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Phenological stages and growth dynamics of *Brassica* as influenced by weather

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ABSTRACT

Brassica crop was sown during two *rabi* seasons 1993-94 with 3 cultivars (*Brassica napus* cv. B. O. 54, *Brassica Juncea* cv. Bold and *Brassica compestris* cv. Toria-T-9) on three dates at 14 days interval to assess the growth and yield fluctuaton with term variation of weather. The above ground biomass, leaf area index, pod area index, crop growth rate, harvest index, intercepted photosynthetically active radiation (IPAR) were computed to study the growth dynamics in relation to weather fluctuations. Results show that above ground biomass production, leaf and pod area index, crop growth rate, harvest index and radiation interception were highly affected by delayed sowing particularly for cultivar B. O. 54 and Pusa Bold but not significantly affected cultivar Toria-T-9. Pod formation and seed filling stage of late sown crop experienced 3-4 °C higher temperature and 2-2.5 mm higher evaporative demand which have reduced dry matter partitioning and radiation utilization efficiency of the late sown cultivars.

Key words : Phenology, Brassica, Growth dynamics, IPAR

Brassica is one of the major crop in India and its productivity is largely influenced by enviornmental factors mainly temperature and radiation. Even under optimum and unlimited irrigated conditions, variation of temperature mainly influences the growth and development of this crop because most of the biological and physiological processes are known to be markedly affected by temperature (Prasad 1989). Grain yield is the product of radiation interception, coversion effiency of intercepted radiation to dry matter and partitioning (Monteith, 1977 Jarwal and Singh 1990). *Brassica*, being a cool season crop, 3-4°C higher temperature during pod formation and seed filling stage affects crop growth and yield (Bose 1973, Polwick and Sawhney 1988). Influence of planting dates, temperature on growth, above dry biomass production, radiation interception and yield of Brassica oilseed crop in a semi-arid enviornment are reported in this paper.

MATERIALS AND METHODS

The experiment was conducted in two *rabi* seasons (1993-94 and 1994-95) at research station of Indian Agricultural Research Intitute, New Delhi (Lat. 28°35' N, Long. 77° 10' E and altitude of 228.7m above mean sea level). Three Brassica oilseed species (*Brassica napus* cv. B.O.54, *Brassica juncea* cv. Pusa Bold and *Brassica campestris* cv. Toria-T-9) were sown

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following the recommended package and practices. All the species were sown on three dates at 14 days interval starting from third week of October to create different crop growth envionments. The following phenololgical events were identified by observing the plants on every alternate day. (i) Emergence : The day when 50 per cent germination of seedlings took place in a plot. (ii) First flower appearance: The day when the apical bud opened into the first flower. (iii)50% flowering: The day when 50 per cent of plants in a plot produced flowers. (iv) 90 % podding : The stage when pods have already set in 90 per cent plants coinciding with the beginning of seed filling identified by opening the pod and pressing the seed. (v) End of seed filling : The stage when no further pod growth took place and pods started turning yellow. (vi) Maturity : The time when 90 per cent of pods in a plot dried, the seeds hardened, turned into brown colour and crop was ready for harvest. For studying plant growth parameters like leaf area index, pod area index, crop growth rate etc., the plant samples were taken at weekly intervals. The leaf area was measured using leaf area meter (LI-3100) and surface area of pod was determined with the help of formula (Area=length x diameter), considering the shape of the pod nearly cylindrical. The leaf area index (LAI) and pod area index (PAI) were computed considering the number of plants per square meter was 22.

$$LAI = \frac{\text{measured leaf area per plant (cm}^2\text{)x22}}{100 \times 100\ (\text{cm}^2)}$$

$$PAI = \frac{\text{measured pod area per plant (cm}^2\text{)x22}}{100 \times 100\ (\text{cm}^2)}$$

The above-ground dry biomass production by the different cultivars was analysed and the crop growth rate was computed using the relationship,

$$CGR\ (g\ m^{-2}\ day^{-1}) = (DW_2 - DW_1)/(t_2 - t_1)$$

Where

DW_1 and DW_2 are the above ground biomass of the crop from unit area ($g\ m^{-2}$) collected at days t_1 and t_2 ($t_2 > t_1$).

