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Effect of sowing time on productivity and thermal utilization of mustard (*Brassica juncea*) under sub-tropical irrigated conditions of Jammu

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ABSTRACT

Field experiments were conducted to study the effect of weather variability on mustard crop at Research Farm of Agromet Research Centre, SKUAST-J, Chatha, Jammu during *rabi* seasons of 2010-11 to 2012-13. Treatments were comprised of three sowing dates (9th October, 24th October and 8th November) and two cultivars of mustard (RL-1359 and RSPR-01). The results revealed that days taken to physiological maturity and yield reduced significantly with delayed sowing. Mustard crop sown on 9th October utilised more thermal, and heat units as compared to 24th October and 8th November sown crops. The shortening of the duration of the crop sown late was due to forced maturity because of higher temperature during reproductive phase of the crop. Heat use efficiency (HUE) was found to be higher for earlier sown crop and it decreased with delay in sowing. Correlation studies indicated that lower night temperature during vegetative phase is favourable and higher day temperature during reproductive phase is not favourable for mustard yield.

Key words: Sowing dates, growing degree days, heliothermal units, photo-thermal unit and heat use efficiency

In Jammu and Kashmir, rapeseed mustard crop is grown on an area of 61000 hectares with an average productivity of 801 kg ha^{-1} which is quite lower than national average (Anonymous, 2013-14). The crop can be raised well under both irrigated and rainfed conditions but is largely grown under the rainfed conditions of low input management during *rabi* season and has good inherent potential to convert natural resources into usable biological energy (Shekhawat *et al.*, 2012). Rapeseed - mustard is considerably sensitive to weather as evidenced from the variable response to different dates of sowing (Kumar *et al.*, 2007). Temperature based agro meteorological indices such as growing degree days (GDD), heliothermal units (HTU) and photo thermal units (PTU) are based on the concept that real time to attain the phenological stage is linearly related to temperature in the range between base temperature and optimum temperature (Monteith, 1981). Shargi *et al.,* (2011) demonstrated that one month delay in sowing can decrease seed yield from about 10 to 50 per cent in different canola cultivars. Therefore, higher productivity of mustard is dependent on the adjustment of sowing with optimum thermal and radiation environment. Keeping these facts in view the present study was conducted to study the effect of sowing environment and varieties on yield of mustard.

MATERIALS AND METHODS

Field experiments were carried out at the research farm of Agromet Research Centre, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu (SKUAST-J), Chatha (32^{0}40' N latitude and 74^0 58' E longitude with an altitude of 332 m above mean sea level) in Shiwalik foothills of N-W Himalayas, Jammu and Kashmir State. The soil of the experimental site was sandy loam in texture having pH of 7.49 with low organic carbon content (3.7 g kg^{-1}), low available nitrogen (221 kg ha^{-1}) and medium in available phosphorus (18 kg ha^{-1}) and potassium (226 kg ha^{-1}). The six treatment combinations of the experiment comprised of three sowing dates *viz.* 9th October (D_1), 24th October (D_2) and 8th November (D_3) and two cultivars RL-1359 (V_1) and RSPR-01 (V_2) replicated four times in randomised block design during *rabi* seasons of 2010-11, 2011-12 and 2012-13 under irrigated conditions. The spacing adopted for both the cultivars of mustard was 30 x 10 cm. Mustard crop was fertilized with recommended dose *i.e.* 40:40:20 kg ha^{-1} of N: P_2O_5: K_2O. Half amount of N and full amount of P and K was applied at the time of sowing and the remaining half N was top-dressed in two splits at 30 and 60 days after sowing

(DAS). The NPK nutrients were supplied through urea, diammonium phosphate (DAP) and muriate of potash (MOP). Five plants were tagged in each plot and data of plant height and various yield attributes were calculated at harvest to assess their contribution to yield. Seed and stover yield of mustard crop was calculated on net plot basis.

Weather data *viz.* maximum temperature, minimum temperature, relative humidity (morning), relative humidity (evening), rainfall, evaporation and bright sunshine hours were recorded from sowing to harvest of the crop in all three years under study at Agro-meteorological Observatory, Chatha, SKUAST-J and the following agro-meteorological indices were calculated.

