with agricultural production are precipitation, air temperature and solar radiation [2]. Phenological development of crop closely followed the changes in weather conditions occurring during crop growing period. The variation in planting dates modifies the microclimate to which the plants are exposed and it is responsible for biomass production and ultimately the yield. It is necessary to understand the knowledge of plant environment interaction for increasing yield of crop. The best genotype with suitable sowing time lead to changes in the crop microclimate which has a direct influence on the plant growth and development and resource utilization. Keeping above factors in view, the present experiments were designed to study the crop weather relationships (interactions) in fodder sorghum under different sowing windows and varieties.

2. MATERIALS AND METHODS

A field experiment entitled "Optimization of Sowing Window for Summer Fodder Sorghum [*Sorghum bicolor* (L.) Moench] Cultivars" was carried out during summer, 2018 on sandy loam soils of dryland farm of S.V. Agricultural College, Tirupati, Acharya N.G. Ranga Agricultural University. The experiment was laid out in a split plot design and replicated thrice. The treatments consisted of four times of sowing *viz.,* I Fortnight of January, II Fortnight of January, I Fortnight of February and II Fortnight of February assigned to main plots and three fodder sorghum varieties *viz.,* CSV 21 F, CSV 30 F and CSV 32 F assigned to subplots.

Agro meteorological indices developed by utilizing various meteorological elements are found in literature to study the crop weather relationships. Agrometeorological indices like Growing Degree Days (GDD), Heliothermal Units (HTU), Photothermal Units (PTU) and Thermal use efficiency (TUE) were computed during different phenophases of sorghum (by adopting the procedure laid out by Rajput [3].

2.1 Growing Degree Days (GDD)

A degree day is the difference between the mean temperature of the day and base temperature. It is a weather based indicator for assessing crop development. It is a measure of heat accumulation used to predict plant developmental rates such as date that crop reaches maturity. Base temperature of 10°C was used for computation of GDD on daily basis for sorghum [4].

$$\text{Growing degree days (°C)} = \sum \frac{Tmax + Tmin}{2} - T_b$$

Where,

Tmin = minimum temperature (°C),

Tmax= maximum temperature (°C) and
Tb = Base temperature = 10°C

2.2 Helio Thermal Units (HTU)

The helio thermal units for a given day represent the product of GDD and the actual hours of bright sun shine for that day. The sum of the HTU for the duration of each phenophase was determined by using the formula.

Accumulated HTU (°C day hour) = GDD × Duration of sunshine hour

2.3 Photo Thermal Units (PTU)

The photo thermal units for each day represent the product of GDD and the day length. The accumulated PTU for each phenophase was determined by the following formula.

Accumulated PTU (°C day hour) = GDD × Day length hour

2.4 Thermal Use Efficiency (TUE)

Thermal Use Efficiency for biomass yield was calculated using the following formula.

TUE (kg ha^{-1} °C day^{-1}) = Biomass yield / GDD

3. RESULTS AND DISCUSSION

3.1 Weather Parameters

The data pertaining to weather parameters recorded during the crop growth period of fodder sorghum as influenced by times of sowing and varieties are presented in Table 2. The variation in climate is especially related to solar radiation, day length, relative humidity, rainfall and temperature.

The temperature maximum and minimum increased by 4.8 and 5.3°C respectively during the crop growth period of fodder sorghum when sowing was extended from I FN of January to II FN of February. Similarly the morning relative humidity was reduced by 5 per cent when sowing was delayed to II FN of February. Daily evaporation was 5.6 mm during the crop growth period of I FN of January sown crop. It steadily increased with delayed sowing and reached maximum of 6.8 mm when the crop was sown during II FN of February. The duration of sunshine reduced from 8.5 hours day^{-1} to 7.9 hours day^{-1} with extended times of sowing from I FN of January to II FN of February. Significant increase or decrease was not observed in other weather parameters.

