Study on Radiation Use Efficiency of Sorghum Based intercropping system

ABSTRACT

A field experiment was executed to determine the Radiation use efficiency in Sorghum based intercropping system during summer 2021. In India, Sorghum is being cultivated under poor resource conditions. Hence, intercropping sorghum with legumes can help in improving the resource use efficiency than sole sorghum. The treatments were T_1-Sorghum Sole crop (SS), T_2-2rows of Sorghum+2rows of Cowpea (2S:2C), T_3-2rows of Sorghum+1row of Cowpea (2S:1C), T_4-2rows of Sorghum+2rows of Greengram (2S:2G), T_5-2rows of Sorghum+1rows of Greengram (2S:1G), T_6-2rows of Sorghum+2rows of Lablab (2S:2L), T_7-2rows of Sorghum+1rows of Lablab (2S:1L).The experiment was carried out in Randomized Block Design and was replicated thrice. The results revealed that Sorghum + Lablab in 2:1 registered the highest leaf area index, dry matter production which ultimately resulted in high Radiation Use Efficiency. Overall, the intercropping system had high RUE than sole Sorghum**.** Thus it was concluded that planting sorghum with legume in 2:1 pattern would be recommended as it has better resource use efficiency than sole sorghum.

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KEYWORDS: Sorghum, Dry matter production, Radiation Use efficiency,Intercepted PAR**,** Intercropping system

INTRODUCTION

Solar radiation is the most important factor for crop growth and development(Yang *et al.*, 2018).The portion of the solar spectrum that plants use in photosynthesis for converting light energy into biomass is of wavelength between 400 and 700 nm. This wavelength limit is so-called photo-synthetically active radiation(Rodríguez*et al.*, 2020). It is expressed in Photosynthetic Photon Flux Density (PPFD) μ mol m^2 s^1. Anything that hinders the sunlight changes the amount of PAR falling on the crop canopy such as cloud cover, shading, and crop arrangement.

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Under optimum water and nutrient condition, the efficiency of photosynthesis is determined by absorbed PPFD. Radiation Use Efficiency is the important factor determining the growth of crops under optimum conditions (Rahman *et al.*, 2019).The change in crop geometry changes the amount of PPFD falling on the green canopy that results in a change in the RUE of crops.

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Sorghum(*Sorghum bicolor*), known as great millet, is an important millet after rice and wheat. It is a promising crop under arid and semiarid conditions. In India, it is being cultivated under resource-poor conditions. Intercropping Sorghum with legume has emerged as a strategy to maximize resource use efficiency(Maitra*et al.*, 2020) In intercropping, different row arrangements result inthe different light interception and radiation use efficiency (Iqbal *et al.*, 2018).

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In intercropping, the shading of the tall crop over the short crop changes the light environment in terms of both quantity and quality (Liu *et al.*,2017).These changes are highly influenced by the row arrangement of component crops and cause both growth and morphological changes (Gong *et al*., 2014,Gao*et al.*, 2010)

To date,the study of RUE in Sorghum-based intercropping with different row arrangements inTamil Nadu is still limited. Therefore the present study is to estimate RUE as the factor for quantifying productivity of Sorghum-based intercropping.

MATERIALS AND METHODS

Experiment site and design

The field experiment was carried on Field No.37 Eastern Block of Tamil Nadu Agricultural University Coimbatore,Tamil Nadu,India during Summer 2021.The intercropping system consists of Sorghum as the main Crop,Cowpea,Greengram, and Lablab as intercrops.The experiment was laid out in Randomized Block Design with 7 treatments and 3 replications.The treatments of the study were T_1-Sorghum Sole crop (SS), T_2-2rows of Sorghum+2rows of Cowpea (2S:2C),T_3-2rows of Sorghum+1row of Cowpea (2S:1C), T_4-2rows of Sorghum+2rows of Greengram (2S:2G),T_5-2rows of Sorghum+1rows of Greengram (2S:1G),T_6-2rows of Sorghum+2rows of Lablab(2S:2L),T_7-2rows of Sorghum+1rows of Lablab (2S:1L).The spacing of sole sorghum was 45 x 15 cm. The plant density maintained in sole Sorghum was 1, 55, 555 plants ha^{-1}maintained. The intercropping arrangement and plant density maintained were

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depicted in fig1.The intercropping was designed as an addictive series. Nutrients, pests, weed management were carried out based on standard recommendations. Irrigation was done once in six days.

