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Radiation interception and utilization by *rabi* soybean as influenced by sowing time and irrigation

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ABSTRACT

A field study was conducted on soybean to assess the influence of sowing time and N-P fertilizer levels on radiation use efficiency. The dry matter accumulation, per cent radiation interception and radiation use efficiency were found to be significantly influenced by sowing time and N-P fertilizer levels. These values declined as sowing time was delayed, while for extinction coefficient a reverse trend was observed. The radiation use efficiency declined from 1.819 g MJ^{-1} to 0.671 g MJ^{-1} as the sowing was delayed from October 17th to November 16th, respectively. The N-P level 120-120 Kg ha^{-1} resulted in radiation use efficiency value of 1.420 g MJ^{-1} compared to 0.990 g MJ^{-1} of the no fertilizer treatment.

Key words: Soybean, Radiation use efficiency, Sowing time, Fertilization

Radiation use efficiency (RUE) provides an estimate on conversion efficiency of the intercepted photosynthetically active radiation (PAR) into biomass. Soybean in Andhra Pradesh is generally grown during *kharif*, the success story of *kharif* crop has attracted many farmers to raise this under irrigated conditions during *rabi* season also. In such situation the influence of shifting sowing time from *kharif* to *rabi* on the crop physiology is to be assessed in terms of RUE. Nitrogen and phosphorus fertilizers have been the key factors for augmenting the production. Crop response to sowing time and N-P fertilizer levels could be better understood when the physiological parameter such as RUE is critically analysed.

MATERIALS AND METHODS

A field experiment was conducted at Agricultural College Farm, Bapatla during *rabi* 1997-98. The soil of test site was loamy sand in texture, slightly alkaline in reaction, low in available nitrogen (251kg ha^{-1}), medium in available phosphorus (48 kg ha^{-1}) and high in available potassium (672 kg ha^{-1}). The treatments consisted of 5 dates of sowing (17th October, 1st November, 16th November, 1st December and 16th December) and 4 levels of N-P fertilizers (N_0P_0, $N_{40}P_{40}$, $N_{80}P_{80}$ and $N_{120}P_{120}$) and were laidout in split-plot design with dates of sowing as main-plots and N-P fertilizer levels as sub-plots and replicated thrice.

Soybean Cv. MACS-13 was sown as per the treatments at a spacing of 30 x 10 cm. Nitrogen and phosphorus were applied as per the treatments through urea and single super phosphate (SSP), respectively. A uniform basal dose of 40 kg K_2O ha^{-1} was applied through muriate of potash. Necessary and timely plant protection measures were taken. Dry matter accumulation at different stages was recorded by destructive sampling of 5 plants. Leaf area was measured with the help of leaf area meter (T area meter MK-2, Delta-T Devices Limited, U.K.).

The incident, reflected and inter cepted photosynthetically active radiation (IPAR) were recorded at 2 hourly interval starting from 0800 hours IST with the help of a line quantum sensor (LICOR Inc., USA) in all the treatments at monthly intervals. The data recorded in μ Einstein m^{-2} s^{-1} was converted to MJ day^{-1} and average of five observations on a particular day was determined.

Accumulated IPAR :

Accumulated IPAR in each treatment was estimated from the value of LAI and incident PAR using the following expression:

$$IPAR = [1-e^{-K\,LAI}]\,PAR$$

where,

IPAR = intercepted PAR (MJ day^{-1})

PAR = incident PAR at the top of canopy (MJ day^{-1})

K = extinction coefficient

LAI = leaf area index.

The extinction coefficient (K) values for different treatments at different stages of crop growth were estimated, from the data recorded by using line quantum sensor and employing those values in the following relation (Saeki, 1963).

$$-K = \ln (I/I_o) \times 1/LAI$$

where,

I = PAR value at the bottom of the canopy

I_o = Incident PAR at the top of the canopy.

