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Mitigating terminal heat stress in physiological parameters of Indian mustard (*Brassica juncea* L.)

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Abstract
Increasing severity of high temperature worldwide presents an alarming threat to Mustard in India as late planting of mustard is very common due to the wide spread intensive cropping system particularly in north-west India. As a result, mustard crop has to face the problem of terminal heat stress. It causes a series of morphoanatomical, physiological and biochemical changes, which affect plant growth and development and results in reduced yield. However, there are various strategies for yield improvement under high temperature stress after anthesis in mustard. Investigation entitled "Studies on terminal heat mitigation in Indian mustard (*Brassica juncia* L.)" was carried out during rabi 2020-21 at Stundent's Instructional Farm of Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya (Uttar Pradesh). The experiment was conducted with NDR-8501. Seeds were sown in three different dates D1 (15th October), D2 (30th October) and D3 (15th November) with heat inducing chemicals. Data pertaining to different parameters were collected at regular intervals. It was observed optimum date for sowing of NDR-8501 was observed as 30 October under Ayodhya district of eastern Uttar Pradesh (North Indian) condition. In case of heat inducing chemicals the higher growth components, seed yield and its contributing traits were recorded when applying of salicylic acid (800ppm) followed by salicylic acid (400ppm) and KNo3 (0.3%). Interaction effect between date of sowing and heat inducing chemicals was also observed. As the sowing delayed, seed yield and its contributing traits was poor performance due to terminal heat stress. Thus by applying heat inducing chemicals, the seed yield could be substituted even delaying in sowing by the month of November and vice-versa.

Keywords: Mitigating, terminal, physiological, parameters, *Brassica juncea* L.

Introduction

Rapeseed-mustard is an important oil seed crop of India belong to the family *brassicacae*. The mustard cultivated in India is known as Indian mustard or Rai (*Brassica juncea* L Czern & Coss). According to Vavilov and Walknish, the mustard is originated in some places of China, India and Europe. Rapeseed-mustard is an important group of edible oilseed crops, next only to groundnut in India. Indian mustard (*Brassica juncea* L.) alone occupies about 85% of the total area under these crops. It is an often cross-pollinated crop and is mostly pollinated by honey bees. Botanically, the genus *Brassica* comprises six species namely *B. nigra*, *B. oleracea*, *B. rapa*, *B. carinata*, *B. juncea* and *B. napus*. Among them, first three species are elementary and diploid with 2n =16, 18 and 20 chromosomes, respectively and other three are tetraploids with chromosomes numbers 2n=34, 36 and 38 respectively. These entire crops are grown under wide range of agro- climatic conditions.

In world, during 2018-19 rapeseed-mustard occupied almost 36.59 million ha area with total production of 72.37 million tonne and 1980 kg ha^{-1} productivity (Anonymous, 2019) [1]. In India, during 2018-19, the area of rapeseed-mustard was 6.23 million per hectare with the production of 9.34 million tonne and productivity of 1499 kg per hactare. (Anonymous, 2019) [1]. However, in Uttar Pradesh during the year 2018-19 the area of rapeseed-mustard was 0.75 million hectare with the production of 1.12 million tonne and productivity of 1483 kg. per hectare but Rajasthan have the highest area 2.37 million hectare and production 4.08 metric tonne with low productivity 1720 kg per hectare as compared to Gujarat which has the highest productivity 1745 kg per hectare in 0.20 million hectare area with 0.34 million tonne production.

Mustard is cultivated in mostly under temperate climates. It is also grown in certain tropical and subtropical regions as a cold weather crop. Generally, plants respond to high temperature stress through developmental, biochemical and physiological changes and the type of the observed response depends on several factors such as stress intensity (SI), stress duration and genotype (Moradshahi *et al*., 2004) [2].