Experimental measurements

Crop Growth Parameters

Leaf Area Index (LAI)

The LAI of both sole and intercrops were measured 30, 45,60(Days After Sowing) DAS.The length and breadth of the leaf were measured and the LAI was worked out based on the following formula.

$$\mathbf{LAI} = \frac{\mathbf{Leaf\ Area}}{\mathbf{Ground\ Area}}$$

Dry Matter Production (DMP)

The DMP was measured 30, 45,60DAS.The plant samples were harvested at regular intervals by cutting plants just above the soil surface. The plants were shade dried followed by oven-dried at 70˚C to constant weight.

Extinction Coefficient (k)

Extinction coefficient (k) is the measure of extinction of any transmitted light in crop canopy (Lunagaria and Shekh, 2006). The erect leaves have a low k value. The k values were significantly different for crop species and development stages (Chimonyo*et al.*, 2018).

The calculation of extinction coefficient(k) is;

$$\mathbf{k} = \frac{-\mathbf{ln(T)}}{\mathbf{LAI}}$$

Photosynthetically Active Radiation (PAR)

The amount of PAR intercepted by the crop was recorded usingthe EMCON Line quantum sensor.During bright sunshine hours, the PAR was measured at the top(I_0) and bottom of the canopy (I).The readings were taken at regular intervals.Measurements were normally taken between 10:00–14:00hrs IST.The calculation of the fraction of PAR transmitted(T) is as follows;

$$\mathbf{T} = \frac{\mathbf{I}}{\mathbf{I_0}}$$

The calculation of the fraction of radiation intercepted by taller crops(Rezig*et al*., 2013)

$$\mathbf{F_{tall}} = \mathbf{1 - e^{(-k \cdot LAI)}}$$

k - Extinction coefficient of tall crop

LAI - Leaf area Index of tall crop

The fraction of radiation intercepted by a lower turbid layer comprising short and taller crop

$$F_{TALL} = \frac{k_t \times LAI_t}{k_t \times LAI_t + k_s \times LAI_s} \times (1 - exp^{(-k_t \times LAI_t - k_s \times LAI_s)})$$

$$F_{SHORT} = \frac{k_s \times LAI_s}{k_t \times LAI_t + k_s \times LAI_s} \times (1 - exp^{(-k_t \times LAI_t - k_s \times LAI_s)})$$

LAI_t, LAI_s - Leaf Area Index of Tall (Solecrop) and short crop (Intercrop) in the lower turbid layer.

k_t, k_s- Extinction coefficient of Tall (Solecrop) and short crop (Intercrop)

Radiation Use Efficiency (RUE)

The Radiation Use Efficiency of sole and intercrop ($g.MJ^{-1}$)can be calculated as

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$$RUE_{Tall} = \frac{TDM_{Tall}}{PAR_o(Ftall + Fshort)}$$

$$RUE_{Intercrop} = \frac{TDM_{Intercrop}}{PAR_o(Fshort)}$$

$$RUE_{System} = RUE_{Tall} + RUE_{Intercrop}$$

RUE_{Tall}–Radiation Use Efficiency of Tall crop ($g.MJ^{-1}$)

$RUE_{Intercrop}$–Radiation Use Efficiency of Intercrop ($g.MJ^{-1}$)

TDM – Total Drymatter (g)

RESULT AND DISCUSSION

Leaf Area Index (LAI)

The results showed that there is a significant difference between LAI of sole Sorghum and intercropped Sorghum. Sorghum in 2:1 Sorghum + Lablab (T_7) registered highest leaf area index0.7, 1.9, 8.3 in 30DAS, 45DAS, 60DAS respectively whereas sole Sorghum(T_1) registered lowest value0.15, 1.0, 5.5 in 30DAS, 45DAS, 60 DAS respectively (Fig2.).This was due to a change in crop geometry in sole and intercrop configuration.