A line Quantum Sensor with an Integrator (LI-188B) was used to measure the photosynthetically active radiation, PAR (400-700nm) at canopy level and its interception. The intercepted PAR (expressed as percentage of the incident PAR) was determined using the following relationship :

Intercepted PAR by whole canopy = $I_C - R_C - T_R + R_R$ where, I_C = incident PAR on the canopy, R_C = reflected radiation by the canopy, obtained from an inverted sensor 50 cm above the canopy. T_R = transmitted radiation through the canopy, measured by keeping the sensors on the ground across the rows diagonally. R_R = reflected radiation from the ground, measured by holding the sensors in the inverse position at 5 cm above the ground.

RESULTS AND DISCUSSION

Weather and phenological stages

The weather conditions of both the seasons are presented in Figure 1. It was observed that in the first crop season, the maximum and minimum temperatures were 3 to 3.5°C higher during vegetative and grain filling stage (90% podding to end of seed filling) as compared to second season. The pan evaportion and saturation deficit were also higher from pod initiation to pod maturity period during grain filling stage of first season. Table 1 shows that duration of all the cultivars was shortened with delayed

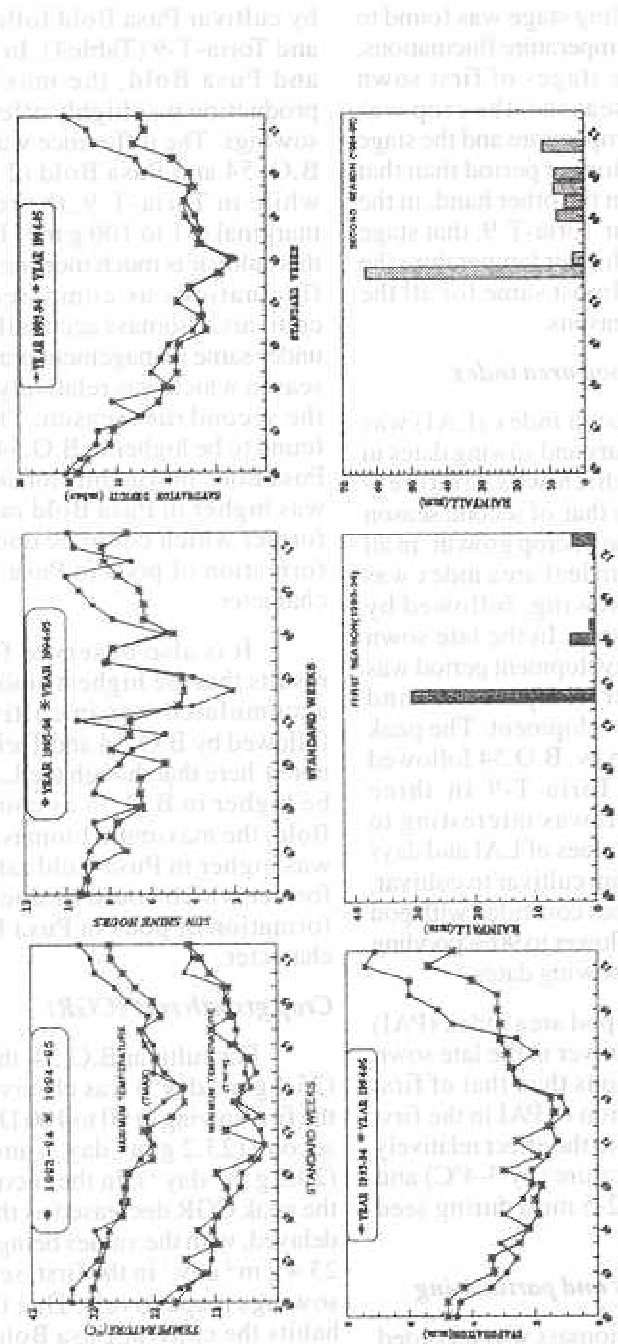

Fig. 1: Weather conditions during crop growth period of two seasons

sowing. The grain filling stage was found to be most sensitive to temperature fluctuations. During grain filling stages of first sown plants for both the seasons, the crop was subjected to cooler temperature and the stage continued for a little longer period than that of late sown crops. On the other hand, in the short duration cultivar Toria-T-9, that stage was little affected by higher temperature the duration remained almost same for all the sowings in both the seasons.

Leaf area index and pod area index

The peak leaf area index (LAI) was lower for all the cultivars and sowing dates in the *rabi* 1993-94 which was relatively warmer (2 to 3°C) than that of second season during vegetative phase of crop growth. In all the cultivars maximum leaf area index was attained in the first sowing, followed by second and third sowing. In the late sown crop, peak leaf area development period was subjected to higher temperature and restricted leaf area development. The peak LAI was the highest in cv. B.O.54 followed by Pusa Bold and Toria-T-9 in three respective sowings. It was interesting to observe that the peak values of LAI and days occurrence differed from cultivar to cultivar, the maximum LAI values coincided with pod formation stage (50% flower to 90% podding stage), irrespective of sowing dates.

