Journal of Agrometeorology 7 (2) : 249 - 254 (Dec 2005)

Relationship of LAI and biomass of soybean with agroclimatic indices

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ABSTRACT

A three years experiment was conducted on farmer's field using cultivar JS 335 of soybean [Glycine *max* (L.) Merrill.] during *Kharif* season of 2002, 2003 and 2004 at Shirol, Kolhapur district, M.S. Leaf area development, dry matter accumulation and seed yield were correlated with agroclimatic indices of growing degree days and heliothermal units. Heat use efficiency was also determined for dry matter accumulation and seed yield. Significant regression relationships were observed for leaf area index and dry matter accumulation with these agroclimatic indices. Seed yield showed significant regression relationship with heat use efficiency. The agroclimatic prediction model can be used to estimate crop growth and yields of soybean.

Key words: Growing degree days, heliothermal units, heat use efficiency

Several agroclimatologists have documented the use of thermal indices to predict phenology (Hundal *et al.*, 1997), leaf area index – LAI (Bembi 1994), growth rate (Singh *et al.*, 1996) and growth and yield (Hundal *et al.*, 2001 and 2003) of crops. Quantitative relationships for soybean describing the time to flowering as a function of temperature and photoperiod have been reported. Soybean [*Glycine max* (L). Merr.] is a short day and thermo-sensitive plant and its response to yield varies with variety and temperature (Doorenbos and Kassam, 1979). According to Johnson *et.al.* (1960) and Jones *et.al.* (1990) phases from flowering to physiological maturity of soybean are sensitive to both photoperiod and temperature. Major *et al.* (1975) used a multiplicative model of temperature and photoperiod to describe the time of flowering. Others have used statistical techniques to obtain equations for predicting flowering date (Hodges and French, 1985; Wang *et al.*, 1987). They concluded that weather data when included for specific growth periods were better than monthly data to explain variations in crop yields.

Location specificity is the problem of regression type yield prediction models. However, the relatively simpler data requirements of the regression type model make it easy to use for large scale yield prediction. Agroclimatic models based on thermal indices can meet these objectives.

Total heat energy available to any crop

Table 1: Correlation (r) of GDD and HTU with LAI and biomass

Growth stage	GDD		HTU	
	LAI	Biomass	LAI	Biomass
First flower	0.37	0.63#	0.79*	0.59
First pod	0.85*	0.80*	0.26	0.46
Pod fill	0.86*	0.84*	0.48	0.53
Harvest		0.39		0.14
Season	0.96*	0.67#	0.86*	0.67#

* Significant at 1 % level and # significant at 5 % level.

is never completely converted to dry matter even under most favorable conditions. Heat use efficiency (HUE) is the efficiency of conversion of heat energy into dry matter which is dependent on crop type, genetic factors and sowing time (Rao *et al.*, 1999). Present study was undertaken to predict the growth and yield of JS-335 variety of soybean with various agroclimatic models.

MATERIALS AND METHODS

Experiments in black cotton soils (>60cm depth) were conducted during the *kharif* of 2002 to 2004 (May- September) with variety JS-335 of soybean at Shirol (16.73° N, 74.60° E, and 564 m elevation), Maharashtra. The experiment comprised of several dates of sowing from 2nd to 29th May of 2002, 2003 and 2004 (Table 2). Plant samples were collected at developmental growth phases viz. first flower, first pod appearance, pod filling and physiological maturity. The first flower stage refers to the period from sowing to the appearance of the first flower in 50% of the canopy denoting the vegetative period of soybean growth. LAI and dry matter accumulation were recorded at each of these stages and hand harvested yield per m^{-2} was measured. Two agroclimatic indices viz. growing degree days (GDD) and heliothermal units (HTU) were calculated as under.

Growing degree days were determined as per Nuttonson (1955)

$$GDD = \frac{(Tmax + Tmin)}{2} - T_b$$

Where Tmax and Tmin are daily maximum and minimum temperatures (°C) respectively and T_b is the base temperature of 10°C for soybean (Hundal *et al.*, 2003).

HTU = GDD °actual bright sunshine hours

LAI, dry matter accumulation and seed yield were related with the accumulated GDD and HTU to find out the best fit relationship.

Heat use efficiency (HUE) for seed and total dry matter production was computed as

$$HUE = \frac{\text{Seed yield or total dry matter}}{\text{GDD}}$$

Table 2: GDD, HTU and heat use efficiency of soybean sown on different sowing dates.