Extinction Coefficient (k)

The Extinction coefficient determines the transmission of radiation through the canopy and canopy layers. The result showed that there was a gradual decline in K value with crop growthand these changes were due to change in canopy characters like LAI. There was a linear relationship between K value and transmission of leaf in all three stages and it was significant (Fig3.).The K value of the sorghum under different planting patternwas presented in Table1.

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Fraction of Intercepted PAR (fPAR)

The fPAR was high in the sole Sorghum in 30, 45 and 60 DAS. The increased spacing between sole sorghum (45 cm) allowed more direct light to intercept by the crop.At 60DAS the fPAR value was found to be higher because of the increased height of the component crops.Among the different treatments of intercropping, the Sorghum in 2:2 pattern intercepted more PAR (T_2, T_4, T6). The higher plant density and foliage cover of component crops at the 2:2 pattern intercepted more PAR than the 2:1 pattern. The total fPAR intercepted by the Sorghum was presented in the fig4.

Dry matter production (DMP)

Similar toLAI, DMP produced by theSorghum in 2:1 Sorghum+ Lablab (T_7)5.1, 32.7, 78.6g plant^{-1} in 30DAS, 45DAS, 60DAS respectively was higher than all other treatments. The sole crop Sorghum (T_1) registered lower values3.4,26.6,67.3g plant^{-1}in 30DAS, 45DAS, 60 DAS respectively (Fig5.).The increased DMP in T_7 might be due to the ability of component crops in maximum utilization of resources due to the differential rooting pattern of for resource utilization which resulting in reduced competition (Bedoussac *et al.*, 2015).The maximum dry matter as well as LAI was enhanced by the low level of competition that prevailed in the 2:1 intercropping system than 2:2 pattern (Wang *et al.*, 2017).

Radiation Use Efficiency (RUE)

The RUE was highin 2:1 Sorghum+ Lablab (T_7)followed by T_3(2:1 Sorghum + Cowpea) where sole Sorghum (T_1) registered the low value at 30, 45 and 60 DAS.The RUE of different treatments were presented in fig6.The PAR intercepted by the sole sorghum was mostly direct which is less efficient in converting to biomass. The addition of legume rows in the intercropping system allowed more diffuse light which was highly efficient in converting to biomass. This resulted in high RUE in intercropping treatments than solitary cropping (Table2). Similarly, 2:1 pattern had better RUE than 2:2 pattern. This was due to the reduced dry matter production in 2:2 pattern than 2:1 pattern. The competition that existed in 2:2 pattern reduced the dry matter production that ultimately reduced the RUE. The average value of RUE of the intercropped Sorghum was 1.4 to 2.5 g MJ^{-1}.

CONCLUSION

Intercropping Sorghum with Lablab and Cowpeahas enhanced the leaf area index, dry matter production which resulted in high Radiation Use efficiency. The intercropping improved the overall light capture and use efficiency of Sorghum than sole cropping. The RUE of Sorghum+ Lablab in 2:1 pattern was stable across all days of observation. Introducing the additional single row of pulses in 2:2 reduced the growth performance of both Sorghum and pulses.Hence intercropping Sorghum with pulses in 2:1 pattern would be recommended since it had better radiation use efficiency than 2:2 pattern.