The problem of heat stress at flowering stage is observed in all the major mustard growing countries including China, Australia, Canada and Europe, but heat stress at seedling and terminal stage is a unique problem to India (Salisbury and Gurung, 2011). There are many studies related with thermo tolerance in oilseed brassica at the flowering (Yadav *et al*., 1989 & 1990) [10, 9] but very little information is available in understanding the heat tolerance at seedling and terminal stages. Further heat tolerance in crop plants is developmental process being regulated, and is known to be stage specific phenomena, meaning tolerance at one stage of plant development may not be correlated with tolerance at the other developmental stages (Wahid *et al*., 2007) [7].
High temperature stress is a major environmental stress that limits crop growth, metabolism and productivity. High temperature stress during reproductive development termed as terminal heat stress. Hall (1992) [5] reported that flowering is the most sensitive stage for temperature stress damage probably due to vulnerability during pollen development, anthesis and fertilization leading to reduce crop yield.
In eastern Uttar Pradesh, Mustard is cultivated after the harvest of rice crop which hasten laid to true maturity. Due to that stress, the mustard crop suffers on later phases of seed development and maturation. Thus, there is an urgent need to mitigate such problems in order to cope up with high temperature. High temperature in Brassica hastens plant development and caused flower abortion with appreciable loss in seed yield. Salicylic acid is a common phenolic compound that promotes photosynthesis under heat stress by influencing various physiological and biochemical process. The ability of salicylic acid to activate the superoxide dismutase has been revealed on certain species of plants (Rao *et al*. 1992) [14].

Methods and Material

The field experiment was conducted at Students Instructional Farm of Acharya Narendra Deva University of Agriculture and Technology, Narendra Nagar, Ayodhya (U.P.) during *Rabi* 2020-21.Geographically, the farm is located between 24.47^0 and 26.56^0 N latitude, 82.12^0 and 83.98^0 E longitudes and at an altitude of 113m above from mean sea level in the gangetic plains of eastern Uttar Pradesh. This area falls in sub-tropical climate zone. 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 characterized by 0.31% organic carbon, 180 kg available N/ha, 11.80 kg available P_2O_5/ha, 180 kg available K_2O/ha, 8.8 pH and 0.96 dS/m Electrical Conductivity (EC). The spacing between rows and plants within a row after thinning was maintained as 30cm and 15cm, respectively. The experiments were laid out in Factorial RBD with three replications at different date of sowing with heat induces chemicals (Table-1).

Table 1: The experiments were laid out in Factorial RBD with three replications at different date of sowing with heat induces chemicals

S. N.	Treatments	Concentration of solution
T_1	Salicylic acid	400ppm
T_2	Salicylic acid	800ppm
T_3	KNO_3	0.3%
T_4	Cycocel	1250ppm
T_5	Thiourea	400ppm
T_6	KCL	1%
T_7	Ascorbic acid	10ppm
T_8	Control	Untreated

Germination (%)

In test three replications of 100 seeds were kept in two layers of moist filter or blotter paper in Petri dish. The sample was kept in seed germinator maintained at 20±1 ^{0}C.
The germination percentage was calculated as below:

$$\text{Germination}(\%) = \frac{\text{Number of seed germinated}}{\text{Total number of seed}} \text{x}100$$

Seedling length (cm)

The randomly selected twenty seedlings used to measure root length and shoot length previously was used to measure seedling length in centimetre and finally averaged.

Vigour index (Abdul Baki and Anderson 1973)

The vigour index was calculated as per the method prescribed by Abdul-Baki and Anderson (1973) and expressed in whole number:
Vigour index was calculated by the multiplication of germination percentage with that of seedling length on the day of final count.