3.2 Growing Degree Days

The crop sown during I FN of January and I FN of February accumulated 104.3 and 102.1 growing degree days respectively for emergence of seedlings. The degree day accumulation was reduced when sowing was delayed and the crop sown very late during II FN of February required 91.6 growing degree days for its emergence. The degree day accumulation from emergence to 4^{th} leaf stage was chiefly influenced by the adopted times of sowing. The crop sown during II FN of February accumulated maximum growing degree days (216.4°C days) followed by II FN of January (190.5°C days). The crop sown during I FN of February (157°C days) and I FN of January (155.3°C days) was exposed to least accumulation of GDD during this corresponding stage. The requirement of accumulated growing degree days to attain subsequent stage of Panicle initiation was gradually increased (187.0 to 331.1°C days) with extended times of sowing from I FN of January to II FN of February and the crop sown during II FN of February accumulated maximum GDD (331.1°C days) for panicle initiation. The trend was continued during the later stage of booting also. The GDD accumulation during 50 per cent flowering was remarkably influenced by the times of sowing and the crop was exposed to maximum of 224.2 growing degree days when it was sown very late during II FN of February. The accumulation of degree days (151.2°C days) during this corresponding period observed steep reduction with sowing of crop during II FN of January. The total requirement of accumulated growing degree days showed increasing trend (1021.8 to 1359.5°C days) with extension of sowing time from I FN of January to II FN of February. These results are in consonance with the findings of Ahmad et al. [5], Prakash et al. [6].

Among the varieties tested, CSV 21F accumulated maximum growing degree days for emergence. CSV 30 F and CSV 32 F were exposed to maximum growing degree days at 4^{th} leaf and booting stages. The CSV 32 F variety required maximum degree day accumulation during Panicle initiation and 50 percent flowering. However, the variety CSV 30 F required maximum degree day accumulation at panicle initiation under late sown conditions. The total growing degree day accumulation was exceptionally influenced by the tested varieties and CSV 32 F variety recorded maximum growing degree day accumulation from sowing to until harvest. The above results were in conformity with the findings of Hemalatha et al. [7], Prakash et al. [6].

3.3 Helio Thermal Units

The crop sown during I FN of January I FN of February and II FN of February required 878.2, 811.6 and 869.2°C day hours respectively for emergence of seedlings. The HTU requirement was reduced to 603.4 when crop was sown during II FN of January. The HTU requirement from emergence to 4th leaf stage was chiefly influenced by the adopted times of sowing.

The crop sown during II FN of February required maximum HTU (1637.9°C day hours) followed by II FN of January (1510.7°C day hours). The crop sown during I FN January required least accumulation of HTU (1361.8) during this corresponding stage. The accumulated HTU to attain subsequent stage of Panicle initiation was gradually increased with extended times of sowing from I FN of January to II FN of February (1535 to 2467.5°C day hours) and the crop sown during II FN of February accumulated maximum HTU (2467.5°C day hours) for panicle initiation. The crop sown very late during II FN of February was exposed to maximum HTU (4169.7°C day hours) during subsequent stage of booting followed by I FN of February (3672.7°C day hours). The HTU requirement during 50 per cent flowering was remarkably influenced by the times of sowing and the crop sown during I FN of February was exposed to maximum HTU (1764.6°C day hours) followed by II FN of February (1456°C day hours). The accumulation of HTU during this corresponding period observed steep reduction with sowing of crop during II FN of January (1045.6°C day hours). The total requirement of HTU showed decreasing trend with extension of sowing time from I FN of January to II FN of February.

The HTU required for the advancement of the crop through different stages to attain final harvest stage was remarkably influenced by the tested varieties. CSV 21 F required maximum HTU for emergence. CSV 30 F and CSV 32 F were exposed to maximum HTU at 4th leaf and booting stages. The CSV 32 F variety required maximum HTU during Panicle initiation and 50 percent flowering. However, the variety CSV 30 F required maximum HTU under late sown conditions. The total HTU requirement was exceptionally influenced by the tested varieties and CSV 32 F variety recorded maximum HTU accumulation from sowing to until harvest. However, the variety CSV 30 F required maximum HTU under late sown conditions. This investigation corroborates with the findings of Thavaprakash et al. [8], Prakash et al. [6].