	GDD (°C day)	HTU (°C hr)	Total dry matter (kg ha^{-1})	Dry matter HUE (kg ha^{-1} °C^{-1} day)	Seed yield (kg ha^{-1})	Seed yield HUE (kg ha^{-1} °C^{-1} day)
9 May 2004	1861	7799	5318.0	2.8	3148.0	1.6
19 May 2004	1754	6948	4131.8	2.3	2520.0	1.4
29 May 2004	1706	6380	4404.0	2.5	2375.5	1.3
4 May 2003	1926	8670	4609.6	2.3	3547.0	1.8
17 May 2003	1834	7711	4197.1	2.2	2915.0	1.5
27 May 2003	1747	6823	3786.5	2.1	2646.0	1.5
2 May 2002	1936	8670	6888.2	3.5	4411.1	2.2
9 May 2002	1861	7059	6838.1	3.4	4060.7	2.1
12 May 2002	1800	6909	6407.4	3.4	3748.3	2.0
27 May 2002	1768	6697	4524.4	2.5	2608.5	1.5

RESULTS AND DISCUSSION

GDD and HTU for soybean season showed significant correlation with LAI as well as biomass (Table 1). Significant relationship of GDD with LAI was observed for first pod and pod fill stages while, HTU showed significant correlation for first flower stage. The analysis indicates that during reproductive growth period GDD and during vegetative growth stage sunshine duration along with GDD appears to affect soybean leaf growth at Shirol. Accumulated growing degree days at first flower, first pod and pod fill growth stages directly seem to influence the biomass at those stages.

Crop maturity and Agro climatic indices

Table 2 denotes the accumulated GDD and HTU over the soybean growing season. For late sown soybean (27th May and later), less heliothermal units and growing degree days are accumulated for maturity. However, for early sown crop (9th May and earlier) comparatively larger thermal units were needed. Hundal et al. (2003) recorded similar results for the PK 416 and SL 295 soybean varieties sown during kharif seasons of 1997-2000 experiments conducted at Ludhiana.

Total dry matter, seed yield and heat use efficiency

Earlier sown crop produced more dry matter and also resulted in higher seed yields than late-sown crop as they availed more growing degree days. Relatively higher HUE for seed yield was recorded when the crop was sown early. It is important to note that the highest HUE for seed yield as well as biomass was recorded for the earliest sowing of soybean (2nd May 2002) as 2.2 kg ha^{-1} °C^{-1} day and 3.6 kg ha^{-1} °C^{-1} day respectively (Table 2). Heat

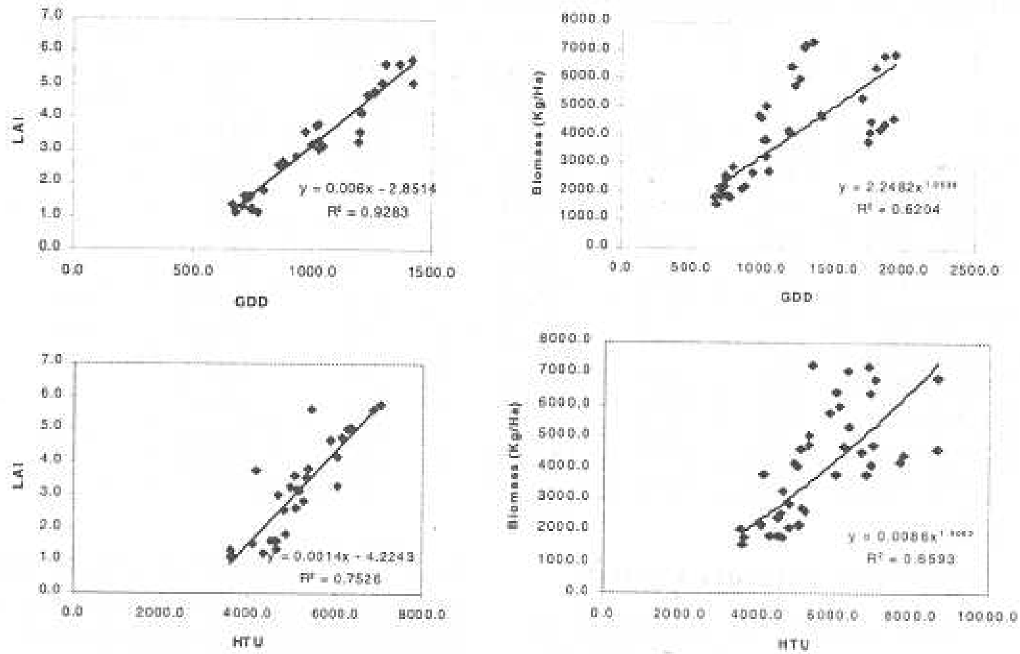

Fig 1: Relationship of GDD and HTU with LAI and biomass

use efficiency decreased with the delay in sowing for all the experiment-years.

Relationship between LAI and total dry matter with agroclimatic indices

Significant linear relationship were observed between LAI and GDD (R^2=0.92); LAI and heliothermal units (R^2=0.75); whereas significant power relationship was noted between total dry matter and GDD (R^2=0.62); total dry matter and HTU (R^2=0.65); as shown in Fig 1. However, influence of HTU on biomass was observed to be non-significant according to sowing time. Seed yield was not found to be correlated with GDD and HTU. It may be noted that Hundal *et al.* (2003) also reported similarly very high relationship (r^2 = ~0.8) of LAI and dry biomass of soybean with GDD and HTU and poor relationship of seed yield with those indices. Hardley *et al.*, (1984), Constable and Rose (1988), Summerfield *et al.*, (1989) and Sinclair *et al.*, (1991) used linear and logistic models based on temperature and photoperiod for predicting flowering date, their r^2 values ranged between 0.8 to 0.9.