In general peak pod area index (PAI) values (Table 3) were lower in the late sown crop for both the seasons than that of first sown crop. The reduction of PAI in the first season was attributable to the effect relatively higher average temperature (by 3-4°C) and evaporative demand (2-5 mm) during seed filling stage.

Above ground biomass and partitioning

The maximum biomass was recorded by cultivar Pusa Bold followed by B.O.54 and Toria-T-9 (Table4). In cultivar B.O.54 and Pusa Bold, the maximum biomass production was highly affected by delayed sowings. The difference was appreciable in B.O. 54 and Pusa Bold (217 to 379 g m^{-2}) while in Toria-T-9, the reductions were marginal (41 to 106 g m^{-2}) It is inferred that this cultivar is much more resistant to thermal fluctuations as compared to other two cultivars. Biomass accumulation was lower under same management practices in the first season which was relatively warmer than in the second *rabi* season. Though LAI was found to be higher in B.O.54 as compared to Pusa Bold, maximum biomass accumulation was higher in Pusa Bold rather than in the former which could be due to the profuse formation of pods in Pusa Bold-a genetic character.

It is also observed from the above results that the highest amount of biomass accumulated was in cultivar Pusa Bold followed by B.O. 54 and Toria T-9. It is to be noted here that though the LAI was found to be higher in B.O.54 as compared to Pusa Bold, the maximum biomass accumulation was higher in Pusa Bold rather than in the former which could be due to the profuse formation of pods in Pusa Bold-a genetic character.

Crop growth rate (CGR)

For cultivar B.O.54, the highest CGR (25.1 g m^{-2} day^{-1}) was observed (Table 5) in the first sowing at 90 to 100 DAS folowed by second (23.2 g m^{-2} day^{-1}) and third sowing (20.2 g m^{-2} day^{-1}). In the second season also the peak CGR decreased as the sowing were delayed, with the values being 28.3, 26.3 and 23.4 g m^{-2} day^{-1} in the first, second and third sowings respectively. Due to profuse pod habits the cultivar Pusa Bold recorded the

Table 1 : Phenological stages as influenced by sowing dates during first and second *rabi* season (1993-97 and 1994-95)

