Agrometeorological Indices & Phenological Behaviour of Mustard (*Brassica Juncea*) Cultivars under Different Growing Environments at Allahabad

Vijendar Singh[1] Satyendra Nath[2] Abhishek James[3] Yogesh Kumar[4]
[4]Department of Agricultural Meteorology
[1,2,3]College of Forestry Sam Higginbottom University of Agriculture, Technology & sciences, Allahabad-211007 (U.P.) India [4]College of Agriculture (COA), CCS Haryana Agricultural University, Hisar-125004, Haryana, India

Abstract— A field experiment was carried out at Sam Higginbottom University of Agriculture, Technology and Sciences, Allahabad during *Rabi* season of 2016-17, to study agrometeorological indices and phenological behaviour of mustard (*Brassica juncea*) cultivars under different growing environments at Allahabad climatic conditions. The main plot treatments consisted three date of sowing (D_1-25th October, D_2-5th November and D_3-15th November) and sub plot treatments consisted three cultivars (V_1- Parasmani, V_2- Varuna and V_3- SRM 777) using split plot design. The results revealed that delayed sowing reduced the length of phenophases in all cultivars. The crop duration was shortest in 25th October as compared to 5th November and 15th November. Among cultivars, the total crop duration was longest in SRM 777 followed by Varuna and Parasmani. Among agrometeorological indices GDD, HTU and PTU requirement were higher in 25th October followed by 5th & 15th Nov. sown crop. In delayed sown crop, higher day and night temperature during reproductive phase leads to forced maturity and reduced the total GDD requirement. The crop sown on 25th October was most efficient in thermal and radiation utilization in comparison with delayed sown crop. Among the cultivars, SRM 777 consumed highest GDD at 25th October as compared to other cultivars and it delayed as per growing environment. 25th October is ideal planting window for increasing yield potential of mustard followed by 5th & 15th November due to efficient utilization of available resources.

Key words: Phenological Studies, Mustard, Agromet Indices, Growing Environment

I. Introduction

Indian mustard (Brassica juncea L. Czern. & Cosson) belong to Cruciferae family and genus Brassica and species Juncea. Temperature and light radiation are key factors affecting crop production. During crop growth period, the occurrence of various phenological events can be estimated by computing accumulated growing degree days (Gouri et. al., 2005). Variation in sowing dates causes differential thermal heat accumulations, which turn affects in leaf area index (LAI), crop growth, and biomass partitioning and finally seed yield (Prasad, 1989). Every crop needs a specific amount of heat unit or growing degree days (GDD) to enter from one phase to another. Phenological development of Brassica is known to be manifestly influenced with temperature and photoperiod. In general, shortening in the maturity phase has been found with increase in temperature and day length (Robertson et al., 2002). Growing degree days (GDD) is most important thermal indices used for estimating the effect of thermal environment on growth dynamics of various crops. GDD is directly related to the amount of HTU and PTU consumed by mustard crop at different phenophases. Thermal time can be used as a tool for characterizing thermal responses in different crops as it is an independent variable to describe plant development (Dwyer and Stewart, 1986). Heat use efficiency (HUE), i.e., efficiency of heat utilization in terms of dry matter accumulation, depends on genetic factors, crop type and sowing time and has great practical application (Rao et al., 1999). Crop phenology is used to estimate the most appropriate date and time of specific development process. The duration of each phenophases determines the dry matter accumulation. Temperature is an important environmental factor that influences the growth and development, phenology and yield of crop (Bishnoi et al., 1995). Indian-mustard is much sensitive to climatic variables; hence, climate change could have significant effect on its production. One month delay in sowing from mid of October resulted loss of 40.6% in seed yield (Lallu, et al., 2010). Indian-mustard suffers from exposure to low temperature during vegetative and early pod filling stage, and relatively higher temperature during germination and maturity. (Aggarwal, et al., 2004; Kumar, et al., 2007 and Adak and Chakravarty, 2010). Hence, it becomes imperative to have the knowledge of exact duration of various phenological stages of crop in a particular growing environment and their impact on its yield.

II. Materials and Methods

The field experiment was conducted at the research farm of Sam Higginbottom University of Technology and Sciences, Allahabad, Uttar Pradesh, India. It is situated at situated 25.45° N 81.85° E and at an altitude of 98 meter above sea level. The climate is typically semi- arid and sub-tropical. The maximum temperature reaches up to 47.7°C in summer and drops down to 1.5°C degree in winter. The experiment included three date of sowing viz. 25th October, 5th November, 15th November and cultivars viz. Parasmani, Varuna and SRM 777. The experiment was laid out in a spilt plot design with four replication.