3.4 Photo Thermal Units

The crop sown during I FN of January and I FN of February required 1329.7, and 1284.3 PTU respectively for emergence of seedlings. The PTU requirement was reduced to 1131.5°C day hours when crop was sown very late during II FN of February. The PTU requirement from emergence to 4thleaf stage was chiefly influenced by the adopted times of sowing. The crop sown during II FN of February required maximum PTU (2653.1°C day hours) followed by II FN of January (2397°C day hours). The crop sown during I FN February required least accumulation of PTU (1930.3°C day hours) during this corresponding stage. The accumulated PTU to attain subsequent stage of Panicle initiation was gradually increased with extended times of sowing from I FN of January to II FN of February (2354.4-3991.0°C day hours) and the crop sown during II FN of February accumulated maximum PTU (3991.0°C day hours) for panicle initiation. The crop was exposed to maximum PTU during the subsequent stage of booting when sowing was delayed to I and II FN of February. The PTU requirement during 50 per cent flowering was remarkably influenced by the times of sowing and the crop sown during II FN of February was exposed to maximum PTU (2597.0°C day hours) followed by I FN of January (2405.4°C day hours). The accumulation of PTU (1806.4) during this corresponding period observed steep reduction with sowing of crop during II FN of January. The total requirement of PTU showed increasing trend with extension of sowing time from I FN of January to II FN of February (12733-16282.8°C day hours). These results are in line with the earlier findings as reported Thavaprakash et al. [8], Maurya et al. [9].

The PTU required for the advancement of the crop through different stages to attain final harvest stage was remarkably influenced by the tested varieties. CSV 21 F required maximum PTU for emergence. CSV 30 F and CSV 32 F were exposed to maximum PTU at 4th leaf and booting stages. CSV 21 F required maximum PTU (2621.0) leaf at 4th leaf stage under delayed sown conditions. The CSV 32 F variety required maximum PTU during Panicle initiation and 50 percent flowering. The total PTU requirement was exceptionally influenced by the tested varieties and CSV 32 F variety recorded maximum PTU accumulation from sowing to until harvest. However, the variety CSV 30 F required maximum PTU (4558.8) under late sown conditions. This investigation corroborates with the findings of Prakash et al. [6].

3.5 Thermal Use Efficiency

Variation in thermal use efficiency was significant during all the dates of sampling due to adopted times of sowing. The crop sown early during I FN of January recorded maximum thermal use efficiency (1.27 g m^{-2} °C day^{-1}) than the crop sown at later dates. The thermal use efficiency was progressively and significantly reduced with extended date of sowing from I FN of January to II FN of February (1.27- 0.71 g m^{-2} °C day^{-1}) where as lowest values of thermal use efficiency (0.71 g m^{-2} °C day^{-1}) were registered when sowing of the crop was delayed to II FN of February.

Among the fodder sorghum varieties tried, the highest thermal use efficiency was recorded by CSV 32 F which superior over rest of varieties. The variety CSV 21 F recorded the lower values of thermal use efficiency.

3.6 Fodder Yield

The data on green and dry fodder yield presented in Table 1 indicated that crop sown during I fortnight of January recorded the maximum green and dry fodder yield which was comparable with crop sown on II fortnight of January. Sowing of the crop at later dates recorded the lower green fodder yields.

Optimum temperature and shorter day length resulted in higher dry fodder yield via optimum metabolic activities and thereby the early sown plants of all varieties had been recorded higher thermal use efficiency. Whereas higher temperatures, lower relative humidity and higher evaporation rates hampered the normal metabolic activities resulting in lower fodder yield as well as lower thermal use efficiency in late sown crop. Among the varieties, irrespective of sowing date CSV 32 F recorded maximum thermal use efficiency than rest of the varieties. It might be attributed to accumulation of more drymatter production due to long duration [10].

