Optimization of sowing window for summer fodder sorghum cultivars by thermo radiation requirements under southern agro climatic zone of Andhra Pradesh in India

~~1.~~

~~2.~~ **ABSTRACT**

Field experiment was conducted during summer season, 2018 on sandy loam soils of dryland farm of S.V. Agricultural College, Tirupati, Acharya N.G. Ranga Agricultural University to study radiation use efficiency of fodder sorghum crop. The experiment was in four times of sowing *viz.*, I FN of January, II FN of January, I FN of February and II FN of February with three fodder sorghum varieties *viz.*, CSV 21 F, CSV 30 F and CSV 32 F. Efficiency of thermal and radiation energy conversion into dry biomass was computed using thermal and radiation indices. Results obtained during study revealed that early planting of crop CSV 32 F resulted in higher thermal use efficiency and radiation use efficiencies with higher fodder yield compared to delayed sowings. The correlation studies between RUE and TUE to LAI, dry matter accumulation and green fodder yield showed ~~that~~ a significant positive linear relationship. The regression coefficients between meteorological indices *v iz.*, RUE and TUE and crop parameters *viz.*, LAI, dry matter production, green fodder yield were significantly influenced by varieties at varied times of sowing. Conversion efficiency of radiation and thermal energy to accumulation of drymatter varied much with times of sowing and varieties.

~~3.~~ ***Key words***: Fodder sorghum, RUE, TUE, times of sowing, varieties

~~4.~~ **1- INTRODUCTION**

Forages and livestock are ~~the~~ an integral part of the Indian agricultural system. Andhra Pradesh supports 59.8 million heads of livestock and ranks seventh in milk

Formatted: Indent: Left: 0.63 cm, No bullets or numbering

Commented [Gh1]: Please delete numbering for abstract and keyword

Commented [Gh2]: Add a before significant

Commented [Gh3]: Please remove space here

Formatted: Indent: Left: 1.11 cm, No bullets or numbering

Commented [Gh4]: Use an

production. Dairy has become a vital component of farming systems in Chittoor district of Southern Agro Climatic Zone of Andhra Pradesh holding the first rank in milk production and is widely known as "Andhra's Anand". The rapid expansion of dairy industry coupled with an acute shortage of green fodder during summer necessitates grappling with growing demand.

Sorghum [*Sorghum bicolor* (L.) Moench] belonging to the family Poaceae, is an important forage crop which is widely grown to meet the green as well as dry fodder requirement of the livestock. In fodder sorghum variation in sowing date modifies the radiative and thermal conditions during its growth. When crop is grown under well-supplied water and nutrient conditions, the temperature and solar radiation are reported to have greater effect on growth and development of crop. Heat and radiation use efficiencies in terms of dry matter or yield are important aspects, which have great practical application. (Rani *et al.*, 2012).

The knowledge on the calculation of, Thermal use efficiency (TUE) and Radiation use efficiency are the basic principles to understand the phenology of crop and to identify the proper time of sowing for different genotypes over temporal and spatial distributions. The slope of the relationship between cumulative dry matter production and intercepted photosynthetically active radiation is known as radiation use efficiency (RUE). In several studies, large within-species variability of RUE was reported for a number of species grown under adequate moisture and nutrient conditions (Kinry *et al.*, 1989). TUE serves to be effective in taking into account and expressing the effect of varying ambient temperature on the duration and for comparing the crop response to the ambient temperature.

Because of such observations, it was conducted to evaluating the genetic variability in fodder sorghum for RUE and HUE under varied sowing dates.

