Ann. Agric. Res. New Series Vol. 36 (3) : 312-317 (2015)

Phenology and productivity of mustard (*Brassica juncea* L.) under varying sowing environment and irrigation levels

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Received : December 2014 ; Revised Accepted: July 2015

Abstract

A field experiment was conducted at Rajasthan College of Agriculture, Udaipur (Rajasthan) during *rabi* seasons of 2008-09 and 2009-10 to study the effect of thermal regimes on phenology and productivity of mustard *(Brassica juncea)* variety Bio-902. The experiment consisted of four dates of sowing (5th October, 20th October, 4th November and 19th November) and four irrigation levels (no irrigation, at vegetative stage, at vegetative and flowering stages and at vegetative, flowering and siliquae development stages). The experiment was laid out in split plot design having four replications. Regression models were developed to predict the seed yield of mustard. The crop sown on 5th October and 20th October gave the maximum seed yield (17.01q ha^{-1}) and significantly higher harvest index over 4th November and 19th November sown crops. Seed yield of mustard have positive correlation with maximum and minimum temperatures up to 75 DAS, thereafter, negative correlation was observed from 90 DAS to maturity. An increase of 1.0°C mean temperature during 90 to 105 DAS caused reduction in seed yield by 4.0 q ha^{-1}. The mean temperatures of 21.0 to 25.5°C and 18.7 to 20.5°C during vegetative and reproductive phase, respectively, was found conducive for higher productivity in mustard. Number of days for reproductive phase, growing degree days (GDD) and helio thermal unit (HTU) decreased with the successive delay in sowing. Late sown crop exhibited higher canopy temperature at 75 and 90 DAS. Application of three irrigations gave significantly higher seed yield by 92.0, 28.0 and 4.0 per cent over no irrigation, one and two irrigations, respectively.

Key words: Mustard, temperature, irrigation level, growing degree days, helio thermal unit, seed yield

India occupies premier position in global oilseed scenario, accounting for about 23.5 per cent area and 17.6 per cent of production (FAO, Year book, 2010). India is the third largest oilseed economy in the world. Among the seven edible oilseeds cultivated in India, rapeseed-mustard contributes 28.6 per cent in the total oilseeds production and ranks second after groundnut and sharing 27.8 per cent in the India's oilseed economy. Oilseed constitutes the second largest agricultural commodity after cereals in India, producing 11.94 MT from 22.9 mha area with the average productivity of 955 kg ha^{-1}. Rapeseed-Mustard accounts for 22.7% area and 25.9% production in total oil seed area and production in India. The average productivity, area and productivity under repeseed and mustard was 5.5 mha, 6.4 MT and 1159 kg ha^{-1}. (Economic Survey, 2011). Mustard is a winter season crop and its physiological and morphological developments are markedly influenced by weather conditions. Among various weather parameters, temperature is considered as prime weather element that affect crop growth and development.

Hall (1992) reported that flowering is the most sensitive stage for temperature stress, probably due to vulnerability for pollen development, anthesis and fertilization. High temperature in mustard causes flower abortion with appreciable loss in seed yield (Rao *et al.*, 1992). Therefore, the present experiment was undertaken to study the effect of thermal regimes on phenology and productivity of Indian mustard variety Bio-902.

MATERIALS AND METHODS

The field experiment was conducted during two consecutive *rabi* seasons of 2008-09 and 2009-10 at Instructional Farm, Rajasthan College of Agriculture, Udaipur situated at Southern part of Rajasthan at 24°34' N latitude and 73°42' E longitude and an altitude of 582.0 m above mean sea level. The Instructional Farm falls under agro-climatic zone IV A "Sub-humid Southern Plain and Aravalli Hills" of Rajasthan and agro climatic zone VIII (Central plateau and hills) of India. The soils of experimental field was clay loam in texture, slightly alkaline in reaction (pH 7.9) and calcareous in nature. The experiment was laid out in split plot design with four replications. The experiment consisted of four dates of sowings (5^{th} October, 20^{th} October, 4^{th} November and 19^{th} November) assigned in main plots and four irrigation levels [no irrigation (I_0), one at vegetative stage (I_1), two at vegetative and flowering stages (I_2), and three at vegetative, flowering and siliquae development stages (I_4)] in sub plot treatments. In each irrigation treatment applies 50 mm depth water. Irrigation depth was measured by Parshall flume. Sowing was done manually followed by irrigation for proper germination. Mustard variety Bio-902 was sown on the stipulated dates as per treatments with a seed rate of 5 kg ha^{-1} at 30 cm x 10 cm spacing followed by irrigation. The crop was fertilized with 60 kg N and 40 kg P_2O_5 ha^{-1}. The temperature data during the crop season were recorded from Meteorological observatory of Instructional Farm, Rajasthan College of Agriculture, Udaipur. The growing degree-days were computed by following formula:

