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An assessment of phenology, thermal time and phasic development model of pigeonpea (*Cajanus cajan* L. Millsp.) cv. GT-100

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ABSTRACT

Pigeonpea (*Cajanus cajan* L., Millsp.) Cv. GT-100 matured between 153 to 141 and 149 to 140 days in 1992 and in 1993 respectively in the climate of Anand (22° 35' N; 72° 55' E) depending upon the date of sowing. The thermal units required to reach physiological maturity ranged from 2220 to 2609 day degrees centigrade (°Cd) in 1992, while in 1993 it ranged from 2372 to 2654 °Cd with a coefficient of variation of 5.7%. The thermal units required to attain different phenological periods were worked out and a linear regression model based on the phenophase-wise data was derived for predicting the onset of a particular phenophase of the crop. The onset of phenophase depended upon the available heat units and accounted for 98% of total variation.

Key words: Pigeonpea, Phenophases, Thermal time

Phenology is an essential component of the crop-weather models, which can be used to specify the most appropriate rate and time of specific developmental processes. Increasing appreciation has been shown in recent years for predicting crop development under field conditions (Angus *et al*., 1980). The duration of each growth phase determines the accumulation and partitioning of dry matter in different organs (Dalton, 1967) as well as crop response to enviornmental and external factors. Reaumur was the first to suggest in 1735 that the duration of particular stages of growth was directly related to temperature and this duration for particular species could be predicted using the sum of daily air temperature (Wang, 1960). In view of potential significance of phenological studies on crop-weather interactions, a field experiment on pigeonpea was planned to develop a thermal time based model.

MATERIALS AND METHODS

Field experiments were conducted during rainy *(Kharif)* seasons of 1992 and 1993 at Agronomy Farm of the B.A.College of Agriculture, Anand. The soil of experimental plot was sandy loam having pH 7.6, field capacity 17% and bulk density 1.5 g cm^{-3}. The experiment was laid out in randomized block design with five replications and four dates of sowing D_1 : First date of sowing corresponding to onset of monsoon, and D_2,D_3, and D_4 at 10-day intervals thereafter. The crop was sown with 60X20 cm spacing in a 6.0X4.8m size plot. The crop was fertilized with 25-40-0 kg NPK ha^{-1}.

Growing degree days (GDD) were computed by taking a base temperature of 10°C (Tikka, 1986; Nihalani, 1989). The total sum of degree days for each phenophase was obtained by using the following formula:

$$\text{Accumulated GDD} = \sum_{ds}^{dh} [(\text{Max.T} + \text{Min.T})/2] - \text{Tb}$$

Where,

Max.T : Daily maximum temperature (°C)
Min.T : Daily minimum temperature (°C)
Tb : Base temperature (°C)
ds : Date of sowing or starting date of the phenophase of interest
dh : Date of harvesting or the end of phenophase of interest.

Five plants from the net plot of each of the replicates were selected randomly for periodic identification of phenological events. Whenever more than three plants from each plot attained a particular stage, the date was considered as the one for attainment of stage. The stages identified by Nihalani (1989) were adopted (Table 1). A linear regression model based on the phenophase wise data pooled over four dates of sowing for two crop seasons was derived for predicting the onset of particular phenophase.

RESULTS AND DISCUSSION

Crop Phenology

The calendar for different phenophases of the crop observed during experimentation period is presented in Fig. 1. The number of days taken by the crop for completion of each phenophase varied with the date of sowing. The crop had maturity period ranging from 153 to 141 and 149 to 140 in 1992 and 1993 respectively. The number of days taken to maturity were the highest by the crop sown under D_1 in both the years and consistently decreased with subsequent sowings. Late sowing curtailed the vegetative period i.e., P_1 to P_4 by 8 days with a difference of 30 days in sowing from D_1 to D_4 in both the years. This is in close agreement with the findings of Dhingra *et al.* (1981). The crop sown in D_1 to D_2 treatments had an extended growing season in 1992 as compared to the corresponding treatments of 1993. This is attributable to the prevalence of higher temperatues in 1993

