

Original Research Article

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Effect of Terminal Heat Stress on Variability in Physiological Traits of Indian Mustard (*Brassica juncea* L.) due to Late Sown Situation

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ABSTRACT

The investigation entitled “Effect of terminal heat stress on variability in physiological traits of Indian mustard (*Brassica juncea* L.) due to late sown situation” was conducted during rabi season during 2017-18 and 2018-19 at Oil seed research Farm Kalyanpur of C. S. Azad University of Agriculture and Technology, Kanpur (U.P.) in randomized block design with three replications and twelve Indian mustard genotype. Physiological parameters i.e., Chlorophyll Content was recorded at anthesis and siliquae initiation stage; Chlorophyll Stability Index (CSI %), Net Photosynthesis Rate [(Pn) ($\mu \text{ mol/m}^2/\text{s}^{-1}$)], Relative Water Content (RWC %) and Canopy Temperature Depression (CTD $^{\circ}\text{C}$) were estimated at pre-flowering and post-flowering stage. Study revealed that DRMRIJ16-3, RGN-403 and RH-1556 recorded higher CSI (0.53, 0.52 and 0.46), net photosynthesis rate (33.5, 33.0 and 32.6), Relative Water Content (60.8, 59.7 and 59.1) and canopy temperature depression (3.5, 3.7 and 3.5) at post-flowering stage, while higher chlorophyll content was recorded (41.3, 40.6 and 39.2) at siliquae initiation stage. The study indicated that mustard genotypes DRMRIJ16-3, RGN-403 and RH-1556 had tolerance to high temperature stress with delayed sowing, as they maintained higher values of these physiological parameters.

Keywords

Chlorophyll
Content, CSI, Net
Photosynthesis
Rate, CTD, RWC
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Introduction

Mustard (*Brassica juncea* L. Czern & Coss) is an important Rabi season oilseed crop which belongs to family cruciferae (Brassicaceae) and genus *Brassica*. Indian mustard or brown mustard is natural amphidiploids having chromosome no. ($2n=36$) with its origin place is China. It is self-pollinated crop but certain amount (2-15%) of cross pollination occurs due to insects and other factors. Mustard is cool season crop, which requires temperature

range from 6 to 27 $^{\circ}\text{C}$, mustard follows C_3 pathway for carbon assimilation and at this temperature the plant achieve maximum CO_2 assimilation range. Mustard is generally grown under rain fed conditions and moderately tolerant to soil acidity. It requires well drained soil having pH near to neutral. Mustard has a low water requirement (240–400 mm) which fits well in the rain fed cropping system. Nearly 20% area of mustard is under rain fed condition. Its seeds are known by different names in different places

e.g., sarson, rai or raya, toria or lahi. White sarson and toria are termed as rape seed, rai or raya or laha is termed as mustard. Oil content in seeds varies from 37 to 49 per cent. The oil obtained is the main cooking medium in northern India and cannot be easily replaced by any other edible oil. The seed and oil of mustard have a peculiar pungency due to presence of glucosinolate and its hydrolysis products such as allyl isothiocyanate (0.30-0.35%) making it suitable to use as condiment in the preparation of pickles and for flavouring curries and vegetables. The oil cake is used as a cattle feed and manure. The leaves of young plants are used as green vegetables as they supply enough sulphur and minerals in the diet.

Indian mustard is sown late due to delay in harvesting of rainy season crops like cluster bean, cotton and rice (Kumar *et al.*, 2013). Under late sown condition, productivity declines primarily due to the shortening of vegetative and reproductive phase. Late sown Indian mustard is exposed to high temperature coupled with high evaporative demand of the atmosphere, during the reproductive phase which consequently results in forced maturity, increased senescence and low productivity (Porter, 2005). Delay planting has been observed to have adverse effect on seed yield. In our country mustard is grown as a winter crop. The rise in temperature, even by a single degree beyond the threshold level is considered as heat stress in the plants (Hasanuzzaman *et al.*, 2013 and Wahid *et al.*, 2007). Climate change has increased the intensity of heat stress and heat stress due to increased temperature is an agricultural problem in many areas in the world as well as in India (Beck *et al.*, 2007). Constantly high temperatures cause an array of morphological, physiological and biochemical changes in plants (Serraj *et al.*, 1999 and Moradshahiet *al.*, 2004).

