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Biomass production of soybean in relation to evapotranspiration and temperature

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ABSTRACT

Soybean is a fast upcoming crop in monsoon season after rice in Chhattisgarh area of central India under rainfed conditions. To find out the relationship between evapotraspiration (ET), temperature and biomass production, experiments were conducted in monsoon seasons of years 1994 and 1995. Biomass production of soybean in relation to cumulative ET and accumulated heat units has been evaluated and expressed as linear regression.

Key words : Evapotraspiration , Growing dergee days, Biomass production, Water balance

In the Chhattisgarh region under rainfed condition farmers usually take rice (about 3.8 million hectares) in bunded fields and small millets and pigeonpea in unbunded fields. Due to higher requirements of water for rice and decreasing trends of rainfall, a recommendation has been made for soybean in unbunded black soils under rainfed condition in monsoon season. In the recent decade, since that recommendation, the area under soybean has increased from 3,000ha to more than 85,000ha in monsoon season in the Chhattisgarh region.

The amount of ET loss for a given crop depends on climatic parameters, type of soils and growth stage of crop and crop types. Allison *et.al.* (1958) and Hanks *et.al.* (1968) studied the relationship between ET and biomass production of different crops grown in lysimeters under rainfed condition. They reported that a linear relationship becomes valid after sufficient ET has occurred from crop establishment in initial stages.

Doorenbos and Pruitt (1977) expressed that the productivity of a crop is also dependent on degree days and also the knowledge of water loss through plant and its utilization in biomass production is an important factor. Cumulative ET (Chakravarty and Sastry, 1983), and degree days (Uchijma, 1975) have been reported to be highly correlated with crop biomass production.

MATERIALS AND METHODS

The experiments were conducted in the years 1994 and 1995 at the research farm of Indira Gandhi Agricultural University, Raipur to examine the evapotranspiration (ET) and degree day relationship with biomass production of soybean (Cv. JS 72-44) during monsoon season under rainfed

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condition. Two sets of gravimetric lysimeters were used for ET measurement. Soybean was sown by seed drill on 3rd July in 1994 and 22nd June in the year 1995 with a row spacing of 30cm. N,P and K were given as locally recommended. The crop was harvested on 7th November in 1994 and 31st October in 1995. Growing degree days (GDD) were computed using a base temperature of 10 °C.

The meteorological data were collected from the experimental field. Above and below ground biomass samples were collected randomly from 5 points at weekly intervals. Leaf, stem, pod and root were dried separately at 70 °C for 72 hours to obtain a constant dry weight.

RESULTS AND DISCUSSION

Water balance

Weekly water balance has been computed from sowing to maturity following the Thornthwaite and Mather book-keeping procedure (1955) and shown in Table 1. The potential evapotraspiration (PET) values required for the water balance computations are estimated by using Penman's equation (1948). From the Table 1 it can been seen that the in grain filling stage (38 -41 SMW) the water deficit is more in the year 1995 as compared to the same stage of 1994.

There was water stress during mid seedling and end of reproductive stages of soybean crop in 1995 but there was very little water stress during the end of reproductive stage in 1994 (Srivastava *et.al.*,1996). As a result of this, the productivity of soybean decreased from 2.3 t ha^{-1} to 1.7 t ha^{-1} (a decrease of 0.55 t ha^{-1}). Total biomass during 1994 was 5.51 t ha^{-1} as compared to 6.13 t ha^{-1} during 1995.

Evapotranspiration and rainfall

The evapotranspiration (ET), Pan evaporation (EP), rainfall (R) during different growth stages for the two *kharif* seasons are shown in Table 2. The total AET(lysimeter) losses during the growing season of soybean varied from 562.2 mm in 1994 to 525.7mm in kharif 1995. The EP values varied from 433.9 mm in 1994 to 523.0 mm in 1995 indicating that the AET and EP values varied independently between the seasons in the different phases.

In the two years of experiment, crop experienced two different rainfall distributions at Raipur. During 1994 rainfall was 1159.4mm and 1995 it was 927.4mm. Rainfall and soil moisture (SMW 30-33) have affected the AET(lysimeter) rate in 1994 and the weekly AET(lysimeter) value reached 45.8mm in vegetative stage which is more compared to the same stage AET (lysimeter) in 1995. This indicates that in the year 1994 the soybean crop AET(lysimeter) was much higher than the corresponding phenophase of 1995 (Table 2).

Crop stagewise ET, biomass and GDD

The stagewise crop AET (lysimeter), biomass and GDD are shown in Table 2 and 3. The AET (lysimeter) losses are highest during the vegetative and reproductive stages accounting more than 80% of the total AET where as the GDD accounting more than 65% of its total during these two stages. In the year 1994 the average dry biomass production was 5510 kg/ha as compare to 6192 kg/ha in 1995(+11.3 %).

Evapotranspiration and biomass production

The patterns of cumulative AET

Table 1: Weekly Climatic water balance (Thornthwaite method) at Raipur during *kharif* 1994 and 1995

