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Response of seed enhancement treatments in improving vigour under elevated temperature conditions in Indian mustard

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ABSTRACT Role of seed treatments for enhancement of seed vigour in response to temperature was investigated on two varieties of Indian mustard (*Brassica juncea*); Pusa Mustard 28 and Pusa Karishma. Both the varieties were given different presowing treatments *viz.* hydropriming (17h/20°C); halopriming (100µM $CaCl_2$ for 18h/20°C); halopriming (0.3% KNO_3 for 18h/20°C); salicylicacid (1500µM SA for 18 h/20°C); osmopriming (20% PEG8000 for 18h/20°C); IncoTec QR (0.02 gm/1000 seed); genius coat 172 (2.5g a.i./kg seed); IncoTec 220 (800 µl/gm seed) and thiram (2gm/kg seed) and compared with untreated control. The varieties were subjected to elevated temperatures of 30°C and 35°C, while temperature of 20°C was taken as control. Temperature stress influenced various quality parameters in all treatments. Results revealed that there were significant differences among the varieties for root length, shoot length and vigour index I under temperature stress conditions. The tolerant variety, PM 28 resulted in significantly higher vigour index I and shoot length than susceptible variety, Pusa Karishma. The maximum first count per cent, germination per cent, root length, shoot length, vigour index I and II and minimum percentage of abnormal seedling, hard seeds and dead seeds were observed in salicylic acid, KNO_3 and hydropriming seed treatments. Salicylic acid had significant effect on all above parameters than KNO_3 and hydro priming under temperature stress conditions. Therefore, salicylic acid priming and halopriming with KNO_3 could be used to improve vigour of brassica under temperatures stress conditions.

Keywords: Indian mustard, pre-sowing treatments, seed enhancement, seed vigour, temperature stress

Addressing the challenge of assured plant stand under elevated temperatures, a consequence of global warming in tropical and sub-tropical regions, would involve the necessary adjustments through modifying field operations such as tillage or pest control and developing easy and cost effective techniques for enhancing the value of seed. Rapid and uniform field emergence is an essential prerequisite to maximize growth, quality and ultimately profit. Greater and better synchronized germination is crucial for obtaining an optimal seedling establishment and better productivity. However, several environmental constraints are major impediments in achieving these. Seedling establishment is a phenological stage at which drought could be particularly harmful to annual plants.

Seed enhancement is defined as all such post harvest treatments, physical, chemical or physiochemical that enhance planting value of seeds [1]. The seeds should have the potential to establish under a wide range of optimal and suboptimal conditions of growth. Various seed enhancement treatments like seed invigoration, coating, pelleting, fortification and pesticidal treatments are known to improve seed quality in different species but response to these treatments are variable and crop specific. Taylor *et al.* [2] used "seed enhancement" as a comprehensive terminology for presoaking hydration (priming), coating technologies and seed conditioning. Several treatments have been applied for enhancement of planting value [3]. One practical approach to increase crop production is seed priming [4] that includes hydropriming, osmoconditioning, osmohardening, hardening, hormone-priming, matrix priming *etc.* Priming offers a means to raise seed performance in many crop species [5]. Heydecker and Coolbear [6] defined seed priming as a pre-sowing treatment in osmotic solution that allows seeds to imbibe water to proceed to the first stage of germination but prevents radicle protrusion through the seed coat. Therefore, seed priming can be accomplished through different methods such as hydro-priming (soaking in water), osmo-priming (soaking in osmotic solutions such as polyethylene glycol, potassium salts, e.g., KCl, K_2SO_4) solid matrix priming and using plant growth regulators (PGRs) [5, 7]. Hence, the present study was conducted to examine the effects of different seed priming methods such as hydropriming, halopriming (KNO_3 and $CaCl_2$), osmopriming (PEG8000), salicylic acid priming,

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coating with IncoTec (QR & 220) and Genius coat, for comparison of their effects on various seed quality and vigour parameters of mustard cultivars under temperature stress conditions.