REFERENCES

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Table 1: Values of K of Sorghum under different planting pattern at 30, 45, 60 DAS

Treatment details	Days After Sowing		
	30	45	60
T_1 - Sorghum sole cropping	1.40^e	0.54^d	0.15^e
T_2 - Paired row of Sorghum + 2 rows of Cowpea (2S:2C)	0.36^c	0.21^c	0.10^d
T_3 - Paired row of Sorghum + 1 row of Cowpea (2S:1C)	0.17^b	0.13^b	0.09^c
T_4 - Paired row of Sorghum + 2 rows of Greengram (2S:2G)	0.43^d	0.32^c	0.08^b
T_5 - Paired row of Sorghum + 1 row of Greengram (2S:1G)	0.34^c	0.16^a	0.08^b
T_6 - Paired row of Sorghum + 2 rows of Lablab (2S:2L)	0.12^b	0.06^a	0.10^d
T_7 - Paired row of Sorghum +1 row of Lablab (2S:1L)	0.11^a	0.06^a	0.05^a
SEd	0.02	0.03	0.03
CD(.05)	0.04**	0.07**	0.01**

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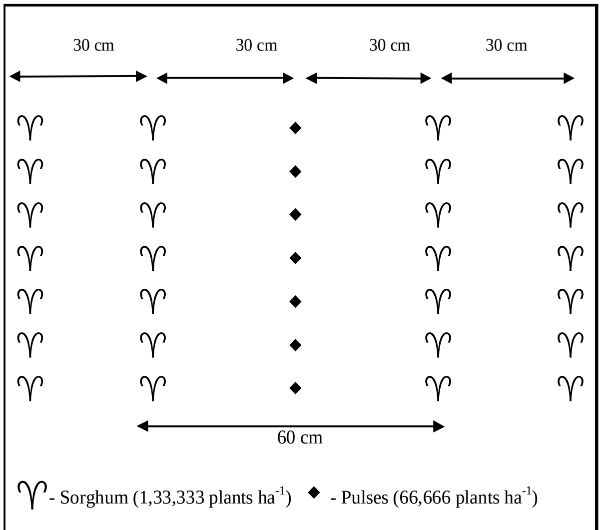
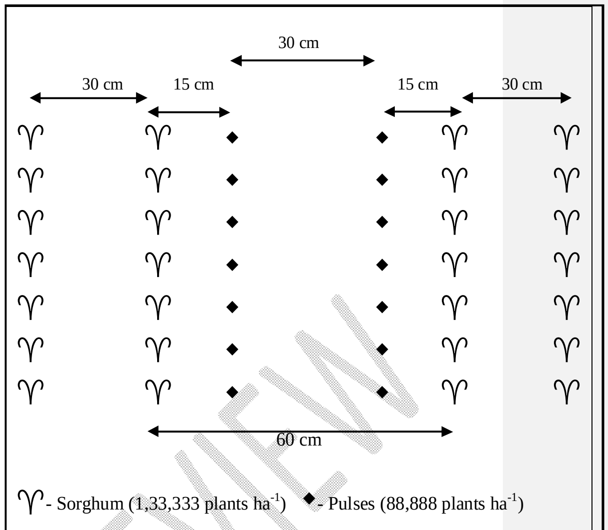
Table 2 Percent improvement in RUE of intercropping system than sole sorghum



2:1 Intercropping system



2:2 Intercropping system

Treatments	**% Improvement of RUE than sole Sorghum**		
	30DAS	**45 DAS**	**60DAS**
T_2(2S:2C)	63.6	24.6	118.0
T_3(2S:1C)	90.0	211.5	210.5
T_4(2S:2G)	81.5	67.4	137.4
T_5(2S:1G)	84.2	144.5	215.4
T_6(2S:2L)	82.6	82.3	145.5
T_7(2S:1L)	93.0	227.3	243.0