A. Phenological Observations

The crop was visually inspected at frequent interval (3 or 4 days) to observe the phenological event such as seedling emergence, early vegetative phase (four leaf stage), first flower, Flowering (when 50% of plants in plot initiation, Seed development, Physiological maturity.

B. Agrometeological Indices

Growing degree days (GDD) accumulated growing degree-days were determined by summing the daily mean temperature above base temperature, expressed in degree day and T_{base} is considered 5ºC.

$$(GDD) = \sum(T_{max}+T_{min})/2- T_{base}$$

Where

T_{max}= daily maximum temperature (ºC)

T_{min}= daily minimum temperature (ºC)

T_{base}=minimum threshold/base temperature (ºC)

Heliothermal units (HTU), degree days hours

The heliothermal units for a day represent the product of GDD and the hours of bright Sunshine for that day. The sum of HTU for particular phenophases was determined according to the equation;

$$HTU= \sum(GDD \text{ x actual bright sunshine hours}) \ (^0C \text{ days hours})$$

Where,

GDD=growing degree days

Photothermal unit (PTU),degree day hrs

Photo thermal unit are accumulated value of growing degree days, multiple by the day length this can be mathematically represented using the following formula.

$$PTU=\sum(GDD \text{ x maximum possible sunshine hours or day length(hrs)}).$$

C. Thermal use efficiency (TUE)

TUE (g m^{-2} °C day^{-1}) is defined as the amount of accumulated Biomass (g m^{-2}) during 30 days interval per unit of cumulative GDD (°C day) during 30 days interval.

III. Result and Discussion

A. Phenology

Among different growing environment, mustard sowing on 25th October takes higher of number of days to attain physiological maturity followed by 5th November and 15th November during Rabi season (Table.1). Among the cultivars, SRM-777 took maximum no. of days to reached physiological maturity followed by Varuna and Parasmani because in late sown crop, exposure of high temperature at reproductive stage then it took lower number of days to reach physiological maturity due to forced maturity.

B. Growing Degree Days (GDD)

Growing degree days or heat units (HU) consumed for completion of different phenological stages of mustard cultivars under different growing environments were worked out and they are presented in Table 2. The cumulative heat units for different phenophase requirement were higher in 25th October sown crop followed by 5th November and 15th November. These values at physiological maturity were 1941.6, 1619.9 and 1547.8 °C day for 25th October, 5thNovember and 15th November respectively. Among the cultivars, highest number of heat units consumed were 1913.6°C day by SRM 777 followed by Varuna (1794.4 °C day) and Parasmani (1907°C day).

C. Heliothermal units (HTU)

The heliothermal units (HTU) accumulation at different phenophases of mustard cultivars under different growing environments were worked out and they are presented in Table 3.The value of HTU at Physiological maturity was higher in the first sown crop as compared to late sown mustard crop. Highest value of HTU was recorded 11450.3, 9557.7 and 9287.8°C day hour at 25th October, 5th November and 15th November respectively. Among cultivars, SRM 777 accumulated highest amount HTU with the value of 12507.6°C and next higher was 8308.8 °C accumulated by Varuna.

D. Photothermal units (PTU)

The Photothermal units (PTU) were accumulated at different phenophases of mustard cultivars under different growing environments and they are presented in Table 4.The earlier sown crop was highest PTU accumulation than late sown crop. The accumulated PTU values for 25th October, 5thNovember and 15th November were 121933.2, 19439.7 and 18576.1 °C day hour, respectively among Brassica juncea SRM 777 accumulated highest PTU with the value of 22967.8 °C hours. The variety was Varuna having higher PTU accumulation with 21540.2 °C day hours. The decrease in PTU accumulation with delay in sown crop was due to that delayed sowing experienced shorter days in combination with lower temperature which caused early reproductive phase in late sown crops. Similar results are supported by Srivastava et al. (2011).

E. Thermal use efficiency (TUE)

The (TUE) were accumulated at different phenophases of mustard cultivars under different growing environments and they are presented in Table 5.The earlier sown crop was highest TUE accumulation as compared to late sown crop.

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Treatments	P_1	P_2	P_3	P_4	P_5	P_6	P_7
25th October	3.6	8.4	34.46	48.2	68.01	87.1	114.3
5th October	4.4	12.5	37.2	51.1	72.1	92.2	111.4
15th November	5.1	14.4	39.5	57.2	76.1	99.02	109.2
PARASMANI	4.2	9.58	40.42	52.8	76.0	89.1	112.2
VARUNA	4.3	10.2	42.08	53.0	78.58	93.2	116.0
SRM 777	4.45	12.2	40.3	55.1	82.02	96.2	123.3

Table 1: Days taken for occurrences of different phenophases in mustard at different growing environment.

