Indian J. Plant Physiol., Vol. 8, No. 4, (N.S.) pp. 349-353 (Oct.-Dec., 2003)

ENVIRONMENTAL PARAMETERS INFLUENCING PHENOLOGICAL DEVELOPMENT OF MUSTARD IN RELATION TO YIELD

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Received on 9 Oct., 2002, Revised on 7 Nov., 2003

SUMMARY

Experiments were conducted during rabi 1993-94, 94-95 and 96-97 to ascertain the effect of environmental parameters and their derivatives viz., mean temperature, growing degree days (GDD), sunshine hours and heliothermal units (HTU) on phenological development, growth and yield of mustard (*Brassica juncea* (L) Czern). Two genotypes of mustard, viz. Kranti and Vaibhav were sown at intervals of ten days starting from October 1 to December 10 (total 8 sowings). Daily maximum and minimum temperatures and sunshine hours were used to calculate GDD and HTU. Optimum sowing dates for mustard were between October 31 to November 20 for achieving maximum yield. The latter was positively correlated with total dry matter production. Multiple regression analysis between duration of growth as dependent variable and sunshine hours, HTU, GDD, and mean temperature during that phase as independent variables yielded correlation coefficient (R^2) values ranging from 0.966 to 0.989. Partial correlation revealed negative correlation between duration of growth and HTU or mean temperature. However, GDD and HTU were found to be positively associated with the duration between successive phenophases. It has been inferred that phenological developmental pattern of mustard regulates its yield and the former is regulated by environmental variables, which could be explained on the basis of GDD. Late sowing of mustard retarded yield by adversely altering reproductive growth.

***Key words*: *Brassica juncea*, growing degree-days, heliothermal units, mustard, phenology.**

INTRODUCTION

Mustard is grown as a winter crop in India, Pakistan and Bangladesh. The optimum sowing date of the crop is between October and November depending upon the specific region (Krishnamurthy 1986). Under normal sown condition, a greater part of the vegetative phase is completed when atmospheric temperature is relatively high, but during flowering, temperature is low and later on as the crop reaches maturity, the temperature and photoperiod gradually increase (Nanda *et al.* 1995). The duration of vegetative phase and time of the season at which seed development commences have been reported to be important determinants of yield (Thurling and Das 1980). Delay in sowing shortens vegetative phase, advances flowering time and reduces dry mater accumulation (Thurling and Das 1980). High temperatures and long photoperiods are also detrimental for siliquae and seed development (Munsi and Kumari 1994). In North India, mustard is cultivated after the harves of kharif crops. With the introduction of late maturing varieties of paddy, sowing of mustard is also delayed and phenological development of crop is affected due to variations in environmental conditions.

A number of models have been proposed to describe the phenological development of plants as a function of

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environmental variables (Daughtry *et al.* 1984, Warrington and Kanemasu 1983). However, for most of the crops, simple models based on temperature alone can often explain over 95 per cent variability in phenological development (Russelle *et al.* 1984). Growing degree days were found to be better estimate of phenological development in *Brassica napus* (Morison *et al.* 1989) and correlated positively with the duration of seed filling period in rapeseed and mustard (Nanda *et al.* 1995). In the present investigation, an attempt has been made to investigate the phenological development of mustard genotypes in relation to environmental variables and their derivatives such as temperature, growing degree days, heliothermal units and sunshine hours on crop yield as little work has been done on these aspects in India.

MATERIALS AND METHDOS

Pot experiments were conducted during *rabi* 1993-94, 94-95 and 96-97 at the Institute of Agricultural Sciences, Banaras Hindu University, Varanasi taking two varieties of mustard (*Brassica juncea* (L) Czern), viz. Vaibhav and Kranti. Sowing was done in cemented pots containing 20 kg soil mixed with FYM (4 : 1). Basal dose of N, P and K were applied in the form of urea, single super phosphate and muriate of potash @ 1.7, 3.7, 0.66 g per pot, respectively. In order to find out the effect of environmental stresses, particularly temperature and sunshine hours on phenology, yield and yield attributes, sowing was done at an interval of 10 days starting from October 1 till November 21. Dry matter accumulation at bolting, complete flowering, complete elongation, flower termination and physiological maturity stages were recorded. Days required to attain these phenophases were also recorded. At harvest, yield and yield attributes were determined. Starting from sowing to physiological maturity, data on daily minimum and maximum temperatures and sunshine hours were also obtained from the meteorology section of the Institute. Daily mean temperature (Tm °C) was calculated according to Chakraborty (1994) using following relationship:

$$\text{Tm} = \frac{\text{Daily maximum temperature + daily minimum temperature}}{2}$$

Growing degree-days (GDD) between successive phenophases were calculated according to Nanda *et al.* (1995) from the following equation:

$$\text{GDD (°C)} = (\text{Tm} - \text{Tb}) \times t$$

Where t is the duration in days and Tm, the mean temperature during that period. The Tb is the base temperature and for the present investigation Tb was taken as 5°C (Nanda *et al.* 1995). The mean sunshine hours per day between two successive growth phases was calculated by the following equation:

$$\text{Mean sunshine hours per day between two phases} = \frac{\text{Total bright sunshine hours between the phases}}{\text{Duration of the phase}}$$

Heliothermal units betwen successive growth stages were calculated as suggested by Singh *et al.* (1990) and Chakraborty (1994) using the following equation:

$$\text{Heliothermal units} = \left[\text{GDD between two growth phases}\right] \times \text{mean sunshine hours during the period.}$$

The harvest index (HI) was calculated using the formula of Donald and Hamblin (1976) as given below:

$$\text{HI (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

Observations pertaining to morphological parameters were recorded and expressed on per plant basis. There were three replications for each observation. Experiments were conducted using randomized block design (Chandel 1984).