2. MATERIALS AND METHODS

Commented [Gh5]: The verb should be passive, so add is

Commented [Gh6]: I think "because" shoul be used here

The field experiment was conducted at S.V. Agricultural College Dryland farm, Tirupati, AcharyaN. G. Ranga Agricultural University, Andhra Pradesh, India (13.5°N latitude and 79.5°E longitude, 182.9 m above mean sea level) during the summer season of 2018. The experimental field was sandy loam in texture which is low organic carbon (0.45 %). The soil is neutral in reaction (pH 7.1), low in available N (175 kg ha^{-1}) and medium in available phosphorus (28 kg ha^{-1}) and potassium (204 kg ha^{-1}). Total rainfall received during the crop growth period was 127.6 mm on 6 rainy days. The experiment was laid out in a split-plot design with three replications. The main treatments consisted of four times of sowings *viz.*, I FN of January , II FN of January, I FN of February, and II FN of February. The sub treatments consisted of three fodder sorghum varieties *viz.*, CSV 21 F, CSV 30 F and CSV 32 F.

A uniform recommended dose of 80-40-30 kg N, P_2O_5 and K_2O ha^{-1} was applied to fodder sorghum. The nutrients were applied in the form of urea, single super phosphate, and muriate of potash. One light irrigation was given 5 days after sowing for better establishment of seedlings and thereafter the field was irrigated at 10 days intervals during the crop growth period. The crop was harvested for green fodder purpose at 50 percent flowering in all the varieties.

The thermal use efficiency was computed by adopting the procedure laid out by Rajput (1980) and GDD were computed on daily basis for sorghum (Kumar, 2003).

Thermal Use Efficiency: (kg ha^{-1} °C day^{-1})

TUE =Biomass yield / GDD

Growing degree days (°C) = $\Sigma \frac{Tmax + Tmin}{2} - T_b$ (1)

Where, Tmin = minimum temperature (°C),

Tmax= maximum temperature (°C) and

Commented [Gh7]: Use “on” here

Commented [Gh8]: Please number equations

Tb = Base temperature = 10°C

Radiation Use Efficiency (g MJ^{-1})

The photosynthetically active radiation (PAR) intercepted by the plant canopy in each plot was measured at data intervals with a SunScan Canopy Analysis System (Delta-T Devices, Cambridge, UK). This system measures PAR above and below the canopy simultaneously by using a sunshine sensor. Sunscan device with a 1 m probe that contains 64 PAR sensors is inserted into the canopy at the ground level. The 1m probe was connected with the sunshine sensor using a 25 m cable and was attached to a handheld computer to store the data. The difference between the above and below canopy sensors calculated as the amount of radiation intercepted by the canopy.

The instantaneous PAR values recorded by the instrument were in terms of μ mol m^{-2} s^{-1}. The daily average values of all these observations were computed and converted into M J m^{-2} day^{-1} (Kumar *et al*., 2008).

$$1\ \mu\ mol\ m^{-2}\ s^{-1} = 0.00078261\ M\ J\ m^{-2}\ day^{-1} \times BSS \qquad (2)$$

Where,

BSS = Bright sunshine hours of the particular day

The calculation of PAR on daily basis was carried out by multiplying values with BSS of the particular day.

$$1\ M\ J\ m^{-2}\ day^{-1} = 0.00078261 \times PAR \times BSS$$

Radiation use efficiency was calculated as the ratio of the dry matter production to intercepted photo synthetically active radiation by the plants.

$$\text{Radiation use efficiency (g MJ}^{-1}) = \frac{\text{Drymatter}}{\text{Intercepted PAR}} \quad (3)$$

Accumulated IPAR was computed by multiplying the daily PAR value with F of the particular day. The daily F was obtained by the graphical extrapolation of recorded values of PAR at data intervals through canopy analyse

Commented [Gh9]: Please correct the spell

5. RESULTS

5.1. LAI and Dry matter accumulation

The data (Table 1) showed that the crop sown during II FN of February recorded the lower LAI and dry matter accumulation compared later sowings. The maximum LAI and dry matter accumulation were observed with the variety CSV 32 F at harvest which was significantly superior to remaining tested varieties during all the dates of sampling.

5.2. 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}) whereas 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.

Commented [Gh10]: Please remove space

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.