Phenological Stages	Season	B.O.54 P1	B.O.54 P2	B.O.54 P3	B.O.54 S.E.m(±)	Pusa Bold P1	Pusa Bold P2	Pusa Bold P3	Pusa Bold S.E.m(±)	Toria-T9 P1	Toria-T9 P2	Toria-T9 P3	Toria-T9 S.E.m(±)
Emergence	I	09(09)	05(05)	06(06)	1.20	06(06)	05(05)	06(06)	0.33	08(08)	06(06)	05(05)	0.80
	II	07(07)	07(07)	06(06)	0.33	06(06)	05(05)	06(06	0.33	05(05)	05(05)	04(04)	0.33
First flower	I	46(37)	44(39)	45(39)	0.67	49(44)	43(37)	47(41)	2.02	34(26)	35(29)	30(25)	1.50
	II	49(42)	46(39)	43(37)	1.50	46(40)	42(37)	41(35)	1.45	35(30)	33(28)	31(27)	0.88
50%Flowering	I	70(24)	68(24)	65(20)	1.13	61(12)	59(16)	57(10)	1.80	45(11)	45(10)	40(10)	0.33
	II	68(19)	68(22)	65(22)	1.00	59(13)	53(11)	51(10)	0.88	46(11)	42(9)	40(9)	0.66
90% Podding	I	115(45)	107(39)	101(36)	1.30	104(43)	101(42)	102(45)	0.80	81(36)	81(36)	77(37)	0.33
	II	115(47)	104(36)	107(42)	3.17	97(38)	92(39)	89(38)	0.33	78(32)	81(39)	75(35)	2.02
End of Seed Filling	I	135(20)	125(18)	116(15)	1.50	124(20)	121(20)	113(11)	3.00	98(17)	97(16)	92(15)	0.58
	II	138(23)	137(17)	122(15)	2.40	122(25)	115(23)	106(17)	1.40	99(21)	103(22)	95(20)	0.57
Maturity	I	149(14)	141(16)	129(13)	0.88	138(14)	135(14)	124(11)	1.00	114(16)	111(14)	160(14)	0.66
	II	152(14)	144(13)	34(12)	0.58	144(22)	137(22)	127(21)	0.33	119(20)	119(20)	118(15)	1.66

Values in parenthesis indicate the number of days between two successive stages
P1 = Frist sowing P2 = Second sowing & P3 = Third sowing
I.- Season 1993-94 and II - Season 1994-95. S.E.m(±) : Standard Error of Mean

Table 2 : Computed leaf area index as influenced by cultivars and sowing dates in the first and second crop season (1993-94 & 1994-95)

Season		B.O.54				Pusa Bold				Toria-T9			
	DAS	P1	P2	P3	S.E.m(±)	P1	P2	P3	S.E.m(±)	P1	P2	P3	S.E.m(±)
I	30	0.49	0.31	0.21	0.08	0.32	0.42	0.42	0.03	0.29	0.31	0.29	0.06
II	30	0.40	0.40	1.40	0.33	0.50	0.55	0.50	0.03	0.40	0.35	0.46	0.03
I	45	1.63	0.51	2.30	0.25	1.50	1.75	0.85	0.29	1.31	1.20	0.50	0.25
II	45	1.00	2.00	2.10	0.35	1.70	1.35	1.15	0.16	1.15	1.30	1.10	0.03
I	60	4.30	2.80	3.20	0.44	3.50	2.20	1.80	0.51	2.30	2.20	1.70	0.19
II	60	4.10	2.80	3.00	0.40	2.10	3.00	3.10	0.32	2.70	2.90	3.50	0.24
I	75	6.10	5.70	4.10	0.61	5.80	5.10	2.90	0.87	3.60	3.30	2.70	0.26
II	75	6.80	5.40	4.40	0.69	5.70	5.10	3.90	0.53	3.70	3.00	2.50	0.35
I	90	7.01	6.60	5.70	0.39	6.10	6.00	5.10	0.32	2.10	1.90	0.60	0.47
II	90	7.20	5.90	5.40	0.53	6.90	5.20	4.30	0.76	1.10	1.00	1.70	0.22
I	105	5.40	4.10	4.70	0.38	4.30	3.80	2.10	0.66	1.10	0.90	0.30	0.24
II	105	4.70	3.40	3.10	0.49	4.50	3.90	3.30	0.35	0.50	0.70	0.40	0.03

Table 3 : Computed pod area index as influenced by cultivars and sowing dates in first and second crop season (1993-94 & 1994-95)