CONCLUSION

The salient findings emanated from the analysis of agroclimatic indices and soybean LAI, biomass and seed yield are given below.

- Seasonal biomass is observed to be

the function of accumulated growing degree days.

- Power relationship for biomass whereas linear relationship for LAI with agro climatic indices is reported. Influence of heat units on dry mass accumulation according to the sowing time is significant.

REFERENCES

Bembi, D. K., 1994. Prediction of leaf area indices and yield of wheat. *J. Agril. Sci.*, Cambridge, 122:13-20.

Constable, G. A. and Rose I. A., 1998. Variability of soybean phenology response to temperature, day length, and rate of change in day length. *Field Crops Res.*, 18: 57-69.

Doorenbos, J. & Kassam, A. H. 1979.Yield response to water. *FAO Irrigation Drainage Paper 33*, United Nations, Rome, pp. 193.

Hardley, P., Roberts, E. H., Summerfield, R. J. and Minchin, F. R.1984. Effects of temperature and photoperiod on flowering in soybean [Glycine max (L.) Merrill.]: A quantitative model. *Ann. Bot.*, (London) 53: 669-681.

Hodges, T. and French, V.1985. SOYPHEN: Soybean growth stages modeled from temperature, day length and water availability. *Agron. J.*, 77: 500-505.

Hundal, S. S., Singh, R. and Dhaliwal, L. K.1997. Agroclimatic indices for predicting phenology of wheat (Triticum aestivum) in Punjab. *Indian J. Agri. Sci.*, 67(6): 265-268.

Hundal, S. S., Haroreet Singh, Prabhjyot-Kaur and Dhaliwal, K.2003. Agroclimatic models for growth and yield of soybean. *Indian J. Agric. Sci.*, 73 (12): 668-670.

Hundal, S. S. Pradhjyot-Kaur and Dhaliwal, L. K.2001. Agroclimatic models for predicting growth and yield of rice in Punjab. (*in*) *Proceeding of the fourth Punjab Sciences Congress*, held at the Punjkab Agricultural University, Ludhiyana, during 9-10 February (2001).

Johnson, H. W., Borthwick, H. A., and Leffel, R. C.1960. Effects of photoperiod and time of planting on rates of development of the soybean in various stages of lifecycle. *Bot Gaz.*, 122: 77-95.

Jones, J. W. Boote, K. J., Jagtap, S. S. and Mishoe, J. W.1990. Soybean development. P.71-90. (*in*) J.Hanks and J.T.Ritchie (ed). Modelling plant and soil systems. *Agron Monogr.*, 31. ASA, CSSA, and SSSA, Madison, WI.

Major, D. J., Johnson, D. R., Tanner, J. W. and Anderson, L. C.1975. Effects of day length and temperature on soybean development. *Crop Sci.*, 15: 174-179.

Nuttonson, M. Y.1955. Wheat climate relationships and use of phenology in ascertaining the thermal and photothermal requirements of wheat.

American Inst. crop Ecology. Washington DC.pp 388.

Rao, V. U. M., Singh, D. and Singh, R.1999. Heat use efficiency of winter crops in Haryana. *J. Agrometeorol.* 1(2):143-148.

Sinclair, T. R., Kitani, S., Hinson J Bruniard and Horie, T.1992. Soybean flowering date: linear and logistic models based on temperature and photoperiod. *Crop Sci.*, 31:786-790.

Singh R.S., Ramakrishna., Y.S. and Joshi,N.L.1996. Growth and response of mustard [Brassica juncea (L.) Czern & Coss] to irrigation level in relation to temperature and radiation regimes. *J. Arid Environ.*, 33: 379-388.

Summerfield, R. A., Roberts, E. H. and Lawn, R J.1989. Measurement and prediction of flowering in soybean in fluctuating field environments.p82-87 *(in)* A J Pascale (ed) Proc, *World Soybean Res. Conf.IV*, Realization, Buenos Aires.

L M Thompson, 1969 Weather and technology in the product of corn in the U S corn belt. *Agron. J.*, 61:453-456.

Wang , J., McBlain, B. A., Hesketh, J. K., Wooley, J. T. and Bernard, R. L.1987. A data base for predicting soybean phenology. *Biotronics.*, 16:25-38.

Whisler, F. D., Acock, B., Baker, D. N., Fye, R. E., Hodges, H. F., Lambert, J. R., McKinion, J. M. and Reddy, V. R.1986. Crop simulation models in agronomic systems. *Advances Agron.*, 40: 141-208.