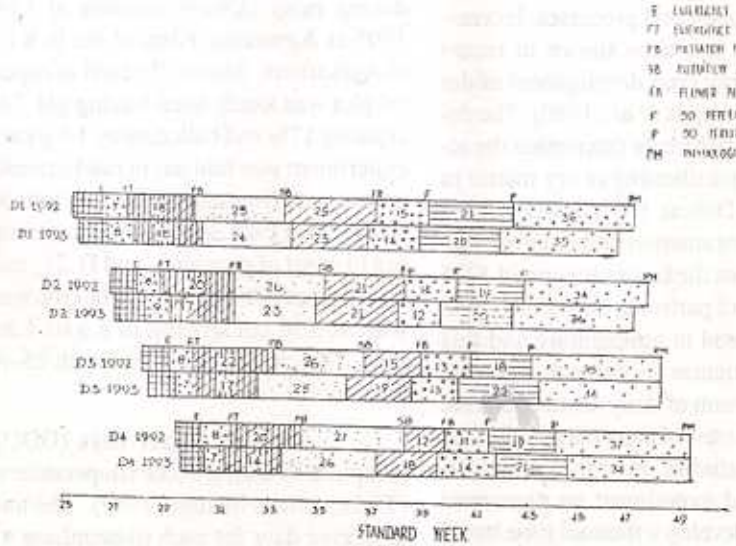

FIG. 1 PHENOLOGICAL CALENDER OF PIGEONPEA CROP

Table 1: Growing degree days (GDD) required to attain various phenophases

Pheno phase	Date of sowing								Mean	SD	CV%
	D1		D2		D3		D4				
	1992	1993	1992	1993	1992	1993	1992	1993			
P_1	150	157	166	165	141	141	148	134	150	10.9	7.3
P_2	359	338	359	334	399	330	367	275	345	36.0	10.4
P_3	449	469	478	449	464	489	478	505	473	19.2	4.1
P_4	447	447	368	407	281	364	241	343	362	73.7	20.0
P_5	274	268	279	227	248	253	196	275	253	28.7	11.4
P_6	396	388	333	388	303	407	307	361	360	41.1	11.4
P_7	534	587	469	569	472	489	483	479	510	46.7	9.2
P_8	1405	1411	1371	1355	1285	1324	1234	1257	1330	77.5	5.9
P_9	670	657	612	616	551	661	502	635	613	58.7	9.6
P_{10}	2609	2654	2452	2539	2308	2473	2220	2372	2453	139.4	5.7

P_1 - Emergence to first trifoliate emergence
P_2 - Emergence of first trifoliate to that of primary branches
P_3 - Emergence of primary branches to that of secondary branches
P_4 - Emergence of secondary branches to flower bud initiation
P_5 - Flower bud initiation to 50 per cent flowering
P_6 - 50 per cent flowering to 50 per cent podding
P_7 - 50 per cent podding to the physiological maturity
P_8 - Emergence to flower bud initiation
P_9 - flower bud initiation to 50 per cent podding
P_{10} - Emergence to physiological maturity

as compared to 1992. In case of D_3 and D_4 however, the reduction in duration of vegetative period caused by high temperatures was apparently balanced by extended flowering period due to occurrence of heavy rain in the 43rd standard meteorological week in 1993, similarly reported by McNaughton *et al.* (1985) and Patel (1992).

Thermal time and crop maturity

Thermal time is widely used for describing the temperature responses to growth and development of crops. Thermal time or GDD requirment for completion of different phenophases of pigeonpea were worked out and presented in Table 1. The thermal units

Table 2 : Actual and predicted calender days required to attain various phenophases

Pheno phase		Date of sowing								Mean	SD	CV%
		D1		D2		D3		D4				
		1992	1993	1992	1993	1992	1993	1992	1993			
P_1	A	7	8	8	9	8	7	8	7	7.8	0.7	9.1
	P	8	9	9	9	7	8	8	7	8.1	0.8	10.2
	D	+1	+1	+1	0	-1	+1	0	0	+0.4		
P_2	A	18	18	20	17	22	17	20	14	18.3	2.4	13.3
	P	20	19	20	18	22	18	20	15	19.0	2.1	10.8
	D	+2	+1	0	+1	0	+1	0	+1	+0.8		
P_3	A	25	24	26	23	26	25	27	26	25.3	1.3	5.1
	P	25	26	27	25	26	27	27	28	26.4	1.1	4.0
	D	0	+2	+1	+2	0	+2	+2	+2	1.1		
P_4	A	25	23	21	21	15	19	12	18	19.3	4.2	21.9
	P	25	25	20	23	16	20	13	19	20.1	4.2	20.9
	D	0	+2	-1	+2	+1	+1	+1	+1	0.9		
P_5	A	15	14	14	12	13	13	11	14	13.3	1.3	9.7
	P	15	15	15	12	14	14	11	15	13.9	1.6	11.2
	D	0	+1	+1	0	+1	+1	0	+1	0.4		
P_6	A	21	20	19	20	18	22	19	21	20.0	1.3	6.5
	P	22	22	18	22	16	23	17	20	20.0	2.7	13.3
	D	+1	+2	-1	+2	-2	+1	-2	-1	0.0		
P_7	A	36	35	34	36	35	34	37	32	34.9	1.6	4.4
	P	30	32	26	32	26	27	27	27	28.4	2.6	9.0
	D	-6	-3	-8	-4	-9	-7	-10	-5	-6.5		
P_8	A	75	73	75	70	71	67	67	65	70.5	4.0	5.7
	P	80	79	77	76	72	73	69	68	74.3	4.5	6.0
	D	+5	+6	+2	+6	+1	+6	+2	+3	3.8		
P_9	A	36	34	33	32	31	35	30	35	33.3	2.1	6.4
	P	37	37	34	34	30	37	28	35	34.0	3.4	9.9
	D	+1	+3	+1	+2	-1	+2	-2	0	0.8		
P_{10}	A	147	142	142	138	137	136	134	134	138.8	4.6	3.3
	P	146	148	137	142	129	137	124	132	136.9	8.3	6.1
	D	-1	+6	-5	+4	-8	+1	-10	-2	1.9		