Season		B.O.54				Pusa Bold				Toria-T9			
	DAS	P1	P2	P3	S.E.m(±)	P1	P2	P3	S.E.m(±)	P1	P2	P3	S.E.m(±)
I	75	0.54	0.60	0.70	0.03	6.00	0.91	0.90	0.10	1.6	0.85	0.65	0.29
II	75	0.90	0.78	0.81	0.03	0.75	0.79	0.79	0.93	1.1	0.09	0.95	0.03
I	90	0.91	1.10	1.10	0.03	1.75	2.00	1.30	0.20	2.1	1.90	1.90	0.03
II	90	1.20	1.00	1.60	0.03	2.01	1.75	1.50	0.18	1.1	1.55	1.05	0.02
I	105	1.81	1.95	1.95	0.10	3.00	2.70	2.30	0.20	2.2	2.00	1.95	0.03
II	105	2.40	2.95	1.95	0.28	3.10	2.70	2.40	0.29	2.3	2.20	2.20	0.03
I	120	2.40	2.10	1.90	0.14	2.80	2.40	2.00	0.23	...	...	...	...
II	120	2.50	2.10	2.00	0.15	3.10	2.90	2.40	0.23	...	...	...	...

Table 4 : Above ground dry biomass production (gm^{-2}) as influenced by sowing dates and cultivars in the first and second crop season (1993-94&1994-95)

Season		B.O.54				Pusa Bold				Toria-T9			
	DAS	P1	P2	P3	S.E.m(±)	P1	P2	P3	S.E.m(±)	P1	P2	P3	S.E.m(±)
I	45	102	883	803	6.2	126	101	161	18.9	131	146	178	13.7
II	45	265	131	202	38.7	203	169	117	25.0	192	198	170	8.5
I	60	248	236	201	14.3	338	245	280	27.1	235	265	265	298
II	60	465	325	203	76.0	548	401	353	126.4	345	360	345	4.9
I	75	645	535	428	63.6	731	435	488	91.0	506	504	498	2.3
II	75	893	678	499	113.8	993	775	575	120.7	603	595	545	18.1
I	90	1225	1013	823	116.1	1131	988	930	59.7	843	768	723	35.0
II	90	1246	1011	811	125.7	1571	1206	1187	124.9	852	808	788	18.9
I	105	1690	1538	1473	64.3	1815	1689	1280	161.4	1206	1168	1165	13.2
II	105	1852	1766	1473	114.7	1776	1696	1501	81.6	1293	1275	1187	32.7
I	120	1645	1546	1423	64.2	1708	1604	1389	93.9	1133	1132	1132	3.2
II	120	1801	1696	1401	119.7	1870	1661	1498	107.6	1271	1220	1170	29.2

P1 = First sowing P2 = Second Sowing P3 = Third sowing

I - First season (1993-94) and II - Second season (1994-95) S.E.m(+) : Standard Error of Mean highest growth rate in all the sowings. In the first season the maximum CGR values attained by this cultivar were 29.4, 25.3 g m^{-2} day^{-1} for first, second and third sowings, respectively. In the second season, this cultivar recorded slightly higher CGR as compared to first with the peak values being 34.8, 30.2 and 25.8 g m^{-2} day^{-1} in the three respective sowings. For cultivar Toria- T-9, during the first season, the peak CGR values were 23.8, 23.3 and 20.3 g m^{-2} day^{-1} in the three respective sowings. The CGR for the second season yielded maximum values of 25.8, 24.8 and 23.3 g m^{-2} day^{-1} for first, second and third sown plants, respectively.