5.3. Radiation use efficiency

The crop sown during I FN of January recorded higher radiation use efficiency compared to the crop sown at other later dates during II FN of January, I FN of February and II FN of February. Irrespective of variety maximum and minimum radiation use efficiency was recorded in I FN of January and II FN of February. Among the fodder sorghum varieties tried, the radiation use efficiency recorded by CSV 32 F was superior over rest of varieties. The variety CSV 21 F recorded the lowest radiation use efficiency.

5.4. Green fodder yield

The crop sown during I FN of January recorded the highest green fodder yield (34.64 t ha^{-1}) which was comparable with II FN of January (32.70 t ha^{-1}), whereas the lowest green fodder yield was recorded with II FN of February (24.50 t ha^{-1}).

CSV 32 F recorded significantly higher green fodder yield among the different varieties tested owing to its superior performance of growth and yield parameters.

5.5. Correlation studies

The correlation studies between RUE and TUE to LAI, dry matter accumulation and green fodder yield showed a significant positive linear relationship. The regression coefficients between meteorological indices *v iz.*, RUE and TUE and crop parameters *viz.*, LAI, dry matter production, green fodder yield were significantly influenced by varieties at varied times of sowing.

Commented [Gh11]: Please use a

Prediction equations were developed between the RUE with measured LAI and dry matter production. The overall best fit was linear with a regression coefficient of determination of R^2 value from 0.982 and 0.987 per cent (Fig. 1). It denotes Intercepted solar radiation with high LAI played significant role in dry matter accumulation.

Table 1: Thermal use efficiency, Radiation use efficiency and Green fodder yield of fodder sorghum varieties as influenced by times of sowing

Treatments	At harvest				
	LAI	Dry matter (kg ha^{-1})	RUE (g MJ^{-1})	TUE (kg ha^{-1} °C day^{-1})	Green fodder yield (t ha^{-1})
Times of sowing					
I FN of January	7.326	13138.7	2.68	1.27	34.64
II FN of January	6.274	11927.8	2.41	1.07	32.70
I FN of February	5.547	10844.9	2.14	0.89	28.96
II FN of February	4.926	9926.5	1.88	0.71	24.50
CD (P= 0.05)	0.175	815.9	0.1	0.09	3.22
Varieties					
CSV 21 F	4.021	8514.0	1.46	0.865	24.46
CSV 30 F	6.607	12419.7	2.48	1.025	29.62
CSV 32 F	7.427	13444.7	2.92	1.0725	36.30
CD (P= 0.05)	0.326	446.8	1.46	NS	1.96

6. DISCUSSION

6.1. LAI and Dry matter accumulation

Crop sown during I FN of January produced higher leaf area index which may be attributed to more number of leaves of larger size due to optimum weather conditions which further resulted in higher dry matter accumulation.

Commented [Gh12]: Add in

Higher LAI and drymatter accumulation in CSV 32 F might be due to better genetic constitution among the varieties. These results were in conformity with the findings of Mishra *et al.* (2017), Srivastava *et al.* (2017).

6.2. Thermal use efficiency

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. These results are in conformity with the findings of Rani *et al.* (2012), Prakash *et al.* (2017), Solaimalai *et al.* (2017)

6.3. Radiation use efficiency

Lower Radiation use efficiency due to elevated temperatures which limited the amount of solar radiation received by the plant during each developmental stage which inturn limits interception of solar energy. Solar radiation is major fuel to drive photosynthesis hence limited solar radiation interception resulted in lower accumulation of drymatter, which further limited the radiation use efficiency. The present investigation confirms the results reported by Rani *et al.* (2012) and Singh *et al.* (2016). It might be due to higher leaf area in CSV 32 F, which inturn directly related to the radiation interception. The present findings corroborate with that of Kiniry *et al.* (1989) and Srivastava *et al.* (2017).