Recording of incident PAR values daily was difficult and the PAR values for the intermittent period between the successive observations were estimated by using the relation suggested by Venkataraman and Krishnan (1992) as

$$PAR = 0.5 \times R_s$$

where, R_s = incoming solar radiation (MJ day^{-1})

The daily R_s values were estimated employing the equation of Doorenbos and Pruitt (1979). The extra-terrestrial radiation (R_A) was estimated as suggested by Duffie and Beckman (1980).

Radiation use efficiency

The radiation use efficiency was determined following the procedure of Hughes *et al.* (1981) for different treatments, which is the value of the slope of the curve of the regression line between accumulated PAR and accumulated dry matter.

RESULTS AND DISCUSSION

Dry matter accumulation

Dry matter accumulation was significantly affected by sowing time. As sowing time was delayed, dry matter accumulation was found to decrease at all stages of crop growth (Table 1).

Fertilizer levels influenced the dry matter at all stages of crop growth. The response between N-P fertilizer levels was linear upto 80-80 and further increase upto 120-120 failed to produce significant differences. This indicates that fertilizer response on growth of soybean was only upto N-P 80-80.

The lower values of dry matter at lower N-P fertilizer levels can be attributed to reduced light interception, reduced radiation use efficiency due to low canopy cover, which are discussed at a later stage. The results are in confirmity with Jamro *et al.* (1990), Naidu and Pillai (1993) who reported maximum dry matter accumulation with N-P application each at 100 Kg ha^{-1}.

Interception of PAR and extinction coefficient (K)

The per cent light interception as influenced by different treatments in the present investigation (Table 2) revealed that sowing time had great influence than N-P fertilizer levels. The light interception decreased with delay in sowing. The decrease beyond 60 DAS was due to commencement of senescence of mature leaves, which is a common feature in most of the short duration grain legumes. Since radiation interception is a function of LAI and plant spread, the differences noticed in the present investigation could be attributed to difference in LAI through out the growing season. Kasim and Dennet (1986) in *Vicia faba* and Muchow *et al.* (1993) in several other pulses demonstrated that such variations in the radiation interception could be brought out by aerial as well as plant stand environment.

The K values in the present investigation are presented in Table 3. Sowing time and N-P fertilizer levels showed considerable influence. As the sowing time was delayed, the K values in the present investigation increased. Balakrishnan and Natarajaratnam (1986) evaluated seasonal effect on pigeonpea and observed that light interception decreased as sowing was delayed from summer to rainy and winter season. But reverse trend was observed in case of K.

Radiation use efficiency (RUE)

Radiation use efficiency provides an estimate on the amount of dry matter produced per unit radiation intercepted. The RUE values presented in Table 4 revealed that both sowing time and N-P fertilizer levels had considerable effect on RUE of MACS-13. The variation in RUE followed the variations in dry matter and LAI in different treatments. The RUE declined as sowing time was delayed. The earlier sown crop (D_1) recorded highest RUE (1.819) followed by D_2 (1.620), D_3 (1.282), D_4 (0.844) and D_5 (0.671). N-P fertilizer levels also were found to influence RUE with N-P 120-120 (T_4) recording about 43 per cent more efficiency than the 'no fertilizer' treatment (T_1). The T_4 fertilizer treatment was found to have the highest RUE value of 1.420 followed by T_3 (1.386), T_2 (1.215) and T_1 (0.990). Unsworth *et al.* (1984) and Sinclair (1986) reported a RUE value of 1.2 g MJ^{-1} for soybean, whereas Charles-Edwards (1987) reported 1.3 g MJ^{-1}. The results of the present study confirms that RUE of soybean is a function of sowing time and fertilization.

REFERENCES

Balakrishnan, K. and Natarajaratnam, N. 1986. Heat unit efficiency in pigeonpea. Madras Agricultural Journal, 73: 101-104.

Charles-Edwards, D. A. 1987. Physiological determinants of crop growth. Academic Press, New York.

Doorenbos, J. and Pruitt, W. O. 1979. Guidelines for predicting crop water requirements. FAO irrigation and drianage paper number 24, 2nd edition, FAO, Rome, Italy pp.156.

Duffie, J. A. and Beckman, W. A. 1980. Solar engineering of thermal processes. John Willey and Sons. New York. pp.1-109.