Vigour index = Germination (%) X Seedling length (cm)

Results and Discussion

It is depicted from the Table no.2 that the germination% of NDR-8501 sown on D1 (15 October), D2 (30 October) and D3 (15 November) were significant germination% in D2 (89.23%) followed byD1 (88.45%) and D3 (87.99%), respectively. In case of spraying of heat inducing chemicals the highest germination% were recorded in T2 (Salicylic acid 800ppm) 90.67% has significant effect followed by T1 (salicylic acid 40ppm) 89.69% and T3 (KNO3 0.3%) 89.50%, respectively.
The seedling length of NDR-8501 sown on D1 (15 October), D2 (30 October) and D3 (15 November) were highest in D2 (15.33cm) followed byD1 (13.06cm) and D3 (8.42cm), respectively. In case of spraying of heat inducing chemicals the seedling length were highest in T2 (Salicylic acid 800ppm) 13.93cmfollowed by T1 (salicylic acid 400ppm) 13.10cm and T3 (KNO3 0.3%) 12.77cm, respectively.
The vigour index of NDR-8501 sown on D1 (15 October), D2 (30 October) and D3 (15 November) were highest in D2 (1369.51) followed byD1 (1156.48) and D3 (741.69), respectively. In case of spraying of heat inducing chemicals the vigour index were highest in T2 (Salicylic acid 800ppm) 1266.50 followed by T1 (salicylic acid 400ppm) 1174.25 and T3 (KNO3 0.3%) 1146.43, respectively.

The present result is in close agreement with the observation of Chauhan *et al*. (2009) [4].

The germination% of NDR-8501 were highest in 92.50% (D2×T2) followed by 90.50% (D2×T1) and 89.50% (D2×T3) respectively.

The seedling length were found 14.50cm (D2×T2) followed by 14.10cm (D2×T1) and 13.50cm (D2×T3) respectively.

The vigour index were highest 1305.00 (D2×T2) followed by 1254.90 (D2×T1) and 1228.50 (D2×T3) respectively.

Table 2: Effect of date of sowing, heat inducing chemicals and its interaction on germination (%), seedling length (cm) and vigour index of Indian mustard NDR-8501

Sowing time	Symbol	Germination (%)	Seedling length (cm)	Vigour index
15 October	D1	88.45	13.06	1156.48
30 October	D2	89.23	15.33	1369.51
15 November	D3	87.99	8.42	741.79
S.Em. ±		0.676	0.090	8.242
CD at 5%		N/A	0.258	23.537
Treatment				
Salicylic acid (400 ppm)	T1	89.67	13.10	1174.25
Salicylic acid (800ppm)	T2	90.67	13.93	1266.50
KNO3 (0.3%)	T3	89.50	12.77	1146.43
Cycocel (1250ppm)	T4	88.40	12.03	1064.61
Thiourea (400ppm)	T5	88.60	12.53	1110.86
KCL (1%)	T6	87.50	11.23	984.00
Ascorbic acid (10ppm)	T7	87.93	11.60	1021.00
Control	T8	86.17	10.97	946.41
S.Em. ±		1.104	0.148	13.459
CD at 5%		N/A	0.422	38.436
Interaction				
Salicylic acid (400 ppm)	D1xT1	89.00	14.10	1254.90
Salicylic acid (800ppm)	D1xT2	90.00	14.50	1305.00
KNO3 (0.3%)	D1xT3	91.00	13.50	1228.50
Cycocel (1250ppm)	D1xT4	88.50	12.50	1106.25
Thiourea (400ppm)	D1xT5	88.70	13.30	1179.71
KCL (1%)	D1xT6	87.50	12.20	1067.50
Ascorbic acid (10ppm)	D1xT7	87.90	12.40	1089.96
Control	D1xT8	85.00	12.00	1020.00
Salicylic acid (400 ppm)	D2xT1	90.50	16.11	1457.96
Salicylic acid (800ppm)	D2xT2	92.50	17.05	1577.13
KNO3 (0.3%)	D2xT3	89.50	16.00	1432.00
Cycocel (1250ppm)	D2xT4	88.70	15.40	1365.98
Thiourea (400ppm)	D2xT5	88.70	15.80	1401.46
KCL (1%)	D2xT6	88.00	14.00	1232.00
Ascorbic acid (10ppm)	D2xT7	88.40	14.50	1281.80
Control	D2xT8	87.52	13.80	1207.78
Salicylic acid (400 ppm)	D3xT1	89.00	9.10	809.90
Salicylic acid (800ppm)	D3xT2	89.50	10.25	917.38
KNO3 (0.3%)	D3xT3	88.50	8.80	778.80
Cycocel (1250ppm)	D3xT4	88.00	8.20	721.60
Thiourea (400ppm)	D3xT5	88.40	8.50	751.40
KCL (1%)	D3xT6	87.00	7.50	652.50
Ascorbic acid (10ppm)	D3xT7	87.50	7.90	691.25
Control	D3xT8	86.00	7.11	611.46
S.Em. ±		1.91	0.26	23.31
CD at 5%		N/A	N/A	N/A