Table 1. Green fodder yield (t ha^{-1}) and dry fodder yield (t ha^{-1}) of fodder sorghum varieties as influenced by times of sowing

Treatments	Green fodder yield (t ha^{-1})	Dry fodder yield (t ha^{-1})
Times of sowing		
I FN of January	35	14
II FN of January	33	13
I FN of February	29	12
II FN of February	25	10
SEm±	1.3	0.4
CD (P= 0.05)	4.5	1.4
Varieties		
CSV 21 F	24	10
CSV 30 F	30	12
CSV 32 F	36	14
SEm±	0.9	0.3
CD (P= 0.05)	2.8	0.8
Times of sowing x Varieties		
S at M		
SEm±	1.88	0.53
CD (P= 0.05)	NS	NS
M at S		
SEm±	2.01	0.58
CD (P= 0.05)	NS	NS

Table 2. Mean weather parameters recorded during the crop growth period of fodder sorghum as influenced by time of sowing and varieties

	Temperature (°C)			Relative humidity (%)			Wind velocity	Bright sun shine	Rainfall	Evaporation
	Maximum	Minimum	Mean	RH I	RH II	Mean	KMPH	hr	(mm)	(mm)
S1 : I Fortnight of January (12.01.2018)										
V1	32.1	16.3	24.2	86	37	61	4.6	8.7	28.4	5.6
V2	32.6	17.2	24.9	86	38	62	4.5	8.4	41.2	5.6
V3	32.8	17.5	25.1	85	38	61	4.5	8.4	41.2	5.6
Mean	32.5	17.0	24.7	85	37	61	4.5	8.5	36.9	5.6
S2: II Fortnight of January (27.01.2018)										
V1	33.4	17.9	25.7	85	35	60	4.4	8.4	41.2	5.9
V2	33.9	18.9	26.4	84	36	60	4.4	8.3	41.2	6.0
V3	33.9	19.0	26.5	84	36	60	4.4	8.3	41.2	6.0
Mean	33.7	18.6	26.2	84	36	60	4.4	8.3	41.2	5.9
S3: I Fortnight of February (10.02.2018)										
V1	34.7	20.0	27.4	83	36	60	4.3	8.2	0.2	6.3
V2	35.2	20.8	28.0	82	36	59	4.4	8.3	12.8	6.5
V3	35.4	21.0	28.2	82	36	59	4.4	8.3	15.0	6.5
Mean	35.1	20.6	27.9	83	36	59	4.4	8.3	9.3	6.4
S4 : II Fortnight of February (26.02.2018)										
V1	36.5	22.4	29.4	80	35	58	4.2	8.1	15.0	6.8
V2	36.9	23.1	30.0	80	36	58	4.3	7.8	99.2	6.8
V3	36.9	22.9	29.9	81	36	58	4.3	7.8	99.2	6.9
Mean	36.8	22.8	29.8	80	36	58	4.3	7.9	71.1	6.8

Table 3. Agro meteorological indices at different growth stages of fodder sorghum as influenced by time of sowing and varieties