The growing degree days (GDD) was calculated by adopting the

$$GDD = \frac{T_{max} + T_{min}}{2} - T_{base}$$

T_{max}-Daily maximum temperature (^{0}C)

T_{min}-Daily minimum temperature (^{0}C)

T_{base}-Base temperature of 5 ^{0}C

Heliothermal units (HTU) = GDD × Actual sunshine hours

Photothermal units (PTU) = GDD × Day length

$$\text{Photothermal Index (PTI)} = \frac{\text{Degree days consumed}}{\text{Number of days}}$$

Heat use efficiency (HUE)

$$= \frac{\text{Seed yield /Total dry matter}}{\text{Accumulated heat units (}^{o}\text{C day)}}$$

The GDD, HTU and PTU were accumulated from the date of sowing to each date of sampling and a particular date of phenophase to give accumulated indices. The different phenological stages of mustard *viz.*, emergence, cotyledon above ground, fifth true leaf exposed, flower bud visible from above, first flower open, lowest pod more than 2 cm long, most seeds green, most seed brown, fully ripened and physiological maturity were observed.

RESULTS AND DISCUSSIONS

Phenological calendar

The calendar days taken from planting to physiological maturity of both of cultivars (RL-1359 and RSPR-01) decreased with delay in sowing. Physiological maturity was delayed by 3-4 days when sown under normal conditions (D_2) and 6-7 days when sown under late condition (D_3) as compared to early sown mustard (D_1). Mustard planted early on 9th October took lesser number of days for fifth true leaf exposure and pod development than later sowings (Table 1). It might be due to favourable soil and air temperature during this sowing time which hastened the seed germination and emergence. However, early sown crop (9th October) took more number of days for flowering and maturity as compared to normal (24th October) and late sowing (8th November). The early, normal and late sown crop matured in 155, 151 and 148 days respectively under sub-tropical conditions of Jammu (Table 1). Late sown crop took more days to complete early stages *viz*., fifth true leaf exposure and pod development. Whereas, from flower bud initiation stage, it took lesser number of days to reach different phenological stages. This might be due to higher temperature after flower bud initiation stage which fulfilled growing degree days requirement and thermal units of crop for achieving different phenological stages, in lesser days as compared to early sown crop when day and night temperature was lower at later stages. Similar findings were reported by Hokmalipour *et al.* (2011) that early sown crop reached to maturity later as compared to delayed sowing dates. However, cultivar RSPR-01 (V_2) took slightly lesser number of days to complete various phenophases than RL-1359 (V_1).

Agrometeorological indices

The accumulated thermal units requirement of mustard crop to attain different phenophases varied with sowing dates and varieties (Table 2). The crop sown on 9th October (D_1) accumulated more GDD (1571^{0}C) to attain physiological maturity than 2nd (1468 ^{0}C) and 3rd (1423^{0}C) dates of sowing. Regarding cultivars, little variation in thermal requirement was observed. Mustard cultivar RL-1359 (V_1) recorded more (1495 ^{0}C) thermal units than RSPR-01 (V_2) (1479 ^{0}C) at physiological maturity. Earlier sown crop availed higher accumulated heliothermal units (AHTU), however, with delay in sowing HTU consumption deceased. At physiological maturity, accumulated HTU was 8884, 8303 and 7525 ^{0}C hrs when mustard was sown early (D_1), normal (D_2) and late (D_3), and 8252 and 8222 ^{0}C hrs for cultivar RL-1359 and RSPR-01, respectively.

Accumulated photothermal unit (APTU) of mustard at physiological maturity was 15033, 13908 and 13570 ^{0}C hrs under the three dates of sowing *i.e.* early (D_1), normal (D_2) and late (D_3), respectively. Between the cultivars, RL-1359 acquired higher PTU (14233 ^{0}C hrs) than RSPR-01 (14108 ^{0}C hrs). Varietal variation for accumulation of GDD, HTU and PTU to complete different phenophases has also been reported by Bhat *et al.* (2015) and Ram *et al.,* (2012).