Grain yield

During *rabi* 1993-94 crop season, the grain yield of three *Brassica* spp. ranged between 20.1 q ha^{-1} in the first sowing of Pusa Bold to 13.7 q ha^{-1} in the third sowing of toria-T-9. (Table 5). In the cultivar B.O.54, the yield reductions in second and third sowings were 9.8 and 29.8 per cent, respectively over the first sowing of firsr season, whereas in Pusa Bold, the yield reductions were 12.9 and 23.3 per cent in two late sown plants (3rd and 16th November). In the second season also, the yield decreased with delay in sowing by 7.6 per cent in second sowing and 17.4 per cent in the third sowing over the first. In contrast to cultivars B.O. 54 and Pusa Bold, the magnitude of reduction in yield due to delayed sowing was marginal (Table 5). Yield due to late sowing was significantly affected ($P<0.05$) for cultivar B.O. 54 and Pusa Bold. This could probablly be because of higher temperature that prevailed at seed filling and maturity phases of late sown crops. In cultivar Toria-T-9, the yield reductions because of late sowing was not much appreciable. Hence, it could be concluded that grain yield of Toria-T-9, was not affected by short term fluctuations of weather which matured before onset pre-summer warm conditions.

Harvest index (HI)

The values of harvest index (HI) of three *Brassica* cultivars as influenced by different planting dates in the two *rabi* seasons under investigation are presented in Table 5. The first sown crop attained higher HI (26.5%) followed by second (26.1%) and third sowings (21.9%). Pusa Bold also recorded higher HI (33.5%) in first sowing, followed by second (32.2%) and third sowings (26.6%). During rabi 1994-95, the HI of three Brassica cultivars ranged from 36.3% in the first sowing of Toria-T-9 to 22.9% in the third sowing of B.O.54. Like *rabi* 1993-94, in this season also there was reduction in HI in the second and third sowings of each cultivar when compared to the first sown crop. The reductions were much appreciable in cultivar B.O. 54 and Pusa Bold, whereas in Toria-T-9 rductions were marginal.

Intercepted photosynthetically active radiation (IPAR)

It is revealed that in first crop season the maximum interception by whole canopy ranged between 81 and 92 per cent in the first sowing of Pusa Bold. In second season the maximum interception ranged between 80 in last sown Toria-T-9 to 84 per cent in the first sown Pusa Bold. It was observed that long duration cultivar B.O.54 and medium duration cultivar Pusa Bold intercepted higher amount of PAR as compared to Toria-T-9, which might be attributed to the higher value of LAI, higher biomass production and longer crop duration of the former varieties. It could be seen that though LAI in Pusa Bold was lower than that B.O. 54, the PAR interception was higher in the former because of profuse habit which played a significant

Table 5: Mean peak CGR (g m^{-2} day^{-1}), peak yield (q ha^{-1}) and harvest index (%). during two *rabi* seasons (1993-94 to 1994-95 as influenced by sowing dates.

Cultivars	First sowing		Second sowing		Third sowing	
	1993-94	1994-95	1993-94	1994-95	1993-94	1994-95
Peak CGR						
B.O. 54	25.1	28.3	23.2	26.3	20.2	23.4
Pusa Bold	29.4	34.8	25.3	30.2	23.3	25.8
Toria-T_9	23.8	25.4	23.3	24.8	20.3	22.3
Peak yield						
B.O. 54	17.3	18.3	15.6	16.9	12.2	13.9
Pusa Bold	20.1	19.5	17.5	18.0	15.4	16.1
Toria-T_9	14.6	15.2	14.5	14.9	13.7	13.9
Harvest index						
B.O. 54	26.5	28.3	26.1	25.2	21.9	22.9
Pusa Bold	33.5	32.3	32.2	33.1	26.2	27.5
Toria-T_9	34.0	36.3	32.1	34.2	32.0	43.3

role in PAR interception enen after occurrence of leaf senescence. As could be expected, maximum PAR interception did not coincide with the time of occurrence of maximum LAI, unilike in cereals. In all the sowings of each cultivar, maximum PAR interception corresponded to the seed filling to early maturity period of crop growth, because by that time the leaf area stopped increasing, the pods occupy a reasonable space covering the ground and intercepted sufficient radiation up to pods occupy a reasonable space covering the ground and intercepted sufficient radiation up to early maturity phase.

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