	Sowing to emergence			4^{th} leaf stage			Panicle initiation stage		
I FN of January	**GDD**	**HTU**	**PTU**	**GDD**	**HTU**	**PTU**	**GDD**	**HTU**	**PTU**
CSV 21 F	119.2	1012.3	1519.1	149.9	1304.3	1903.7	144.7	1190.9	1821.7
CSV 30 F	96.9	811.1	1235.0	160.6	1390.6	2041.8	186.2	1516.8	2344.1
CSV 32 F	96.9	811.1	1235.0	160.6	1390.6	2041.8	230.2	1900.0	2897.4
Mean	104.3	878.2	1329.7	157.0	1361.8	1995.8	187.0	1535.9	2354.4
II FN of January									
CSV 21 F	109.9	1018.2	1392.2	183.4	1440.4	2306.7	171.5	1088.5	2131.3
CSV 30 F	98.0	905.1	1242.4	195.3	1553.4	2456.5	203.3	1937.8	2522.4
CSV 32 F	87.0	795.1	1103.9	192.9	1538.3	2427.8	232.0	2214.9	2876.2
Mean	98.3	603.4	1246.2	190.5	1510.7	2397.0	202.2	1747.0	2509.9
I FN of February									
CSV 21 F	121.3	988.9	1522.5	156.2	1491.5	1941.1	188.1	1698.1	2309.1
CSV 30 F	92.6	723.0	1165.1	154.9	1497.8	1924.9	255.9	2107.4	3146.2
CSV 32 F	92.6	723.0	1165.1	154.9	1497.8	1924.9	294.9	2368.9	3622.0
Mean	102.1	811.6	1284.3	155.3	1495.7	1930.3	246.3	2058.1	3025.8
II FN of February									
CSV 21 F	107.5	1028.2	1326.7	217.8	1555.9	2667.7	279.2	2132.4	3370.7
CSV 30 F	91.3	865.7	1127.2	217.8	1651.8	2670.7	378.9	2807.8	4558.8
CSV 32 F	76.1	713.7	940.5	213.5	1706.1	2621.0	335.2	2462.4	4043.6
Mean	91.6	869.2	1131.5	216.4	1637.9	2653.1	331.1	2467.5	3991.0

	Booting stage			50 per cent flowering stage			Total		
I FN of January	**GDD**	**HTU**	**PTU**	**GDD**	**HTU**	**PTU**	**GDD**	**HTU**	**PTU**
CSV 21 F	323.9	3000.6	4024.0	323.9	3000.6	4024.0	323.9	3000.6	4024.0
CSV 30 F	403.5	3713.7	4992.2	403.5	3713.7	4992.2	403.5	3713.7	4992.2
CSV 32 F	377.5	3416.8	4661.4	377.5	3416.8	4661.4	377.5	3416.8	4661.4
Mean	368.3	3377.0	4559.2	368.3	3377.0	4559.2	368.3	3377.0	4559.2
II FN of January									
CSV 21 F	354.4	1111.7	4331.2	120.1	639.8	1451.5	939.2	7772.6	11612.9
CSV 30 F	485.5	3734.3	5909.7	167.7	1211.5	1996.6	1149.6	9342.2	14127.6
CSV 32 F	513.2	3850.8	6237.9	166.0	1285.5	1971.9	1190.1	9684.6	14617.7
Mean	451.0	2899.0	5492.9	151.2	1045.6	1806.7	1093.0	8933.1	13452.7

	Booting stage			50 per cent flowering stage			Total		
I FN of February									
CSV 21 F	412.4	2885.5	4983.6	164.6	1362.7	1955.2	1042.4	8426.8	12490.5
CSV 30 F	519.8	3920.2	6244.8	215.7	1974.1	2545.9	1238.6	10222.4	15062.9
CSV 32 F	541.3	4212.3	6489.1	224.8	1957.1	2641.7	1308.4	10759.1	15842.8
Mean	491.1	3672.7	5905.8	201.7	1764.6	2380.9	1196.5	9802.8	14465.4
II FN of February									
CSV 21 F	401.0	3433.7	4747.7	161.5	1193.6	1888.5	1165.8	9343.9	14001.2
CSV 30 F	546.7	4613.6	6431.9	245.0	1519.8	2825.6	1479.5	11458.1	17699.8
CSV 32 F	542.2	4461.7	6396.1	266.2	1654.5	3077.0	1433.1	10998.3	17147.3
Mean	496.6	4169.7	5858.6	224.2	1456.0	2597.0	1359.5	10600.1	16282.8

4. CONCLUSIONS

It can be concluded that early sowing (I FN of January) had favorable agro-climatic conditions particularly temperature, day length and sunshine hours interms of required accumulation of Growing degree days, Photo thermal units and Helio thernal units from sowing to harvest compared to other dates of sowing. Estimation of growing degree days, helio thermal units, photo thermal units and thermal use efficiency indicated that the I Fortnight of January is more suitable for sowing of the fodder sorghum to explore full benefits of favourable weather conditions for best economic output.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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