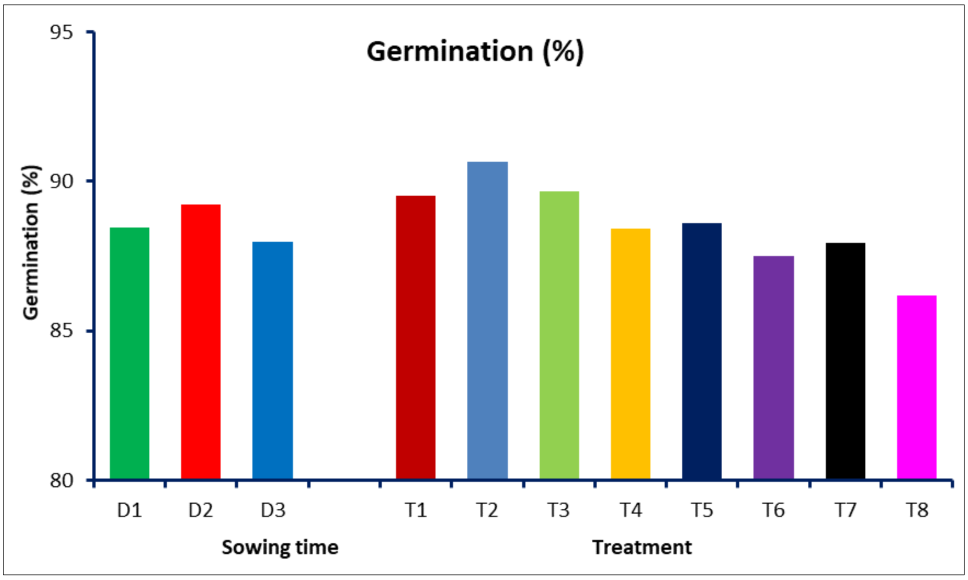

Fig 1: The germination percentage of NDR-8501 in relation to date of sowing and heat inducing chemicals