Hughes, G., Keatinge, J. D. H. and Scott, S. P. 1981. Pigeonpea as a dry season crop in Trinidad, West Indies. II. Interception and utilization of solar radiation. Tropical Agriculture, 58: 191-199.

Jamro, G. H., Memon, G. H. and Ibupota, K. A. 1990. Effect of combined nitrogen and row spacing on nodulation and grain yield of soybean. Sarhad Journal of Agriculture, 6 : 107-112.

Kasim, K. K. and Dennett, M. D. 1986. Radiation absorption and growth in *Vicia faba* under shade at two densities. Annals of Applied Biology, 109: 639-650.

Muchow, R. C., Robertson, M. L. and Pengelly, B. C. 1993. Radiation use efficiency of soybean, mungbean and cowpea under different environmental conditions. Field Crops Research, 32: 1-16.

Naidu, M .V. S. and Pillai, R. N. 1993. Effects of nitrogen and phosphorus levels on yield, dry matter production and uptake of cationic micronutrients in soybean. Journal of Maharashtra Agricultural Universities, 18 : 302-303.

Saeki, T. 1963. Light relations in plant communities (In). Environmental control of plant growth L.T. Evans (Eds.). Academic Press, New York pp.79-94.

Sinclair, T. R., Muchow, R. C., Ludlow, M. M., Leach, G. J., Lawn, R. J. and Foale, M. A. 1987. Field and model analysis of the effects of water deficits on carbon and nitrogen accumulation by soybean, cowpea and blackgram. Field Crops Research, 17: 121-140.

Unsworth, M. H., Lesser, V. M. and Heagle, A. S. 1984. Radiation interception and the growth of soybeans exposed to Ozone in open-top field chambers. Journal of Applied Ecology, 21: 1059-1079.

Venkataraman and Krishnan, A. 1992. Crops and weather. (Pb.) Indian Council of Agricultural Research, New Delhi pp.588.

Table 1: Dry matter production (g m^{-2}) at different growth stages of soybean as affected by dates of sowing and $N-P_2O_5$ levels

Treatments	Days after sowing 30	Days after sowing 60	Maturity
Dates of sowing (D)			
D_1 - October 17	68.6	346.8	424.1
D_2 - November 1	63.8	304.2	362.8
D_3 - November 16	50.5	245.4	295.3
D_4 - December 1	45.2	198.4	241.9
D_5 - December 16	50.1	196.8	241.0
SEm	3.09	7.19	12.1
CD (0.05)	10.1	23.5	37.7
$N-P_2O_5$ levels (Kg ha-1)			
$T_1 - N_0P_0$	37.6	210.8	266.6
$T_2 - N_{40}P_{40}$	50.9	249.1	297.1
$T_3 - N_{80}P_{80}$	66.9	284.1	342.2
$T_4 - N_{120}P_{120}$	67.0	289.5	346.4
SEm	1.65	6.04	8.41
CD (0.05)	4.77	17.40	24.30
Interaction	NS	NS	NS
C.V.(%)	11.5	9.05	10.40

Table 2 : Light interception (as a per cent of incident) at different stages of crop growth as affected by dates of sowing and N-P_2O_5 levels

	D_1 (Oct. 17) Days after sowing					D_2 (Nov. 1) Days after sowing					D_3 (Nov. 16) Days after sowing					D_4 (Dec. 1) Days after sowing					D_5 (Dec. 16) Days after sowing				
	30	45	60	75	Mean	30	45	60	75	Mean	30	45	60	75	Mean	30	45	60	75	Mean	30	45	60	75	Mean
T_1	57.8	66.2	75.4	66.9	66.6	56.9	64.6	74.6	66.9	65.8	55.4	63.1	73.1	65.4	64.2	53.9	62.7	72.3	64.6	63.4	53.1	62.3	72.3	63.9	62.9
T_2	61.9	71.9	76.5	70.7	70.3	60.8	70.0	76.2	69.2	69.0	62.7	67.7	75.8	67.7	68.5	60.0	66.2	74.2	66.9	66.8	58.5	65.0	73.9	66.2	65.9
T_3	66.5	73.4	77.7	74.7	73.1	64.5	72.2	76.9	71.2	71.2	63.5	72.1	76.2	70.0	70.4	61.5	70.0	75.0	68.5	68.8	58.9	69.2	74.6	68.1	67.7
T_4	67.0	73.5	78.1	74.2	73.2	64.5	72.2	77.7	71.9	71.6	64.0	72.3	76.5	71.4	71.1	62.3	71.9	76.2	70.8	70.3	59.0	71.5	76.2	69.6	69.1
Mean	63.3	71.2	76.9	71.6		61.7	69.7	76.3	69.8		61.4	68.8	75.4	68.6		59.4	67.7	74.4	67.7		57.3	67.0	74.2	66.9	

