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Thermal time and phenological model for *Brassica juncea*

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ABSTRACT

Field experiments were carried out on the sandy loam soils of the Indian Agricultural Research Institute (New Delhi) farm area with two *Brassica* cultivars Pusa Jaikisan and Varuna which were grown for two consecutive *rabi* seasons (2001-02 & 2002-03) following standard recommended agronomic practices. The crops were sown on ten different dates at weekly interval starting from 1st October to 3rd December to enable the crop to get exposed to different weather conditions during its various phenological stages. The first crop season was relatively warmer than the second season. Pusa Jaikisan matured between 112 to 135 and 118 to 138 in first and second season, respectively. On the contrary, Varuna took 115 to 142 and 122 to 147 days, thus taking 1 to 9 days more to mature in two crop seasons. The thermal time required to attain a given phenological stage decreased as sowing was delayed in both the cultivars and seasons. Based on the thermal time required to attain different phenological events (mean of two seasons data) a "PHENOLOGICAL MODEL" was developed (written in standard 'C' language) to predict the days required to attain various phenophases of the *Brassica* cultivars. The model developed was validated with two independent data sets. The model predicted the different phenological events with less than ± 5 per cent error in 70 percent cases and less than ± 10.5 per cent error in the other cases and seems to be promising in forecasting the phenological events.

Key Words: *Brassica*, Phenology, Thermal time, Phenological model

Brassica is an important oilseed crop in India which contributes 30 per cent of the total oil seed production of the country. This is highly sensitive to weather showing quite diverse patterns of growth and development to different sets of environmental conditions. The rates of crop growth and development are a function of the energy receipt and thermal regime in any given crop-growth season. Phenological development in *Brassica* is known to be altered by photoperiod and temperature, with a general trend of shortening of phase as day length and/or temperature increases. (Mendham and Sailsbury, 1995 and Robertson *et al*., 2002). Only the floral initiation is influenced by both temperature and photoperiod while the duration of other phenological stages is determined only by temperature but not

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Table 1a: Days taken to reach different phenological stages and the coefficient of Variation (CV) in Pusa Jaikisan in the ten sowing dates during *rabi* 2001-02 (I) and 2002-03 (II)

Phenological events		Sowings dates										CV (%)
		P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	
Emergence	I	6	5	6	6	5	6	7	7	8	8	16.7
	II	6	6	6	6	6	7	7	8	9	9	17.8
1st flower	I	36	38	40	43	46	47	50	51	56	57	15.6
	II	37	38	39	43	46	47	49	61	63	62	20.8
50% flowering	I	39	42	44	48	52	53	57	59	63	64	16.8
	II	40	42	43	49	52	54	58	69	69	69	20.9
90 % podding	I	72	76	81	86	89	89	90	89	87	85	7.3
	II	77	80	82	88	90	90	91	93	94	90	6.6
End of seed filling	I	120	122	125	124	123	121	118	113	108	103	6.3
	II	126	127	127	128	126	122	120	117	115	109	5.2
Maturity	I	135	137	139	137	135	132	129	123	117	112	7.1
	II	138	140	140	141	139	134	130	127	124	118	6.0

photoperiod. (Myers *et al.*, 1982). There is no response of photoperiod in flower bud initiation when photoperiod is shorter than 12 hours However, under Indian conditions, photoperiodically sensitive bud visible stage of *Brassica* crop always occurs before 21 March, when the increasing photoperiod first exceeds 12 hours. Therefore duration of developmental phases of the crop grown under field conditions are generally determined solely by temperature and so, within a species, require the same thermal time for completion of the phenophases (Nanda *et al.*, 1996).

Thermal requirement for attaining different phenological stages of *Brassica* crop was found to be varying from variety-to-variety (Chand *et al.*, 1995) as well as from species to species (Kar and Chakravarty, 1999). The thermal units

Table 1b: Days taken to reach different phenological stages and the coefficient of Variation (CV) in Varuna in the ten sowing dates during *rabi* 2001-02 (I) and 2002-03 (II)

Phenological events		Sowings dates										CV (%)
		P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	
Emergence	I	6	6	6	6	6	7	7	7	8	8	12.3
	II	6	6	6	7	7	7	8	8	9	9	15.9
1st flower	I	37	38	41	47	48	52	56	57	59	60	17.5
	II	38	39	40	46	[illegible]	51	62	65	64	65	21.7
50% flowering	I	43	45	48	53	55	59	65	66	67	68	16.7
	II	45	46	47	54	56	62	75	76	74	74	21.3
90 % podding	I	76	78	81	86	90	93	94	90	88	87	7.1
	II	77	80	81	89	92	93	99	98	93	92	8.5
End of seed filling	I	125	126	125	123	122	120	119	113	109	105	6.1
	II	130	129	128	127	127	124	123	121	114	111	5.2
Maturity	I	142	143	141	139	137	134	131	124	120	115	7.4
	II	147	146	144	143	141	137	136	133	125	122	6.3

accumulated for attaining different phenological events of same cultivar decrease gradually as sowing delayed from normal sowing time (Kar and Chakravarty, 1999 and Kanth *et al.* 2000). In view of potential significance of phenological studies on crop simulation studies, the present study was undertaken to develop a model to predict different phenophases based on thermal time.