	1994						1995					
SMW*	Rain (mm)	PET (mm)	ET (mm)	WS (mm)	WD (mm)	MAI (mm)	Rain (mm)	PET (mm)	ET (mm)	WS (mm)	WD (mm)	MAI (mm)
25	-	-	-	-	-	-	22.2	12.6	12.6	0.0	0.0	1.0
26	-	-	-	-	-	-	8.6	38.7	15.4	0.0	23.3	0.4
27	71.2	29.1	29.1	36.1	0.0	1.0	41.2	35.7	35.7	0.0	0.0	1.0
28	258.4	18.4	18.4	240.0	0.0	1.0	74.0	25.3	25.3	0.0	0.0	1.0
29	184.2	19.6	19.6	164.6	0.0	1.0	150.6	19.1	19.1	0.0	0.0	1.0
30	15.8	26.2	26.0	0.0	0.2	0.99	141.2	25.5	25.5	27.5	0.0	1.0
31	50.2	20.2	20.2	19.8	0.0	1.0	61.8	24.2	24.2	37.6	0.0	1.0
32	55.4	20.2	20.2	35.2	0.0	1.0	78.8	24.6	24.6	54.2	0.0	1.0
33	75.2	25.2	25.2	50.0	0.0	1.0	151	26.9	26.9	124.1	0.0	1.0
34	112.6	24.1	24.1	88.5	0.0	1.0	16.4	27.1	26.9	0.0	0.0	0.99
35	111.0	21.1	21.1	89.9	0.0	1.0	111.2	25.5	25.5	75.2	0.0	1.0
36	111.8	25.8	25.8	86.0	0.0	1.0	4.8	28.0	27.3	0.0	0.7	0.97
37	21.8	27.3	27.3	0.0	0.1	1.0	3.0	26.8	24.5	0.0	2.3	0.92
38	10.8	24.5	23.8	0.0	0.7	0.97	21.2	29.0	27.9	0.0	12.1	0.96
39	39.2	26.1	26.1	0.0	0.0	1.0	13.0	28.2	25.7	0.0	2.5	0.91
40	4.4	25.8	24.5	0.0	1.3	0.95	0.0	30.4	23.8	0.0	6.5	0.78
41	31.0	24.1	24.1	0.0	0.0	1.0	2.6	26.0	19.6	0.0	6.4	0.75
42	2.0	25.3	22.6	0.0	2.7	0.89	25.8	24.0	24.0	0.0	0.0	1.0
43	1.8	23.1	19.0	0.0	4.1	0.82	0.0	22.6	15.5	0.0	7.1	0.68
44	2.6	18.1	14.2	0.0	3.9	0.79	0.0	9.6	--	0.0	3.4	0.64
Total	1159.4	424.2	411.3	810.1	13.0		927.4	509.8	450.0	318.6	64.3	

Where WS = Water surplus
WD= Water deficit
MAI = Moisture availability index

Crop Stage	*SMW
Seedling	27-29
Vegetative	30-35
Reproductive	36-41
Maturity	42-44

(lysimeter) and biomass production at different days after sowing (DAS) are shown in Table 4. From the table it can been seen that in both the years there is variations in AET(lysimeter) and biomass production. In the year 1994 cumulative AET (lysimeter) is high than the year 1995 but the biomass production is less in 1994 as compared to 1995. To find out the relationship between the AET (lysimeter) and biomass production correlation coefficients and regression analysis are worked out and presented below:

The correlation and regression equation between cumulative AET (lysimeter) and biomass production was worked out and is given below:

Correlation coefficient	Regression equation
0.94**	Y=3.4X-553

** Significant at 1% level

Y=Biomass production in grams meter^{-2}

X= Cumulative AET(lysimeter) in mm

Table 2 : Stagewise AET (lysimeter) and rainfall of soybean crop at Raipur in *Kharif* season.

CROP STAGE	1994			1995		
	AET(mm)	EP(mm)	Rain(mm)	AET(mm)	EP(mm)	Rain(mm)
Seedling (3)*	52.2	75.4	510.0	35.0	109.3	72.0
Vegetative(6)	242.5	140.8	421.2	181.3	140.6	657.4
Reproductive(6)	238.1	148.2	218.2	247.7	166.2	169.6
Maturity(3)	29.4	69.5	6.6	61.7	107.0	28.4
Total (18)	562.2	433.9	1156.0	525.7	523.1	927.4

* Figures in brackets are weeks

Table 3: Stagewise GDD and biomass in two years of experiments.

Crop stage	1994		1995	
	GDD(°C)	Total Biomass(Kg/ha)	GDD(°C)	Total Biomass(Kg/ha)
Seedling(3)*	458	150	341	180
Vegetative(6)	660	2054	744	2490
Reproductive(6)	676	3276	752	3502
Maturity(3)	222	30	352	20
Total	2016	5510	2189	6192

* Figures in brackets are weeks

Table 4: Cumulative AET (lysimeter) and total dry matter production of soybean crop in the year 1994 and 1995.

Days after sowing(DAS)	Cumulative ET(mm)		Biomass production(gm^{-2})	
	1994	1995	1994	1995
32	132	85	17	33
57	219	152	45	83
62	284	239	182	251
72	327	303	438	445
82	396	364	800	686
92	460	421	1121	960
102	519	466	1178	1252
112	543	486	1332	1470
126	566	528	1339	1482

The correlation was highly significant in both the years. The total AET (lysimeter) requirement for soybean crop varied between 500-550mm in Raipur climatic condition and it varied accordingly with rainfall amount and its pattern of distribution in crop growing season.

GDD and biomass production

At different accumulated GDD levels, biomass production in two years are shown in Table 5. In the year 1995 during earlier phenophases there was more accumulation of biomass as compared to the year 1994 for same value of GDD. But at later stages in the year 1995 the rate of accumulation of biomass is more as compared to the year 1994. The GDD calculation has been carried out upto 1700 GDD i.e. starting of physiological maturity.

Table 5 : Biomass production of soybean crop at different unit of GDD

GDD(°C)	Biomass Production (gm^{-2})	
	1994	1995
400	17	26
600	40	63
900	285	222
1000	438	445
1300	735	608
1500	1056	915
1700	1150	1205

The correlation and regression equation between growing degree days and biomass production of soybean pooled for two years is given below:

$Y = 1.2GDD - 598$ $(r=0.96^{**})$

** Singnificant at 1% level

Y = Biomass production in grams $meter^{-2}$

GDD= Growing degree days in °C

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