Accumulated GDD = $\Sigma (T_{mean} - T_{base})$

Where,

T_{mean} = (Maximum temperature + Minimum temperature)/2

T_{base} = Base temperature of mustard crop (5°C) as suggested by Rao, 2008

Irrigation water productivity was calculated as suggested by Chandra (2015)

Irrigation water productivity (kg/ha – cm) = Yield/total irrigation water depth

RESULTS AND DISCUSSION

Effect of temperature on yield

Mean seed yield of mustard showed negative relationship with the mean temperature experienced between 90 to 105 days after sowing

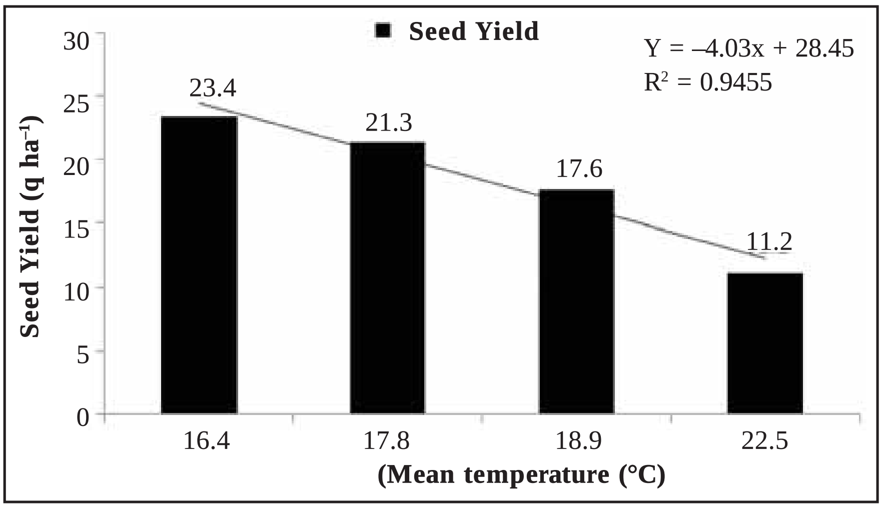

Fig. 1. Relationship between mean temperature (90-105 DAS) and seed yield of mustard under three irrigation (mean of 2008-09 and 2009-10)

(Fig. 1). An increase of 6.1°C temperature between 90 to 105 DAS resulted in decline of seed yield of mustard by 12.20 qha^{-1} under assured irrigation. Two years mean data revealed that the highest seed yield of 23.4 qha^{-1} was obtained under 5th October sown crop when the mean temperature was 16.4°C during 90-105 days of crop growth. While the lowest seed yield of 11.2 qha^{-1} was recorded under 19th November sown crop when the mean temperature was 22.5°C during 90-105 days. Data (Table-1) also shows higher mean temperature 90 DAS onwards under 4th November and 19th November sown crops. High temperature stress directly or indirectly affects plant photosynthetic functions by changing the structural organization and physiochemical properties of thylakoid membranes. The rate of photorespiration increase with increasing temperature which reduces net photosynthesis and probably the seed yield of the crop (Hayat *et al.* 2009). According to Angadi *et al.* (2000) in *Brassica* species, a temperature of 35 / 15°C for 1 week during early flowering reduces seed yield drastically. Rao *et al.* (2011) has also reported that increase in temperature decrease seed yield of mustard.

Days taken to attain various phenophases of mustard

Data pertaining to days taken for vegetative and reproductive phase as influenced by different weather environments are presented in Table 3. Data show that vegetative phase of mustard was extended by 4 to 5 days in delayed sowing (4th November & 19th November) as compared to timely sown crop (5th October). However, reproductive phase of the crop was shortened by 8 to 10 days with delayed sowing (from 76 days to 66 days). Early sown crop took 114 days for maturity.