MATERIAL AND METHODS

The experiment was conducted in two *rabi* seasons (2001-02 & 2002-03) on the sandy loam soils of research farm of Indian Agricultural Research Institute, New Delhi (28°35'N, 77°10'E and 288.7 m AMSL). The climate of the station is semi arid with hot dry summers and cold winters.

Two *Brassica* cultivars *viz.* Pusa Jaikisan and Varuna were sown on ten different dates at the interval of 7 days starting from 1st October to 3rd December to enable the crop to get exposed to different weather conditions during its various phenological stages. The experiment was laid out in randomized block design with two replications and the other recommended cultural practices are followed.

Based on visual observations,

Table 2a: Accmulated growing degree-days in Pussa Jaikisan under different sowings during *rabi* 2001-02 (I) and 2002-03 (II).

Phenological events		Sowing dates										CV
		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	(%)
Emergence	I	137	113	121	125	112	111	111	108	98	98	10.5
	II	111	111	104	91	96	99	88	98	88	83	9.9
1st flower	I	759	747	732	718	695	648	594	536	537	517	14.7
	II	747	717	683	665	640	607	567	557	521	509	13.3
50% flowering	I	809	810	789	780	758	701	659	611	598	575	13.0
	II	799	775	734	730	707	676	627	612	584	568	11.8
90% podding	I	1299	1220	1156	1113	1050	975	916	857	825	799	17.0
	II	1255	1214	1126	1032	959	912	884	851	850	821	16.1
End of seed filling	I	1683	1586	1522	1462	1397	1332	1263	1184	1107	1050	15.4
	II	1628	1535	1450	1412	1365	1262	1215	1163	1151	1090	13.5
Maturity	I	1845	1762	1698	1632	1567	1498	1442	1352	1260	1207	14.0
	II	1754	1679	1621	1589	1531	1433	1371	1338	1320	1264	11.3

phenological - emergence, first flower appearance, 50% flowering, 90% podding, end of seed filling, and maturity were identified following the criteria adopted by the Kar (1996).

Growing degree-day was computed with base temperature as 5°C following Kar and Chakravarty (1999). The mean cumulative heat units accumulation during two *rabi* seasons to attain different phenological events of Pusa Jaikisan and Varuna were computed grouping early (1st Oct to 14th Oct), normal (15th to 30th Oct), late (1st Nov to 20th Nov) and very late (>20th Nov) sown crops and these data were used for developing the phenological model.

RESULTS AND DISCUSSION

Crop phenology

As can be expected, the number of days taken to complete each phenophase varied with cultivars and with dates of sowing (Table 1a and 1b). Pusa Jaikisan matured between 112 to 135 and 118 to 138 days in 2001-02 and 2002-03, respectively in crops sown on various dates. On the contrary, Varuna took 115 to 142 and 122 to 147 days, thus taking 1 to 9 days more to

Table 2b: Accmulated growing degree-days in Varuna under different sowings during *rabi* 2001-02 (I) and 2002-03 (II).

Phenological events		Sowing dates										CV
		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	(%)
Emergence	I	140	134	121	125	112	126	111	108	99	98	12.1
	II	111	111	104	109	114	99	103	98	87	83	10.2
1st flower	I	772	748	747	767	718	684	633	590	556	536	13.3
	II	764	731	696	695	675	659	636	593	534	530	12.1
50% flowering	I	879	856	837	841	779	743	712	663	622	605	13.3
	II	874	833	778	779	763	738	711	682	623	612	11.4
90% podding	I	1323	1238	1156	1113	1063	1006	948	867	825	821	16.8
	II	1255	1214	1120	1037	983	925	939	904	835	850	14.6
End of seed filling	I	1718	1622	1522	1445	1384	1321	1280	1184	1122	1082	15.5
	II	1654	1553	1475	1398	1377	1288	1251	1231	1134	1127	12.9
Maturity	I	1895	1839	1738	1664	1597	1531	1480	1368	1309	1260	13.9
	II	1863	1739	1678	1616	1565	1486	1484	1458	1341	1347	10.8

mature in two crop seasons. The number of days taken to maturity was the highest by both the cultivars in four early sowings in both the years and consistently decreased with subsequent sowings. Early sowings caused reduction of vegetative period by 7 days but prolonged the pod development period 8 days. Late sowing increased the vegetative growth period by 13 days, while pod growth period was reduced sharply by 26 days in both the cultivars and seasons. This is in close agreement with the findings of Kar and Chakravarty (1999). In *Brassica*, in spite of reduction of seed yield due to shorter vegetative growth period, early sowings are advisable under rain fed conditions for better utilization residual soil moisture. In the second season, when the temperatures were relatively lower, both the cultivars took more time to reach the various physiological stages (except seedling emergence) as compared to the first season.