Where, P_1: Seedling emergence, P_2: Early vegetative phase (four leaf stage), P_3: First flower, P_4: 50 %flowering, P_5: Pod initiation, P_6: Seed development, P_7: Physiological maturity.

Treatments	P_1	P_2	P_3	P_4	P_5	P_6	P_7
25th October	98	187	874	1081	1357	1553	1941
5th October	105	228	664	840	1075	1354	1620
15th November	116	300	611	787	1018	1358	1548
PARASMANI	91	208	995	1145	1422	1580	1908
VARUNA	94	230	818	963	1260	1440	1795
SRM 777	121	272	872	1007	1303	1485	1914
Mean ± SD(D)	106 ±9	238 ±57	716 ±139	902 ±157	1150 ±182	1421 ±114	1703 ±209
Mean ± SD(V)	102 ±16	236 ±33	895 ±91	1038±95	1328 ±84	1502 ±71	1872 ±67

Table 2: Growing degree days GDD (ºC day) consumed by mustard cultivars at various phenophases under different growing environments

Where, P_1: Seedling emergence, P_2: Early vegetative phase (four leaf stage), P_3: First flower, P_4: 50 %flowering, P_5: Pod initiation, P_6: Seed development, P_7: Physiological maturity

Treatments	P_1	P_2	P_3	P_4	P_5	P_6	P_7
25th October	852	1608	6817	6810	7327	8230	11451
5th October	693	1732	3652	4704	5267	7311	9558
15th November	986	2580	3177	3384	5090	7740	9288
PARASMANI	791	1788	7363	7786	8247	8532	12974
VARUNA	827	1955	5889	6068	8389	8848	11829
SRM 777	1052	2284	6278	5437	7818	8316	12058
Mean ± SD(D)	843 ±146	1973±529	4548 ±1978	4966 ±1727	5894 ±1243	7760±459	10099±1178
Mean ± SD(V)	890 ±141	2009±252	6510 ±763	6430 ±1215	8151 ±297	8565±267	12287±605

Table 3: Heliothermal units (°C day hour) requirement of mustard cultivars at various phenophases under different growing environments

Where, P_1: Seedling emergence, P_2: Early vegetative phase (four leaf stage), P_3: First flower, P_4: 50 %flowering, P_5: Pod initiation, P_6: Seed development, P_7: Physiological maturity.

Treatments	P_1	P_2	P_3	P_4	P_5	P_6	P_7
25th October	1136	2038	9526	11458	14519	16649	21933
5th October	1144	2485	7038	8988	11502	15300	19440
15th November	1264	3180	6476	8420	11503	15345	18576
PARASMANI	1055	2267	10547	12251	15215	17854	22896
VARUNA	1090	2507	8670	10325	14238	16272	21540
SRM 777	1318	2964	9243	10674	13942	16780	22968
Mean ± SD(D)	1181±71	2567±575	7680±1623	9622±1615	12508±1741	15764±766	19983±1743
Mean ± SD(V)	1154±142	2579±354	9486±961	10499±246	14465±666	16968±807	22468±804

Table 4: Photothermal units (ºC) requirement of mustard cultivars at various phenophases under different growing environments

Where, P_1: Seedling emergence, P_2: Early vegetative phase (four leaf stage), P_3: First flower,

P_4: 50 %flowering, P_5: Pod initiation, P_6: Seed development, P_7: Physiological maturity

Treatments	P_1	P_2	P_3	P_4	P_5	P_6	P_7
25th October	0.10	0.24	0.78	0.86	1.15	1.46	1.69
5th October	0.07	0.19	0.61	0.76	1.13	1.39	1.46
15th November	0.03	0.14	0.48	0.67	1.03	1.22	1.83
PARASMANI	0.02	0.15	0.17	0.46	0.67	1.02	1.03
VARUNA	0.10	0.18	0.25	0.71	1.04	1.11	1.20
SRM 777	0.14	0.22	0.32	1.01	1.13	1.25	1.32

Table 5: TUE (g/m^2 °C) requirement of mustard cultivars at various phenophases under different growing environments

Where, P_1: Seedling emergence, P_2: Early vegetative phase (four leaf stage), P_3: First flower,

P_4: 50 %flowering, P_5: Pod initiation, P_6: Seed development, P_7: Physiological maturity