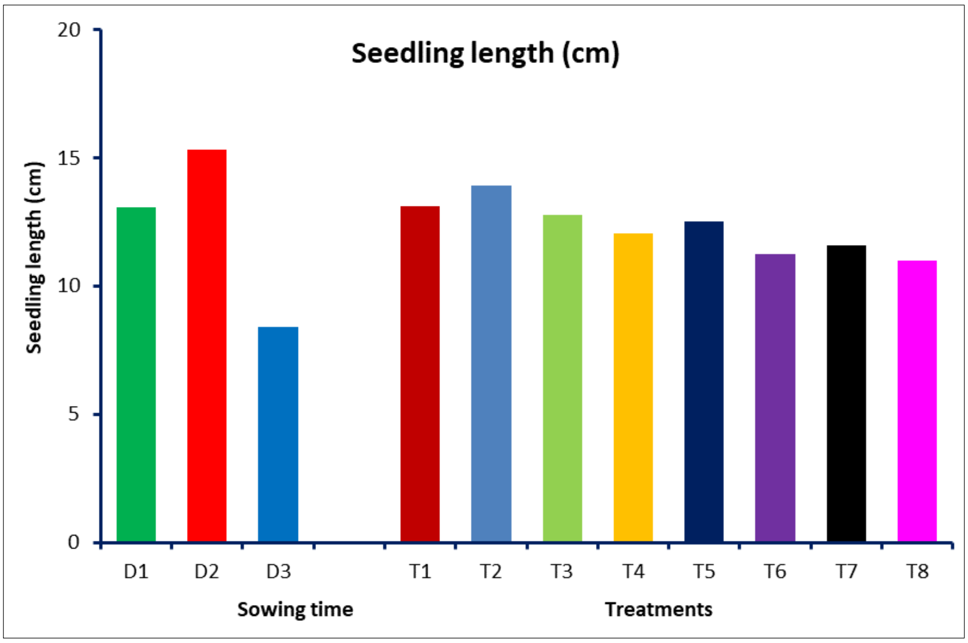

Fig 2: The seedling length of NDR-8501 in relation to date of sowing and heat inducing chemicals

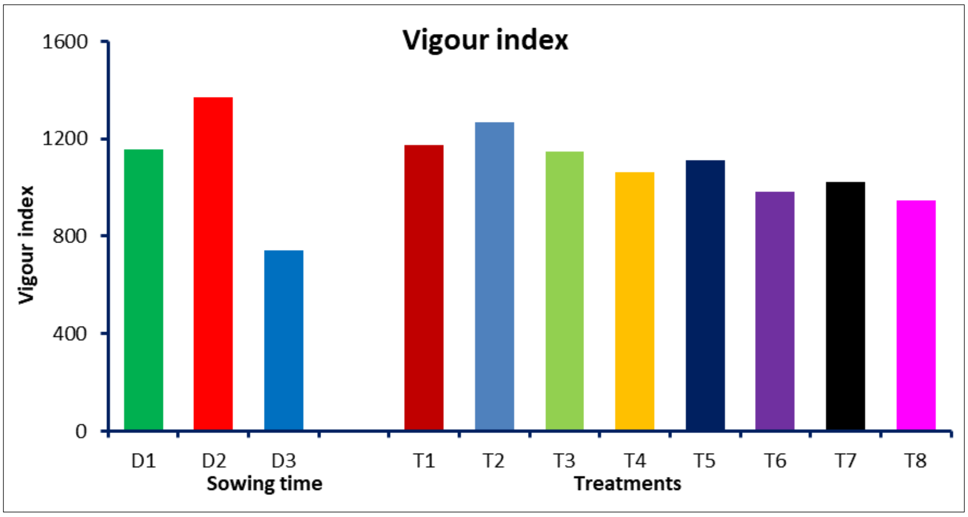

Fig 3: Vigour index of NDR-8501 in relation to date of sowing and heat inducing chemicals

Conclusion
The heat inducing chemicals which apply to NDR-8501 the significant effect was observed as Salicylic acid (800ppm) followed by salicylic acid (400ppm) and KNO3 (0.3%) in relation to seed yield and its contributing traits. Significantly, the higher growth components, seed yield and its contributing traits were recorded when the crop was grown 30 October, 2021 (D2) along with the application of 800ppm salicylic acid T2 (D2×T2), followed by D2×T1 and D2×T3. Interaction effect between date of sowing and heat inducing chemicals was also observed. As the sowing delayed, seed yield and its contributing traits was poor performance due to terminal heat stress. Thus by applying heat inducing chemicals, the seed yield could be substituted even delaying in sowing by the month of November and vice-versa. It can be concluded from the present observation that application of salicylic acid enhanced the activity of ant oxidative enzymes in Indian mustard plant under elevated temperatures. The elevated activity of ant oxidative enzymes counter the direct as well as indirect effects of temperature stress thereby, improving the photosynthetic efficiency, metabolism and growth in Indian mustard.

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