Thermal time and crop phenophases

The thermal units required for attaining maturity in Pusa Jaikisan ranged from 1207 to 1845°D in the first season, while in the second season, they ranged from 1264 to 1754°D in different sowing dates (Table 2a and 2b). In Varuna, the degree-days varied from 1260 to 1895°D

Table 3: Thermal requirement (°D) of *Brassica* crop for attaining different Phenophases.

Phenological events	Sowing time							
	Early (1st to 14th Oct)		Normal (15th to 30th Oct)		Late (1st to 20th Nov)		Very late (After 20th Nov)	
	Pusa Jaikisan	Varuna	Pusa Jaikisan	Varuna	Pusa Jaikisan	Varuna	Pusa Jaikisan	Varuna
Emergence	118	124	108	119	108	115	98	99
1st flower	742	755	688	744	585	636	527	546
50% flowering	799	854	750	819	643	693	582	614
90% podding	1247	1254	1075	1110	899	940	806	823
End of seed filling	1607	1636	1434	1450	1237	1262	1079	1102
Maturity	1760	1834	1606	1660	1406	1480	1234	1285

and 1347 to 1863°D in the first and second season, respectively. The mean coefficient of variation of GDD accumulated in different phenophases ranged from 9.9 to 17.2 and 10.1 to 16.7 in Pusa Jaikisan and Varuna, respectively. A decreasing trend in accumulated GDD for attaining any phenological events was observed with successive delay in sowings in both the cultivars and the seasons. These results are supported by the findings of Chand *et al*., (1995)

Development of phenological model

A "PHENOLOGICAL MODEL OF BRASSICA" was written in standard "C" language and was compiled using Turbo C++ IDE. The programme has two input data files- weather file and crop file. Daily weather data (mean temperature or GDD) may be given in weather file. The programme computes or reads GDD values in the weather file from the very first day of sowing and keeps on accumulating. Crop data file contains the thermal units accumulated for attaining different phenophases of the crop. The thermal unit accumulation in early, normal, late and very late sown crop are given separately for the cultivars. The crop data used in the model are presented in the Table 3.

Validation of the model

The model thus developed was validated with two independent data sets (personal communication, unpublished) generated from the field experiments during two successive *rabi* seasons (2000-01 & 2001-02) in adjoining field. A comparison between the observed and predicted days required to reach the phenological stages (first flowering, 50% flowering, end of seed

Table 4: Actual (A), predicted (P) and percent deviation (D) from observed day required to attain various phenophases of Pusa Jaikisan and Varuna during *rabi* 2000-01 and 2001-02.

Phenophases		Pusa Jaikisan		Varuna	
		1st October	15th October	1st October	15th October
2000-01					
1st flower	A	33	39	37	42
	P	36	38	36	41
	%D	+ 9.0	- 2.6	- 2.7	- 2.4
50% flowering	A	43	49	48	53
	P	39	44	44	48
	%D	- 9.3	- 10.2	- 8.3	- 9.4
End of seed filling	A	119	118	130	128
	P	124	119	124	120
	%D	+ 4.2	+ 0.9	- 0.9	- 6.3
Maturity	A	135	132	148	141
	P	133	133	143	137
	%D	-1.5	+ 0.8	- 4.6	- 2.8
2001-02					
1st flower	A	32	42	37	42
	P	35	40	38	44
	%D	+ 9.4	- 4.8	+ 2.7	+ 4.8
50% flowering	A	45	52	49	57
	P	45	47	45	51
	%D	0.0	- 9.6	- 8.2	-10.5
End of seed filling	A	124	122	138	128
	P	124	125	138	126
	%D	0.0	+ 2.5	0.0	- 0.6
Maturity	A	141	138	156	154
	P	133	138	149	146
	%D	- 5.6	0.0	- 4.5	- 5.2

filling and maturity) revealed that in both the seasons in most of the cases deviation of predicted values from observed values was less than ± 10 percent (Table 4). This suggests that the crop data file used in the model is reasonably appropriate. However, inclusion of field data for more numbers of seasons will improve the model. Thus, the thermal time based model developed based on the present field experiments might be useful to predict the occurrence of the phenological events in Brassica cultivars with reasonable accuracy and hold promise for future use.

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