RESULTS AND DISCUSSION

Present investigation revealed that productivity of mustard varieties is maximum when sowing is done between October 31 to November 20 (Table 1). Too early or too late sowing reduced total crop growth duration (Table 2). Early sowing reduced the duration between sowing to bolting, complete flowering to enlongation and flower temination to physiological maturity phases, while late sowing increased the duration between sowing to bolting, but it drastically reduced the duration between flower termination to physiological maturity. Such observations have already been reported by Thurling and Das (1980). Multiple regression analysis indicated that the durations between different phenophases were associated and dependent on growing degree days (GDD) (Table 3). Simple correlation coefficient indicated that sunshine hours

Table 1. Total dry matter production, seed yield and harvest index (%) of mustard at different sowing dates (mean of three years and two genotypes).

Sowing date	Dry mater (g plant^{-1})	Yield (g plant^{-1})	Harvest index (%)
October 1	17.35	4.465	25.73
October 11	17.13	4.423	25.82
October 21	20.29	4.885	24.08
October 31	18.96	5.444	28.71
November 10	17.10	5.380	31.46
November 20	18.76	5.246	27.95
November 30	13.90	3.928	28.26
December 10	11.28	2.852	25.28
CD at 5%	1.92	0.773	

during flower termination to physiological maturity this value ranged from 274 to 221 (Table 5). Low GDD is an indicative of faster growth rate (Wallace *et. al.* 1995). When crop was sown too early, the GDD between sowing to bolting phase has been higher (Table 5) indicating low growth rate during this phase, while growth rate during flower termination to physiological maturity has been faster under such sowing. When sowing was done too late, growth rate during all the growth phases except complete flowering to complete elongation, has been very fast as the GDD during these periods were low. This indicated that change in sowing dates from normal has direct influence on growth rate during different phenophases in mustard. It is concluded that the GDD is a better estimate to correlate phonological development in mustard. Simple correlation coefficient between yield and yield attributes data of three years on two genotypes revealed that in mustard besides other attributes dry matter production is the major determinanant of yield as there is direct correlation between these two parameters (Table 6). Changes in the sowing date affected productivity. Too early sowing reduced vegetative and pod growth periods, while too late sowing

Table 2. Days required between various phenophases under different sowing dates in mustard (mean of three years and two genotypes).

Sowing date	Days required between various phenophases				
	Sowing to bolting	Bolting to complete flowering	Complete flowering to elongation	Complete elongation to flower termination	Flower termination to physiological maturity
October 1	33	13	20	3	15
October 11	37	10	25	6	18
October 21	37	13	25	5	21
October 31	40	16	25	6	23
November 10	40	17	25	5	20
November 20	46	13	25	4	16
November 30	43	15	25	4	14
December 10	44	14	26	3	9

and GDD were positively correlated (Table 4). All the studied environmental parameters were positively correlated with the duration of growth in mustard (Table 4). The sowing dates which yielded higher (October 31 to November 20) experienced GDD between 569 to 640°Cd during sowing to bolting stages (Table 5), while,

Table 3. Multiple regression of duration of growth between various phenological phases and sunshine hours (bx1), GDD (cx2), heliothermal units (dx3) and mean temperature (ex4) during that period in mustard.

Year	Intercept (a)	bx1	cx2	dx3	ex4	R	R^2
1993-94	4.46	0.67x1	1.79x2	-0.98x3	-0.20x4	0.995	0.989
1994-95	23.21	0.03x1	1.45x2	-0.40x3	-0.32x4	0.984	0.969
1996-96	26.73	0.10x1	1.18x2	-0.07x3	-0.43x4	0.983	0.966

Table 4. Partial and simple correlation coefficient between duration of growth during various phenological phases and sunshine hours, GDD, heliothermal units and mean temperature during that period in mustard.

Parameter	1993-94		1994-95		1996-97	
	Partial correlation	Simple correlation	Partial correlation	Simple correlation	Partial correlation	Simple correlation
Sunshine hour	0.988	0.559	0.137	0.187	0.423	0.082
GDD	0.941	0.723	0.942	0.927	0.852	0.922
HTU	-0.823	0.671	-0.603	0.794	-0.091	0.876
Mean temperature	-0.807	0.084	-0.773	0.177	-0.870	0.164

Table 5. Growing degree days (GDD°C) calculated between different phenophases in mustard under different sowing dates (mean of three years and two genotypes).

Sowing date	GDD (°Cd) between phenophases				
	Sowing to bolting	Bolting to complete flowering	Complete flowering to complete elongation	Complete elongation to flower termination	Flower termination to physiological maturity
October 1	693	224	290	40	167
October 11	726	159	300	66	193
October 21	669	179	276	41	216
October 31	640	170	273	51	274
November 10	562	189	252	59	259
November 20	569	144	267	51	221
November 30	506	145	297	53	213
December 10	498	145	337	44	158

Table 6. Simple correlation coefficient between yield and yield attributes in mustard. Based on the observations of three years and two genotypes.

	TDMP per plant	Seed yield per plant	Seed yield per siliqua	Seed number per siliqua	1000 seed weight	Harvest index
Seed yield per plant	0.81					
Seed weight per siliqua	0.42	0.33				
Seed number per siliqua	0.08	-0.06	0.74			
1000 seed weight	0.21	0.57	0.54	0.15		
Harvest index	-0.26	0.61	-0.05	-0.17	0.22	
Siliquae per plant	0.46	0.73	-0.32	-0.57	0.16	0.61

reduced all the phenophases, except complete flowering to complete elongation phase (Table 2) resulting in poor dry matter production and yield. It is also concluded that too late sowing is more deleterious for the crop as this might adversely affect reproducitve and post reproductive growth (Nanda *et al.* 1995).

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