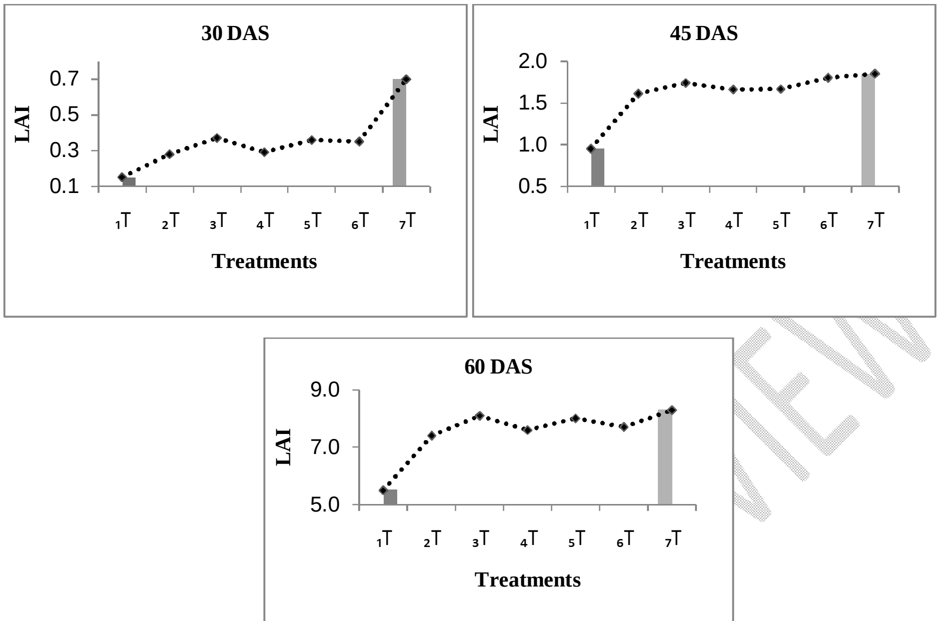


Fig2: Leaf Area Index of Sorghum in the different intercropping systems at 30, 45, 60DAS