With regard to irrigation levels, the number of days required to attain maturity were increased with increasing levels of irrigation in all sowing dates. The reproductive phase was increased by 2 and 4 days with the application of two and three irrigations over no irrigation.

Table 1. Mean temperature experienced during the crop season (Mean of two years)

Sowing date	1-15 DAS	16-30 DAS	31-45 DAS	46-60 DAS	61-75 DAS	76-90 DAS	91-105 DAS	106 to maturity
5th October	26.4	23.9	22.1	19.2	20.7	18.0	16.4	19.8
20th October	24.0	22.5	19.5	20.7	18.4	16.8	17.8	19.0
4th November	21.8	19.3	20.6	18.1	16.2	18.7	19.0	21.1
19th November	19.3	20.6	18.1	16.2	18.7	19.0	22.5	24.6

Table 2. Days taken to attain different phenophases of mustard under varying weather environment and irrigation levels (2008-09 and 2009-10)

Treatment	Phenophases	I_0	I_1	I_2	I_3	Mean
5th October	Vegetative	37	38	39	39	38
	Reproductive	73	73	77	82	76
	Total	110	111	116	121	114
20th October	Vegetative	38	39	39	40	39
	Reproductive	71	72	76	79	74
	Total	109	110	115	118	113
4th November	Vegetative	42	43	43	43	42
	Reproductive	66	66	68	72	68
	Total	108	109	110	115	110
19th November	Vegetative	41	43	44	45	43
	Reproductive	65	65	67	69	66
	Total	106	108	110	114	109
Mean	Vegetative	40	41	41	42	41
	Reproductive	69	69	72	76	71
	Total	108	110	113	117	112

Table 3. Accumulated GDD (°C day) required to attain different phenophases of mustard (Mean of 2 years)

Treatment	Phenophases	I_0	I_1	I_2	I_3	Mean
5th October	Vegetative	731	749	756	765	750
	Reproductive	1000	998	1061	1120	1045
	Total	1731	1747	1817	1885	1795
20th October	Vegetative	642	658	664	671	659
	Reproductive	957	963	1022	1063	1001
	Total	1599	1621	1686	1734	1660
4th November	Vegetative	650	666	666	673	663
	Reproductive	863	863	888	955	892
	Total	1513	1529	1554	1628	1556
19th November	Vegetative	608	623	623	633	621
	Reproductive	903	924	968	1033	957
	Total	1510	1546	1591	1666	1578
Mean	Vegetative	658	674	677	686	673
	Reproductive	931	937	985	1043	974
	Total	1589	1611	1662	1729	1647

Similarly, total crop duration also increased by 2, 5 and 9 days with application of one, two and three irrigations, respectively over no irrigation.

Growing degree days (GDD)

Data with respect to GDD required for vegetative and reproductive phase of the crop in Table 4 show that GDD required for vegetative phase were less as compared to that required for reproductive phase in all sowing dates (Table 4). The highest GDD of 1885°C days were required for maturity under 5th October sown crop with three irrigations. Total GDD required for maturity was decreased with delayed sowing. Among the different irrigation levels, it was noted that the lowest GDD of 1589°C days were required under no irrigation. The GDD requirement increased from 1589 to 1729°C days with the increasing level of irrigation from no irrigation to three irrigations. Kaur and Hundal (2006) in *Brassica* species under Punjab condition reported that accumulated GDD required for maturity decreased with delayed sowing.

Helio Thermal Units (HTU)

Data pertaining to helio thermal units (HTU) in Table 5 show that reproductive phase of the

Table 4. Helio Thermal Unit (°C day hours) required to attain different phenophases of mustard (Mean of 2 years)

Treatment	Phenophases	I_0	I_1	I_2	I_3	Mean
5th October	Vegetative	6195	6312	6314	6378	6300
	Reproductive	6909	6845	7379	7864	7249
	Total	13104	13157	13692	14242	13549
20th October	Vegetative	5296	5431	5494	5554	5444
	Reproductive	6827	6881	7282	7621	7153
	Total	12123	12312	12776	13175	12596
4th November	Vegetative	4871	4979	4978	5018	4961
	Reproductive	6300	6333	6544	7153	6582
	Total	11171	11312	11522	12170	11544
19th November	Vegetative	4404	4521	4521	4607	4513
	Reproductive	7140	7316	7721	8305	7620
	Total	11544	11836	12242	12912	12133
Mean	Vegetative	5192	5311	5327	5389	5304
	Reproductive	6795	6844	7231	7736	7151
	Total	11987	12154	12558	13125	12456