MATERIALS AND METHODS

Materials

The study was conducted on the freshly harvested seeds of two varieties of Indian mustard (*Brassica juncea* L.)-temperature stress tolerant Pusa Mustard 28 and susceptible Pusa Karishma, which were supplied by Division of Genetics, ICAR-IARI, New Delhi. Efficacy of seed enhancement treatments on seed quality and vigour parameters under temperature stress conditions was evaluated at the laboratory of Division of Seed Science and Technology, ICAR-IARI, New Delhi during 2013. All the varieties were given different pre-sowing treatments *viz.* hydropriming (16 h/20 °C) (T2); halopriming (100μM $CaCl_2$ for 18h/20 °C) (T3); halopriming (0.3% KNO_3 for 18h/20 °C) (T4) and salicylic acid (1500 μM SA for 18 h/20 °C) (T5); osmopriming (20% PEG8000 for 18 h/ 20 °C) (T6); coating; IncoTec QR (0.02 g/1000 seed) (T7), genius coat 172 (2.5 g a.i./kg seed) (T8), IncoTec 220 (800 μl/gm seed) (T9) and thiram (2gm/kg seed) (T10) and compared with untreated control (T1). All the chemicals used were of analytical grade or above, unless otherwise stated. The primed seeds were dried back to original moisture. The varieties were grown under elevated temperatures of 30 °C and 35 °C, while temperature of 20 °C was taken as control.

Simulation of temperature stress conditions

For testing the above seed enhancement treatments, temperatures were maintained at 30°C & 35°C in germinators and subsequently compared with the performance of seeds tested at 20°C (control). For testing temperature stress under field conditions, four replications of 200 seeds from each treatment were sown on 07.10.2013, 25.10.2013 and 11.11.2013 (control), when soil temperatures during the day were 35°C, 30°C and 25°C and mean temperatures during germination period were around 28 °C, 23 °C and 18 °C respectively.

Field evaluation

Three treatments that showed better performance under laboratory conditions were sown on different dates as mentioned above to observe the effect on speed of emergence and percentage of seedling establishment. The field experiment was laid in RBD with four replications of each treatment. Plant-to-plant spacing of 10 cm and row-to-row spacing of 45 cm was maintained and the recommended package of practices was followed to raise a healthy crop.

Moisture Content

The moisture content of both the varieties was determined using low temperature constant oven method at 103±1 °C for 17±1 hours [8] just before the seed treatments. It was 9.3% and 9.4% in Pusa Mustard 28 and Pusa Karishma respectively. After the treatment the varieties were dried back over silica gel, using desiccators, to the initial level of moisture.

Observations recorded

The seeds were tested for various quality parameters *viz.* per cent first count, germination percentage., seedling vigour indices, speed of germination and field emergence percentage. The methods used for recording the various observations are explained below;

First count (%)

Seeds from pure seed fraction were used for estimation of first count(%). Four replicates of 50 seeds each were placed on filter papers (TP) and the number of normal seedling were recorded on 5th day and expressed in percentage.

Germination (%)

It was determined as per ISTA [8]. Four replications each of 50 seeds were placed on top of two layers of moist filter paper and placed in the walk-in-germinator maintained at 20 °C. At the end of test on 7th day, seeds were categorized into normal seedling, abnormal seedling, hard and dead seeds and percentage of normal seedling was used to calculate standard germination (%).

Seedling length

Ten normal seedlings were taken at random from each replication during final count. The root, shoot and total length of each seedling were measured in centimeter. The mean values from each replication were used for comparison of vigour.

Seedling dry weight

Ten normal seedlings which were selected at random for observing seedling length were dried in a hot air oven at 70 ± 1 °C for 48 h. Seedling dry weight was determined and expressed as mg/seedling.

Vigour Indices

The vigour indices were computed adopting the method of Abdul Baki and Anderson [9] by using following formula:

Vigour index I=Germination (%) × Seedling length
Vigour index II=Germination (%) × Seedling dry weight

Speed of germination

Speed of germination was calculated following the procedure of Maguire [10] as

Speed of germination = $\sum (n/t)$

Where n is the number of seeds newly germinating at time t and t is days from sowing.

Field emergence percentage

Hundred seeds were sown in four rows per replication during *Rabi* 2013 and the number of seedlings that emerged was counted 15 days after sowing. The emergence was expressed in percentage

Statistical analysis of data

The data collected from the physiological experiments were subjected to statistical analysis using the SPSS package (version 10). Before analysis, the per cent data of the seed quality variables were transformed to arc sine values. The analysis for LSD and Duncan's multiple range tests for homogenous sub sets were performed. The variance ratio was studied in all cases for significance at 5% level of probability. The data of two varieties tested under different stress levels was pooled where non-significant differences amongst the varieties were noticed.

RESULTS AND DISCUSSION

Variable effects of seed enhancement treatments under different stress conditions of temperature were observed on all traits under study.