Commented [Gh13]: Please add the

6.4. Green fodder yield

The higher green fodder productivity with I fortnight of January sowing is attributed to prevalence of maximum and minimum temperatures within the favorable limits of the crop. Reduction in the yield of green and dry fodders with late sown crop (II fortnight of February) may be attributed to less production of forage owing to exposure of the crop to higher temperatures of maximum and minimum at all growth stages elevated by 4.3 and 5.8ºC respectively. Similar findings were reported from the studies of Deshmukh *et al*. (2009).

The significantly higher leaf area plant^{-1} recorded in CSV 32 F contributed for increased accumulation of photosynthates which finally attributed for higher green fodder yield. Similar results were obtained by Satpal *et al*. (2015) and Shinde *et al.* (2015).

6.5. Correlation studies

Prediction equations were developed between the TUE with measured LAI and dry matter production. The overall best fit was linear with coefficient of determination (R^2) values from 0.677 to 0.643 (Fig. 2). As the temperature was optimum throughout the growing period crop utilized heat more efficiently with balanced ratio of photosynthesis results in better drymatter accumulation.

Commented [Gh14]: Add space here

Prediction equations were developed between the green fodder yield with calculated RUE and TUE. The overall best fit was linear with coefficient of determination (R^2) values from 0.887 to 0.741 (Fig. 3) . Under good agronomic management with adequate moisture and nutrients availability, the amount of dry matter accumulated by a crop is directly proportional to cumulative intercepted photo-synthetically active radiation and prevalence of maximum temperatures within the favorable limits resulted in better accumulated heat units which became instrumental in boosting up the growth and yield. These findings were in accordance with the results obtained by Kiniry *et al*. (1989) and Singh *et al*. (2016).

Commented [Gh15]: Please add updated and more references to do discussion in detail.