Phenothermal index (PTI)

Among different dates of sowing, 9th October sown

Table 1: Days taken by to attain different phenophases and mustard yield under different sowing dates and varieties (Mean of three years)

Treatments	5th true leaf exposed	Pod development (2 cm long)	Most seeds brown	Physiological maturity	Seed yield (kg ha^{-1})	Biological yield (kg ha^{-1})
Sowing dates						
D_1	24.2	78.0	133.5	155.0	1136	6130
D_2	27.9	78.2	131.7	151.4	828	4550
D_3	32.2	85.2	130.9	148.5	610	3594
CD (5 %)					60.2	512.4
Cultivars						
V_1	28.4	81.0	132.2	152.8	896	4911
V_2	27.7	79.9	131.9	150.5	819	4604
CD (5 %)					48.5	136.1

Table 2: AGDD (^{0}C), AHTU (^{0} C hrs) and APTU (^{0} C hrs) for various phenological stages under different sowing dates and cultivars (Mean of three years)

Treatments	AGDD	AHTU	APTU	AGDD	AHTU	APTU
Sowing dates		**5th true leaf exposed**			**Pod development (2 cm long)**	
D_1	368	2461	3485	817	4517	7522
D_2	335	2242	3142	775	4358	7117
D_3	337	1827	3117	697	3294	6393
Mean	347	2177	3248	763	4056	7011
Cultivars						
V_1	349	2203	3273	765	4081	7043
V_2	345	2150	3224	760	4032	6979
Mean	347	2177	3249	763	4057	7011
Sowing dates		**Most seeds brown**			**Physiological maturity**	
D_1	1243	6830	11995	1571	8884	15033
D_2	1211	6338	11184	1468	8303	13908
D_3	1177	6088	11003	1423	7525	13570
Mean	1210	6419	11394	1487	8237	14170
Cultivars						
V_1	1226	6459	11439	1495	8252	14233
V_2	1194	6378	11348	1479	8222	14108
Mean	1210	6419	11394	1487	8237	14171

crop recorded higher values of PTI at various phenophases than later two sowing dates. PTI values to the tune of 15.21, 12.01 and 10.41 ^{o}C days day^{-1} were observed during 5th true leaf stage at D_1, D_2 and D_3 sowing dates, respectively. Comparatively lower values of PTI were obtained for pod development (2 cm long) and most seeds brown stages than 5th true leaf stage (Table 3). PTI gradually decreased from emergence to later phenological stages in all three dates of sowing, being highest at emergence and lowest at most seeds brown stage; however, the values of PTI at physiological maturity were almost similar to emergence stage indicating a decrease in daily heat consumption

Table 3: Phenothermal index (°C days day^{-1}) and heat use efficiency (kg ha^{-1} °C^{-1} day^{-1}) for different phenological stages of mustard crop sown under different dates of sowing and cultivars

Treatments	PTI (°C days day^{-1})				HUE (kg ha^{-1} °C days^{-1})			
	5th true leaf exposed	Pod development (2 cm long)	Most seeds brown	Physiological maturity	5th true leaf exposed	Pod development (2 cm long)	Most seeds brown	Physiological maturity
Sowing dates								
D_1	15.21	8.75	10.50	15.26	0.76	3.99	6.19	5.05
D_2	12.01	8.35	8.15	13.98	0.77	3.77	5.66	4.89
D_3	10.47	6.79	7.68	13.05	0.74	3.74	4.96	4.37
Mean	12.56	7.96	8.78	14.09	0.74	3.83	5.60	4.76
Cultivars								
V_1	12.45	8.05	8.87	14.61	0.78	3.96	5.88	4.88
V_2	12.29	7.81	8.48	13.60	0.72	3.70	5.37	4.67
Mean	12.37	7.93	8.67	14.11	0.75	3.83	5.63	4.77

Table 4: Correlation coefficient between weather parameters during different phases of crop growth and seed yield of mustard

	Max T	Min T	GDD	RF	RH1	RH2	EP
PS1	-0.322	0.363	0.110	0.503*	0.569**	0.218	0.250
PS2	-0.678**	-0.017	-0.458*	0.565**	0.230	0.325	0.228
PS3	0.160	0.150	0.063	-0.137-	0.562**	0.216	0.350

*Significant at 5 % ** Significant at 1 %

PS1- Emergence to flower bud initiation, PS2- Flower bud initiation to pod formation and PS3- Pod formation to maturity