A= Actual, P= Predicted, D= Deviation

P_1 - Emergence to first trifoliate emergence
P_2 - Emergence of first trifoliate to that of primary branches
P_3 - Emergence of primary branches to that of secondary branches
P_4 - Emergence of secondary branches to flower bud initiation
P_5 - Flower bud initiation to 50 per cent flowering
P_6 - 50 per cent flowering to 50 per cent podding
P_7 - 50 per cent podding to the physiological maturity
P_8 - Emergence to flower bud initiation
P_9 - flower bud initiation to 50 per cent podding
P_{10} - Emergence to physiological maturity

accumulated to reach the physiological maturity ranged from 2220 to 2609 °Cd in the year 1992, while in 1993, they ranged from 2372 to 2654 °Cd in the different treatments. The average value of GDD was 2453 °Cd with a coefficient of variation value of 5.7%. Further, a decreasing trend in accumulated GDD with delayed sowing was noticed as observed by Dhingra *et al*. (1981) earlier. When longer periods (P_8 or P_{10}) are considered for accumulation, standard deviations are high with relatively low C.V. Highest standard deviation with high C.V. is noticed in respect of P_4 during critical stage of bud initiation with respect to dates of sowing.

Phasic development model

A linear regression model based on the phenophase-wise data pooled over four dates of sowing for two years was derived for predicting the onset of any particular phenophase. The regression model so obtained was as given below:

$Y = -0.2314 + 0.056^{**}$ AGDD ($R^2 = 0.98$)

where,

Y = number of days predicted

AGDD = accumulated GDD or thermal units for that particular phenophase.

The model indicated that GDD accounted for 98 per cent variation in the onset of different phenophases. By using this model, the dates required for various phenophases to occur can be predicted by using minimum values of GDD required to reach that particular phenophase. The actual and predicted days for each phenophase as obtained by the model are given in Table 2. The deviations remained in the range of +2 days to -2 days in each phenophase from emergence upto 50 % podding i.e., P_1 to P_6 phases. The deviations were larger (5 to 10 days) in respect of phenophases P_7, P_8 and P_{10} which cover longer periods of accumulation. Higher C.V. values for the actual and predicted days in P_4 phase i.e., emergence of secondary branches to flower bud initiation was probably due to the fact that the rate of progress to flower bud initiation is always associated with both photoperiod and temperature.

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REFERENCES

Angus, J.F., Cunninghom, R.B., Moncur, M.W. and Mackenzil, D.H. 1980. Phasic development in field crops. I. Thermal response in the seeding phase.Field Crops Research, 3: 365-378.

Dalton, L.G. 1967. A positive response of yield on maturity of sorghum. Crop Science, 7: 721-726

Dhigra, K.K., Singh, S. and Tripathi, H.P. 1981. Phenological behaviour and yield of pigeonpea genotypes under different date of planting and row spacings. Proceedings of International Workshop on pigeonpea. Volume 2, 15-19 Dec.1980, ICRISAT, Patancheru, 229-234.

McNaughton, K.G., Gandar, P.W. and McPherson, H.G. 1985. Estimating the effects of varying temperature on the rate of development of plants. Annals of Botany, 56 : 579-595.

Nihlani, A.L. 1989. Assessment of yield of pigeonpea (*Cajanus cajan* L. Milsp.) in

relation to heat units. M.Sc thesis, Gujarat Agricultural University, Anand (unpublished).

Patel, J.R. 1992. Effect of post-monsoon irrigation, biofertilizer and nitrogen level on growth and yield of pigeonpea (Cajanus cajan L.Milsp.) var. BDN-2 in vertisol of south Gujarat. Ph.D. thesis, Gujarat Agricultural University, Navasari (unpublished).

Tikka, S.B.S. 1986. Pigeonpea genetics and improvement. Sharda publishing Academy, Sidhpur, pp. 207-244.

Wang, J.Y. 1960. A critique of the heat unit approach to plant response studies. Ecology, 41: 785-790.