Heat stress has significant negative effect on the leaf chlorophyll content however, the

reduction is time dependent. Reduction in total chlorophyll content is related with photosynthesis reduction as a result of reduce antenna size and thus less light harvesting during heat stress (Al-Khatib and Paulsen, 1984; Blum, 1986; harding *et al.*, 1990; Shanmugam *et al.*, 2013). High temperature damage photosynthetic membrane and resulted in chlorophyll loss (Al-Khatib and Paulsen, 1984). The terminal heat stress at pre-flowering and post-flowering stage accelerate maturity and significantly reduce CSI, CTD, RWC, photosynthetic rate and ultimately reduce grain yield. Indian mustard for different physiological parameters viz., chlorophyll content, membrane stability index (MSI%), relative water content (RWC%) and electrolyte leakage and yield related to terminal heat tolerance (Kavita and Pandey 2018). Therefore, present study was conducted effect of terminal heat stress on variability in physiological traits of Indian mustard due to exposure late sowing elevated temperature.

Materials and Methods

The field experiment was conducted at Oil seed research Farm Kalyanpur of C. S. Azad University of Agriculture and Technology, Kanpur, (U.P.) India. This farm is situated about 3 km away from main campus of university on South side of G.T. road runs towards Delhi. The experimental place Kanpur is situated at latitude of 26° 28' North and longitude of 80° 24' East, on altitude of 129 meter about mean sea level. It has semi-subtropical climate. The average annual rainfall of the region is 762 mm and most of it is received since last week of June to middle of October month and some occasional showers are also received during winter months. The experimental site was having sandy loam soil with pH 7.7, organic carbon 0.41%, available nitrogen 183.4 kg/ha, available phosphorous 18.3 kg/ha, and available potassium 248.2 kg/ha. Soil moisture content i.e. water holding capacity (33.5 %),

Field Capacity (19.2%) in soil at sowing time of crop was sufficient for proper germination of crop seeds. The experiments were laid out in a randomized block design with three replications. Twelve mustard genotype viz., Vardan, Ashirwad, NPJ-207, NPJ-208, RGN-403, PBR-417, DRMRIJ 16-3, DRMR-2035, RRN-911, RH-1556, RGN-368 and BPR 541-4 were sown under late sown condition during 2017-18 and 2018-19.

CSI, Net Photosynthesis Rate, CTD and RWC were estimated viz., at pre-flowering and post-flowering stage, while Chlorophyll Content measured at anthesis and siliquae initiation stage. Chlorophyll Content (SPAD) was recorded by a hand-held device chlorophyll model: SPAD-502 PLUS (company MANTOLA), Rate of Photosynthesis ($\mu \text{ mol/m}^{-2}/\text{s}^{-1}$) was measured using CI-301 CO₂ Gas analyzer CID, Inc. Chlorophyll Stability Index (%) Green plant pigments are thermo sensitive and its degradation occurs when it is subjected to higher temperature. It was estimated at given below procedure.

Two clean glass tubes were taken and 5 mg of representative leaf sample was placed in each tube with 50 ml of distilled water. One tube was subjected to heat in water bath at $56^{\circ}\text{C} \pm 1^{\circ}\text{C}$ for exactly 30 minutes. Other tube was kept as control. The leaves are then ground in mortar for 5 minutes with 100ml of 80% acetone. The slurry was filtered with Whatman no. 1 filter paper. This chlorophyll extract was further examined immediately for light absorption with photoelectric colorimeter using red filter (No. 66). A parallel leaf sample of 250 mg in another tube was then estimated for chlorophyll content without heating simultaneously and light absorption was measured with colorimeter as explained.

$\text{CSI} (\%) = (\text{Chlorophyll in the stressed plant leaf} / \text{Chlorophyll in control plant Leaf}) \times 100$

Canopy temperature depression (CTD) $^{\circ}\text{C}$ was measured were made by using a handy Infra-red Thermometer (Tele-temp AG-42 USA).

- The difference between ambient and canopy temperature has to be entered in the data book.
- Canopy in the area earmarked for final observation may be focused for Canopy temperature Depression measurement.
- Care should be taken to see that angle and the distance between the canopy and the Infra red thermos-meter remain constant for each plant.
- Observation should be recorded between 10:00 to 13:00 hours (mid day).

Relative water content (%) of third leaf from top of the main shoot was estimated as per method Suggested by Weatherley and Slatyer (1970) as follows-

$$\text{RWC} (\%) = (\text{Fresh weight} - \text{oven dried weight}) / (\text{Turgid weight} - \text{oven dried weight}) \times 100$$