Table 3 : Light interception (as a per cent of incident) at different stages of crop growth as affected by dates of sowing and N-P_2O_5 levels

	D_1 (Oct. 17) Days after sowing					D_2 (Nov. 1) Days after sowing					D_3 (Nov. 16) Days after sowing					D_4 (Dec. 1) Days after sowing					D_5 (Dec. 16) Days after sowing				
	30	45	60	75	Mean	30	45	60	75	Mean	30	45	60	75	Mean	30	45	60	75	Mean	30	45	60	75	Mean
T_1	0.18	0.15	0.15	0.16	0.16	0.20	0.17	0.15	0.16	0.17	0.24	0.22	0.15	0.18	0.20	0.28	0.22	0.15	0.18	0.21	0.32	0.23	0.15	0.18	0.22
T_2	0.15	0.15	0.14	0.15	0.15	0.20	0.16	0.14	0.16	0.17	0.20	0.19	0.14	0.16	0.17	0.21	0.21	0.15	0.17	0.19	0.27	0.22	0.15	0.17	0.20
T_3	0.15	0.14	0.13	0.15	0.14	0.15	0.15	0.13	0.15	0.15	0.16	0.15	0.14	0.16	0.15	0.17	0.16	0.14	0.16	0.16	0.19	0.17	0.15	0.17	0.17
T_4	0.14	0.13	0.13	0.14	0.14	0.15	0.15	0.13	0.15	0.15	0.15	0.15	0.14	0.15	0.15	0.16	0.16	0.14	0.15	0.15	0.18	0.16	0.14	0.16	0.16
Mean	0.16	0.14	0.14	0.15		0.18	0.16	0.14	0.16		0.19	0.18	0.14	0.16		0.21	0.19	0.15	0.17		0.24	0.20	0.15	0.17	

Table 4 : Radiation use efficiency (RUE) (g MJ^{-1}) as affected by dates of sowing and N-P_2O_5 levels

Treatments	Radiation - use efficiency	Coefficient of determination (R^2)	Standard error of estimate
D_1T_1	1.362	0.91	33.3
D_1T_2	1.741	0.91	39.1
D_1T_3	2.091	0.92	43.1
D_1T_4	2.085	0.92	44.8
D_2T_1	1.316	0.91	28.7
D_2T_2	1.576	0.93	30.6
D_2T_3	1.742	0.93	32.8
D_2T_4	1.848	0.92	36.4
D_3T_1	1.002	0.94	19.8
D_3T_2	1.461	0.93	30.2
D_3T_3	1.299	0.95	20.9
D_3T_4	1.368	0.95	23.4
D_4T_1	0.709	0.96	12.4
D_4T_2	0.809	0.96	13.5
D_4T_3	0.902	0.97	12.9
D_4T_4	0.956	0.97	14.4
D_5T_1	0.562	0.97	10.6
D_5T_2	0.488	0.97	11.1
D_5T_3	0.789	0.97	12.9
D_5T_4	0.844	0.98	13.3

Mean of fertilizer levels

D_1	D_2	D_3	D_4	D_5
1.819	1.620	1.282	0.844	0.671

Mean of dates of sowing

T_1	T_2	T_3	T_4
0.990	1.215	1.386	1.420