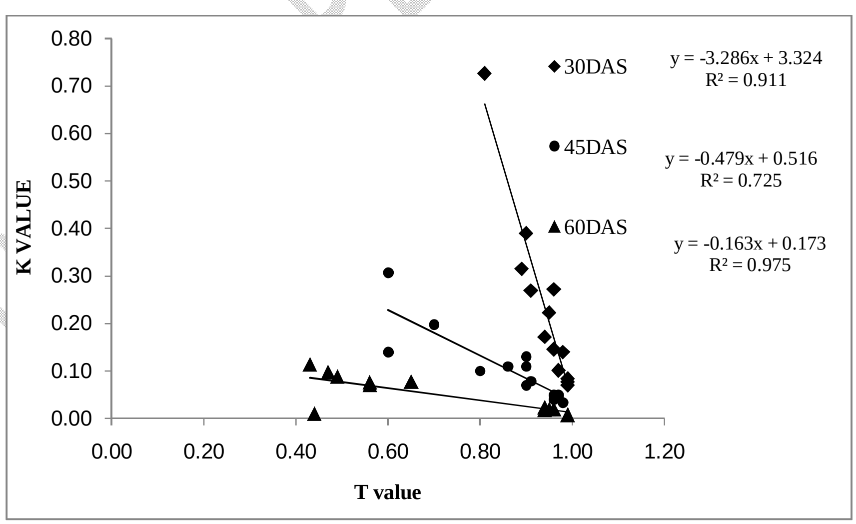


Fig3. Linear Regression between k and T at 30, 45, and 60 DAS

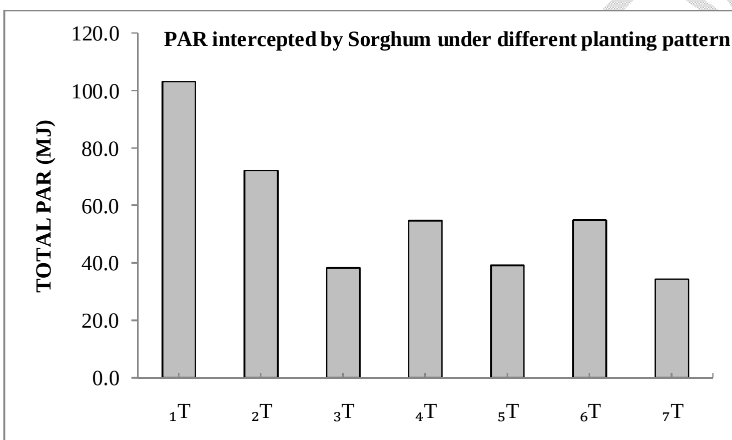
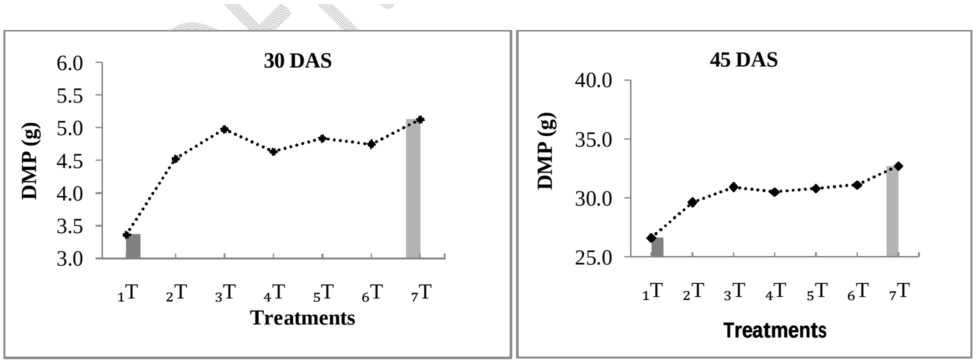


Fig4. Total PAR intercepted (fPAR) by Sorghum under different planting pattern



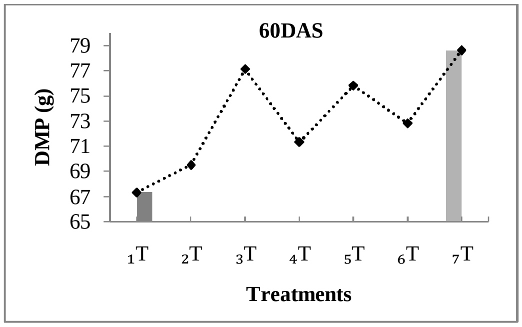


Fig5. Total Dry matter produced by the Sorghum under different planting pattern at 30, 45, 60DAS

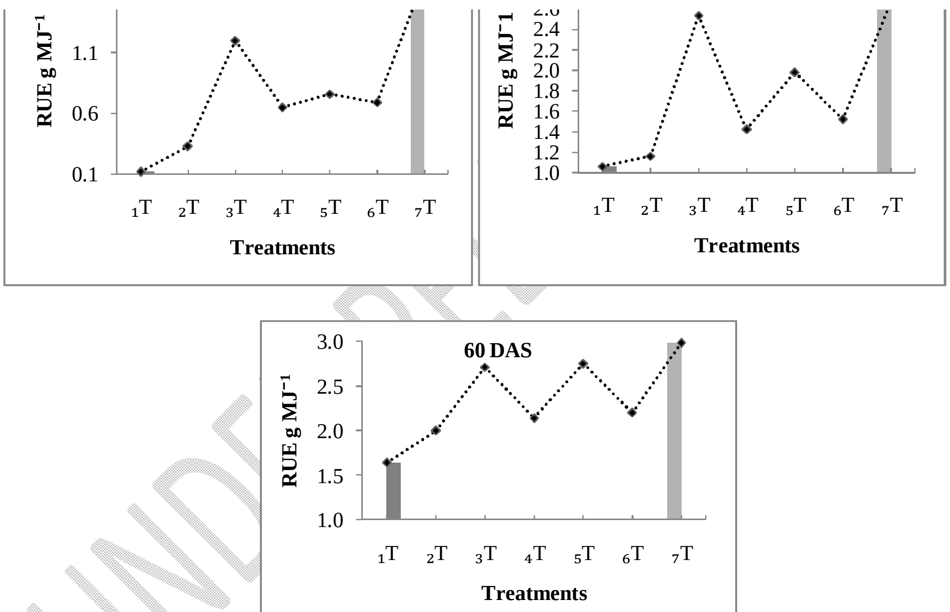


Fig6.Radiation Use Efficiency of Sorghum under different planting pattern at 30, 45, 60DAS