Results and Discussion

Chlorophyll SPAD value in leaf tissue was recorded more at anthesis than siliquae initiation stage showed significant differences among tested mustard genotypes under late sown situation (Table 1). Chlorophyll content in the different mustard genotypes varied significantly from 38.6 to 45.9 at anthesis stage and from 32.2 to 41.3 at siliquae-initiation stage. The data pooled over the years (Table-1) indicated that mustard genotypes DRMRIJ 16-3 (45.9) followed by NPJ-208 (45.7), RGN-403 (45.5) and Vardan (44.7) at anthesis stage and DRMRIJ 16-3 (41.3) followed by RGN-403 (40.6) and RH-1556 (39.2) at siliquae initiation stage identified as superior genotypes under given situation as these maintained higher chlorophyll content (SPAD value) in leaf

tissue as compared to other genotypes. Genotype PBR-417 (38.6) and RGN-368 (39.4) at anthesis, RRN-911 (32.2) and RGN-368 (32.8) at siliquae initiation proved poor performer under late sown situation as these gave significantly lowest value of SPAD in leaf. Similar to our finding Jangid and Srivastava (2018) was also suggested anthesis stage chlorophyll content in flag leaf decreased in plant January 10 and 25 December as compared to 26 November.

Chlorophyll stability index (CSI %) was estimated at pre-flowering and post-flowering stage are presented in Table-1. In general the value of CSI was higher at pre-flowering than post-flowering stage in all tested genotypes of mustard during both years of experimentation. Chlorophyll stability index in the different mustard genotypes varied significantly from 0.52 to 0.64 at pre-flowering stage and from 0.37 to 0.53 at post-flowering stage. Result based on pooled analysis over two years data revealed that mustard genotypes RGN-368 (0.64) and RRN-911 (0.63) remained statistically at par at pre-flowering and genotypes DRMRIJ 16-3 (0.53) and RGN-403 (0.52) at post-flowering maintained significantly higher value of CSI (%) and proved their superiority over other genotypes grown in late sown situation. The significantly lowest value of CSI (%) was exhibited in PBR-417, BPR 541-4 (0.52) and Vardan (0.53) at pre flowering and NPJ-207(0.37) and BPR 541-4 (0.38) at post flowering which showed that these genotypes indicates its greater susceptibility to heat stress at terminal stage. The varietal differences in CSI, among the genotypes in the present study seems to be associated with the ability of different genotypes to reduced more destruction of CSI under high temperature at seed filling stage under late sown condition. Dogra *et al.*, (2018) revealed that heat stress decreased Chlorophyll Stability Index.

Rate of photosynthesis (Pn) ($\mu \text{ mol/m}^2/\text{s}^{-1}$) of all twelve promising mustard genotypes was noted more at post-flowering than pre-flowering stage during both years of experimentation. Pooled analysis of both years data showed that mustard genotypes DRMRIJ 16-3 (27.1) followed by NPJ-208 (26.5) and RGN-403 (26.4) at pre-flowering and DRMRIJ 16-3 (33.5) followed by RGN-403 (33.0) and RH-1556 (32.6) at post-flowering performed better as these maintained significantly higher rate of photosynthesis ($\mu \text{ mol/m}^2/\text{s}^{-1}$) under late sown environment over the other genotypes of mustard tested. Genotypes RGN-368 (24.3) and BPR 541-4 (24.4) at pre-flowering and RRN-911 (29.3) and RGN-368 (29.8) at post-flowering appeared poor performer under given situation as these showed significantly lower value of Net Photosynthetic Rate ($\mu \text{ mol/m}^2/\text{s}^{-1}$) than other genotypes.

The varietal variation in net photosynthesis among the genotypes in the present study seems to be associated with the ability of different genotypes due to their genetic potential with heat tolerance through higher leaf area might has utilized more solar radiation and enhanced the photosynthesis activity in plants. Our findings are in agreement with the earlier studies on Indian mustard by Cmejo *et al.*, (2005) and Singh *et al.*, (2014). Canopy Temperature Depression (CTD⁰C) of 12 promising mustard genotypes at pre flowering and post flowering are presented in Table 2.

Mustard genotypes RGN-403 (3.7), RH-1556 (3.5) and DRMRIJ 16-3 (3.5) exhibited higher value of CTD difference at both pre and post flowering stages, while the lowest value of CTD was observed in PBR-417 (2.9) and RGN-368 (2.9) at pre flowering and RRN-911 (2.4), PBR-417 (2.5) at post flowering under late sowing stress based on pooled analysis of both years data. Similar results were founded by Gill (2007).