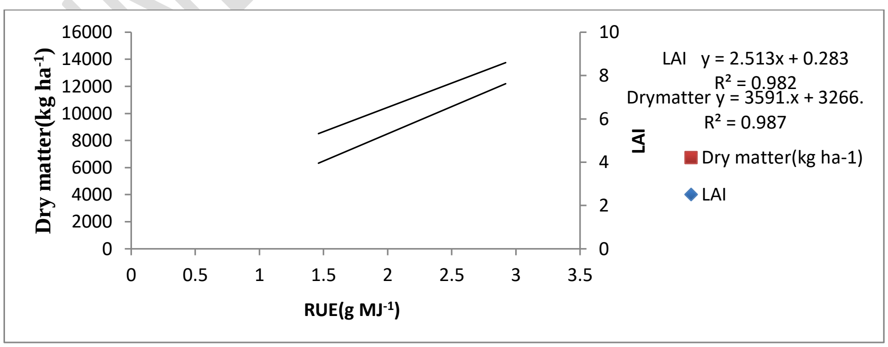

Fig.1: Relationship between RUE *Vs* Dry matter and LAI

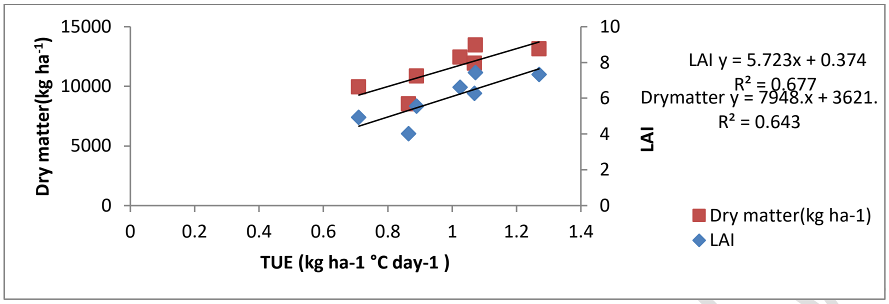

Fig.2: Relationship between TUE *Vs* Dry matter and LAI

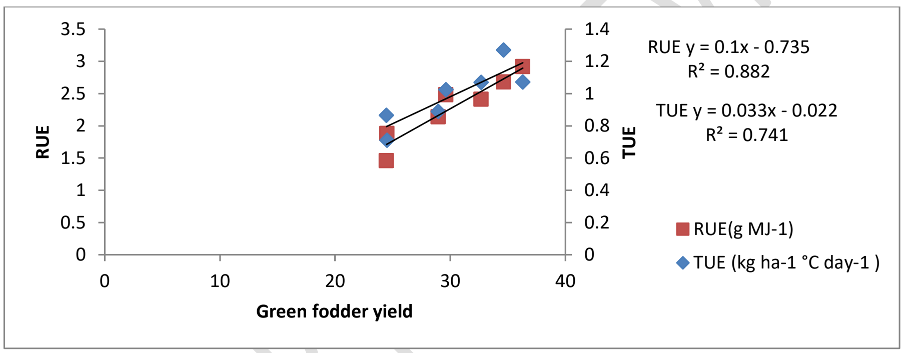

Fig.3: Relationship between green fodder yield *Vs* RUE and TUE

7. CONCLUSION

Estimation of thermal use efficiency and radiation use efficiencies indicated that the I FN of January is more suitable for sowing of the fodder sorghum to explore full benefits of favourable weather conditions for best economic output. Among the fodder sorghum varieties tested, the variety CSV 32 F performed better than the other varieties owing to its genetic attributes with better resource conversion efficiency compared to rest of the varieties for higher yield.

References

Kiniry, J.R., Jones, C.A., O'toole., Blanchet, R., Cabelgueenne and Spanel, D.A. 1989. Radiation –use efficiency in biomaas accumulation prior to grain filling for five grain –crop species. *Field Crop Research*. 20(1): 51-64.

Kumar, A., Pandey, V.,Shekh, A. M and Kumar, M.2008.Radiation use efficiency and weatherparameter influence during life cycle of soybean(*Glycine max*. [L]

Mirrll) production as well accumulation of dry matter. *American-Eurasian Journal of Agronomy* 1 (2): 41-44.

Kumar, N. S. 2003. A note on thermal unit requirement for phenological development in pearlmillet, sorghum, tomato and brinjal. *Journal of Agromateorology*.5 (1): 120-123.

Prakash, V., Mishar, J.S., Kumar, R., Kumar, R.S., Kumar, S.K., Dwivedi., Rao, K.K and Bhatt, B.P. 2017. Thermal utilization and heat use efficiency of sorghum cultivars in middle Indo-Gangetic plains. *Journal of Agromateorology*.19(1): 29-33.

Rajput, R.P. 1980. Response of soyabean crop to climate and soil environment *Ph. D Thesis*.Indian Agricultural Research Institute, Pusa, New Delhi.

Rani, L.P., Sreenivas, G and Raji Reddy, D. 2012.Thermal time requirement and energy use efficiency for single cross hybrid maize in south Telangana agro climatic zone of Andhra Pradesh. *Journal of Agrometeorology*.14 (2):143-146.

Singh, S.R., Khichar, M.L., Niwas, R., Kumar, A and Anurag. 2016. Growth, biomass and yield of rainfed pearl millet in relation to agrometeorological indices. *Forage research.* 41(4): 212-217.

Solaimalai, A., Raj Kumar, A., Palanisamy and Murugan, E. 2017. Influence of sowing windows and fertilizer management practices on yield attributes, yield, heart use efficiency, accumulation of heat units and growing degree days of *rabi* sorghum under rainfed condition. *International Journal of Current Microbiology and Applied Sciences*6(4): 2507-2513.

Srivastava, N.N. ,Rao V.U.M and SubbaRao, A.V.M. 2009. Radiation and water use efficiencies of a popular variety (SPV 462) and a promising hybrid (CSH 14) of sorghum under semi arid climatic conditions of Hyderabad. *Indian Journal of Dryland Agricultural Research& Development.* 24(2): 46-52.