Table 5. Effect of different sowing environment and irrigation levels on seed yield and harvest index of mustard (2008-09 & 2009-10)

Treatments	Seed yield (qha^{-1})			Harvest Index (%)			Irrigation water productivity (kg / ha-cm) Pooled basis
	2008-09	2009-10	Pooled	2008-09	2009-10	Pooled	
Sowing dates							
5th October	15.37	18.65	17.01	29.13	30.21	29.67	149.10
20th October	15.59	18.42	17.01	28.77	30.24	29.51	150.27
4th November	14.2	12.80	13.50	26.99	27.21	27.10	122.66
19th November	9.66	9.95	9.81	24.53	24.82	24.68	95.90
CD (P=0.05)	1.325	1.460	1.272	1.29	1.383	1.393	8.540
Irrigation levels							
I_0	9.11	9.54	9.33	23.34	23.96	23.65	-
I_1	10.86	14.35	12.61	26.38	27.52	26.95	126.09
I_2	16.46	17.57	17.02	29.69	30.96	30.33	113.44
I_3	18.37	18.36	18.37	30.01	30.05	30.03	91.82
CD (P=0.05)	1.203	0.838	1.106	1.29	0.987	1.141	8.540

crop required more helio thermal units than vegetative phase in all the sowing dates. Delayed sowing caused reduction in helio thermal units requirement for vegetative as well as reproductive phase. The maximum HTU of 13549°C day hours was recorded under 5th October sown crop. With respect to irrigation levels, it was noted that HTU for maturity of the crop was increased with each successive increase in number of irrigations. Application of one, two and three irrigations resulted into 167, 571 and 1138°C day hours more HTU over no irrigation, respectively.

Seed yield and harvest index

Pooled data of 2 years, show that 5th October and 20th October sown crop gave the maximum seed yield (17.01 qha^{-1}) which was significantly superior over 4th November and 19th November sown crop (Table 5). The crop sown on 4th November and 19th November resulted in the reduction in seed yield by 21.0 and 42.0%, respectively over 5th and 20th October sown crop. High temperature negatively affected plant growth and survival and hence crop yield (Boyer, 1982). Similar result was also reported by Kaur and Hundal (2006) in *Brassica* species under Punjab conditions, while maximum harvest index 29.67 % was recorded under 5th October sown crop, which was at par with 20th October sown crop. The crop sown on 4th November and 19th November gave 9.0 and 17.0 % lower harvest index as compared to 5th October sown crop. Angadi *et al.* (2000) also concluded that high temperatures of 35 / 15°C reduced harvest index significantly. A significant increase in harvest index was observed up to application of two irrigations. Application of two irrigations gave too high higher harvest index over no irrigation and one irrigation, respectively. The crop sown on 20th October gave the maximum irrigation water productivity (150.27 kg / ha-cm) which was significantly higher over 4th November and 19th November sown crops but at par with 5th October sown crop. Irrigation water productivity was highest 186.57 (kg / ha-cm) in no irrigation and it decreased with successive increase in number of irrigations.

Data in Table 6 show that seed yield of mustard has positive correlation with maximum and minimum temperatures up to 75 DAS. However, from 90 DAS to maturity, seed yield has negative correlation with maximum and minimum temperatures which is also supported by Rao *et al.* (2011).

Table 6. Correlation coefficient between seed yield and temperatures at different growth stages of mustard

Temperature	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	105 DAS	106 to maturity
Maximum Temp.	0.651	0.597	0.631	0.685	0.055	-0.603	-0.628	-0.683
Minimum Temp.	0.543	0.504	0.415	0.566	0.459	-0.556	-0.689	-0.652
Mean Temperature	0.656	0.629	0.542	0.655	0.291	-0.646	-0.670	-0.678

Conclusion

An increase of 1.0°C mean temperature during 90 to 105 days after sowing caused reduction in seed yield of mustard by 4.0 q/ha. The highest growing degree days of 1885°C day and helio thermal units of 14242°C day hours was required for attaining maturity under early sown crop (5th October) with three irrigations. Mustard sowing from 5th October to 20th October is conducive for getting higher seed yield.

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