Table.1 Chlorophyll content, Chlorophyll Stability Index and Net photosynthesis rate at different growth stages in Indian mustard under late sown condition (pooled 2 years)

Genotypes	Chlorophyll content (SPAD)		Chlorophyll Stability Index (CSI) (%)		Net photosynthesis rate (Pn) ($\mu\text{mol/m}^2/\text{s}^{-1}$)	
	Anthesis	Siliquae-initiation	Pre-flowering	Post-flowering	Pre-flowering	Post-flowering
Vardan	44.7	37.8	0.53	0.45	25.7	32.3
Ashirwad	42.6	34.8	0.54	0.39	24.6	31.3
NPJ-207	40.3	35.7	0.58	0.37	25.2	31.3
NPJ-208	45.7	38.6	0.59	0.41	26.5	32.1
RGN-403	45.5	40.6	0.56	0.52	26.4	33.0
PBR-417	38.6	33.7	0.52	0.43	25.1	31.1
DRMRIJ 16-3	45.9	41.3	0.54	0.53	27.1	33.5
DRMR-2035	44.1	37.2	0.55	0.41	25.3	32.3
RRN-911	41.5	32.2	0.63	0.39	25.1	29.3
RH-1556	44.6	39.2	0.61	0.46	25.7	32.6
RGN-368	39.4	32.8	0.64	0.41	24.3	29.8
BPR 541-4	39.5	34.3	0.52	0.38	24.4	30.1
Mean	42.7	36.6	0.57	0.43	25.5	31.5
S.E.(d)	0.96	0.78	0.01	0.01	0.44	0.69
C.D.5%	1.94	1.57	0.02	0.45	0.89	1.40

Table.2 Canopy Temperature Depression, Relative Water Content, Membrane Injury Index and seed yield at different growth stages in Indian mustard under late sown condition (pooled 2 years)

Genotypes	Canopy Temperature Depression (CTD ⁰ C)		Relative Water Content (%)		Seed Yield(g plant ⁻¹)
	Pre-flowering	Post-flowering	Pre-flowering	Post-flowering	
Vardan	3.9	3.2	78.9	57.6	16.5
Ashirwad	3.3	3.1	77.0	55.7	15.4
NPJ-207	3.8	3.0	76.8	55.9	15.5
NPJ-208	3.8	3.4	78.8	58.4	16.8
RGN-403	4.3	3.7	79.5	59.7	17.7
PBR-417	2.9	2.5	76.7	54.8	13.5
DRMRIJ 16-3	4.0	3.5	79.6	60.8	18.5
DRMR-2035	3.5	3.1	78.5	57.1	16.5
RRN-911	3.4	2.4	76.8	54.9	12.6
RH-1556	4.2	3.5	78.9	59.1	17.5
RGN-368	2.9	2.6	76.0	54.6	13.1
BPR 541-4	4.1	2.8	76.7	54.6	14.3
Mean	3.6	3.1	77.8	56.9	15.7
S.E.(d)	0.21	0.13	0.86	1.05	0.66
C.D.5%	0.43	0.26	1.74	2.11	1.34

Relative water content (RWC%) as influenced by late sowing estimated at pre flowering and post flowering stages are given in Table 2 clearly revealed that it varied significantly due to genotypes under late sown condition during both years of study i.e., 2017-18 and 2018-19. The pooled data analysis over the two years at pre flowering stage revealed that genotypes DRMRIJ 16-3 (79.6) being at par with RGN-403 (79.5), Vardan (78.9) and RH-1556 (78.9) proved its superiority as these maintain significantly higher relative water content in their leaves over other genotypes, while the lowest value of RWC were recorded in genotypes RRN-911 (38.2) and RGN-368 (38.3). At post flowering also again genotypes RH-1556 (63.0), RGN-403 (62.0) and DRMRIJ 16-3 (61.5) maintain higher status of RWC over the other genotypes, while lowest value of it at this stage was recorded in PBR-417 (56.5) and Ashirwad (56.6) under late sown environment. Our present findings are in agreement with the Indian mustard Ram *et al.*, (2014) and Sudhir *et al.*, (2013) and also similar results due to late sown has also been reported in the literature Sairam *et al.*, (2002); Kumar *et al.*, (2013); Kavita and Pandey (2018) in mustard crop.

Seed yield (g plant^{-1}) recorded at harvest (Table 2) showed significant genotypic variation among 12 genotypes under late sown condition analysis of both years data resulted that the genotypes, DRMRIJ 16-3 (18.5) followed by RGN-403 (17.7) and RH-1556 (17.5) were found significantly superior in seed yield indicating that these were suitable genotypes for late sowing environments with higher seed yield potential over the others genotypes. Genotypes RRN-911 (12.6) followed by RGN-368 (13.1) were unable to perform better under late sown condition as these exhibited significantly lowest seed yield over rest of the genotypes should be avoided for late sowing. Similar reduction in seed yield and genotypic

differences in late sown brassica crops were observed by Lallu *et al.*, (2010); Gawariya *et al.*, (2015); Hasan *et al.*, (2016) and Singh *et al.*, (2017).

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