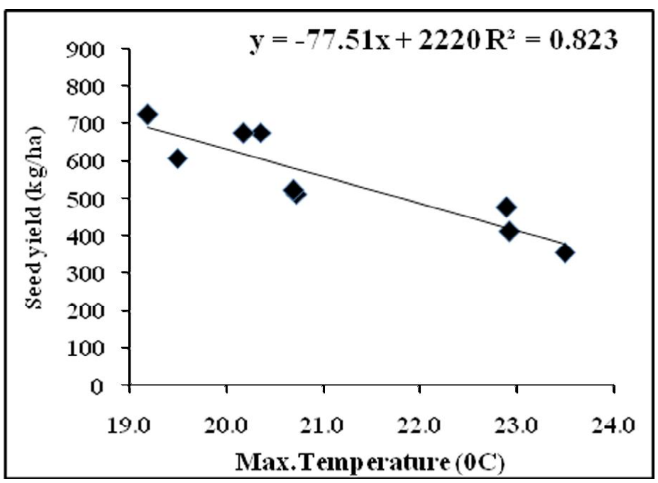

Fig 1: Effect of maximum temperature (^{0}C) during reproductive stage on mustard seed yield

towards maturity. This might be due to gradual decrease in day and night temperature, which resulted in decrease in PTI of that phenophase as the sowing was delayed (Neog *et al.*, 2008). Cultivar RL-1359 recorded more PTI values at all the phenological stages under study than RSPR-01.

Yield

Delayed planting of mustard resulted in a significant decline in the yield (Table 1). Significantly maximum seed and biological yield was obtained with mustard crop sown on 9th October (D_1). Seed yield of mustard under normal (D_2) and late sown conditions (D_3) was respectively 37.2 and 87.6 per cent lower as compared to early sown crop (D_1). Higher seed yield of mustard crop under D_1 may be due to accumulation of higher thermal units. Significantly higher seed yield and biological yield under early and normal sowing dates may be due to the fact that the early sown crop got longer time period to utilize available resources and favourable temperature, whereas, shorter time was available for the late sown crop to utilize available growth factors (light, nutrients, moisture *etc.*) responsible for poor plant growth, which resulted in poor dry matter accumulation, leading to decline of yield. These results are in agreement with the results of Shargi *et al.* (2011) and Akhter *et al.* (2016).

Regarding the cultivars, RL-1359 (V_1) produced significantly higher seed and biological yield (Table 1) as compared to RSPR-01 (V_2). The yield enhancement of cultivar

RL-1359 over RSPR-01 was about 7.7 per cent. Better seed and biological yield of cultivar RL-1359 may be on account of accumulation of higher thermal units, which may be genotypic character of this cultivar, suitable for irrigated sub-tropical conditions of Jammu.

Heat use efficiency (HUE)

HUE increased from vegetative growth to reproductive growth stages; however it decreased slightly at physiological maturity of the crop (Table 3). Among dates of sowing, heat use efficiency was found to be higher (5.05 kg ha^{-1} ^{o}C day^{-1}) for earlier sown crop (D_1) and it decreased with delay in sowing. It might be due to higher seed yield in early sowing which increased the thermal efficiency. Kingra and Kaur (2012) also observed similar results. Regarding cultivars, RL-1359 (V_1) observed more HUE values than RSPR-01 (V_2) at various phenological stages under study. The higher heat use efficiency with variety RL-1359 might be due to its higher seed yield (Table 1).

Correlation studies

The correlation analysis among seed yield and weather parameters (Table 4) during different phenophases *viz*. emergence to flower bud initiation (PS_1), flower bud initiation to pod formation (PS_2) and pod formation to maturity (PS_3) revealed that minimum temperature, rainfall, morning relative humidity during phenophase PS_1 had significant positive correlations while maximum temperature and growing degree days during phenophase PS_2 showed negative correlations. This indicated that lower night temperature during vegetative phase is favourable and higher day temperature during reproductive phase is not favourable for mustard yield. Rainfall during early and reproductive phase is highly beneficial to proper establishment of plants and higher yield. Seed yield of mustard showed highly significant negative relationship with temperature during reproductive period of the crop (Fig. 1). A unit increase in minimum temperature during reproductive period reduced the yield by 77.5 kg ha^{-1} in mustard crop under irrigated conditions.

CONCLUSION

It is concluded that early sown mustard crop (9th Ocotober) accumulated more AGDD, APTU and AHTU, PTI and HUE as compared to normal and late sown crops and by record higher seed and biological yield under irrigated conditions. Both the mustard cultivars differed significantly for yield attributes and yield.

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