Effect of seed quality enhancement treatments on seed germination and vigour parameters under different temperature stress levels

In the two varieties studied, no significant differences were observed in their mean first count (i) and mean germination percentage (ii). The values were found to be significantly decreased in increased temperature stress levels. It was noticed that they were significantly lower (i. 83.4, ii. 88.4) at 35°C temperature than at 30°C temperature and control (with no temperature stress). Treatments also revealed significant variations. Out of ten treatments, five (Salicylic acid, KNO_3, PEG, hydropriming and QR IncoTec) were found significantly superior over control (i.84.9, ii. 89.9). It was significantly higher in seeds treated with Salicylic Acid (i.88.6, ii. 93.6) which was at par with KNO_3 treated seeds (i.87.6, ii. 92.6) than all other treatments. All interactions (variety x stress level, variety x treatment, treatment x stress level and variety x stress level x treatment) effects were found to be non-significant (Tables1 & 2). However, highest values (i. 90.3, ii. 95.3) were observed in variety PM 28 in salicylic acid treated seeds tested without any temperature stress whereas, it was lowest (i. 81, ii. 86) in temperature stress susceptible variety Pusa Karishma tested under conditions of 35°C temperature level.

Table 1. Effect of seed quality enhancement treatments on first count (%) of different varieties under variable temperature levels.

Treatments	PM 28 Temperature stress level (SL)			Mean	PUSA KARISHMA Temperature stress level (SL)			Mean	Mean
	20°C	30°C	35°C	(VXT)	20°C	30°C	35°C	(VXT)	(Treatment)
Control	89.0(70.7)	84.3(66.7)	82.3(65.2)	85.2	89.0(70.7)	83.7(66.2)	81.0(64.2)	84.6	84.9a
Hydropriming	89.7(71.2)	88.7(70.4)	84.7(67.0)	87.7	89.7(71.3)	86.3(68.3)	84.0(66.4)	86.7	87.2bcd
CaCl2	89.0(70.7)	86.7(68.6)	84.0(66.5)	86.6	89.0(70.7)	84.7(67.0)	83.0(65.7)	85.6	86.1abc
KNO3	89.7(71.2)	89.7(71.3)	85.3(67.5)	88.2	89.7(71.3)	87.0(69.0)	84.3(66.7)	87.0	87.6cd
Sal. Acid	90.3(71.9)	90.7(72.3)	86.3(68.5)	89.1	90.3(71.0)	88.0(69.7)	86.0(68.0)	88.1	88.6d
PEG	89.0(70.7)	88.3(70.1)	84.3(66.8)	87.2	89.0(70.7)	86.3(68.5)	84.0(66.5)	86.4	86.8bc
QR (IncoTec)	89.7(71.4)	87.7(69.5)	83.7(66.2)	87.0	89.7(71.4)	86.0(68.0)	83.3(65.9)	86.3	86.7bc
Genius Coat 172	89.0(71.7)	87.3(69.3)	82.3(65.2)	86.2	89.0(70.7)	85.3(67.5)	82.7(65.4)	85.7	85.9abc
IncoTec 220	89.0(70.7)	87.3(69.2)	83.0(65.8)	86.4	89.0(70.7)	85.7(67.8)	80.7(64.0)	85.1	85.8ab
Thiram	89.0(70.7)	86.3(68.4)	83.3(66.0)	86.2	89.0(70.7)	85.0(67.3)	81.3(64.5)	85.1	85.7ab
Mean (VXSL)	89.3	87.7	83.9		89.3	85.8	83.0		
Mean (Variety)		87.0a				86.1b			
Mean (SL)	89.3c	86.6b	83.4a						

CD (p=0.05%) VAR= 0.54, SL=0.82, TREAT=1.2, VXSL=NS, VXT=NS, SLXT=NS, VXSLXT=NS

* The figures in parenthesis are arc sine transformed values of per cent.

Table 2. Effect of seed quality enhancement treatments on mean germination (%) of different varieties under variable temperature levels.

Treatments	PM 28 Temperature stress level (SL) 20°C	30°C	35°C	Mean (VXT)	PUSA KARISHMA Temperature stress level (SL) 20°C	30°C	35°C	Mean (VXT)	Mean (Treatment)
Control	94.0(76)	89.3(71)	87.3(69.2)	90.2	94.0(76)	88.7(70.4)	86.0(68.1)	89.6	89.9a
Hydropriming	94.7(76.7)	93.7(75.5)	89.7(71.4)	92.7	94.7(76.7)	91.3(72.9)	89.0(70.7)	91.7	92.2bc
CaCl2	94.0(76)	91.7(73.3)	89.0(70.7)	91.6	94.0(76)	89.7(71.3)	88.0(69.8)	90.6	91.1abc
KNO3	94.7(76.7)	94.7(76.8)	90.3(72)	93.2	94.7(76.7)	92.0(73.8)	89.3(71.2)	92.0	92.6cd
Sal. Acid	95.3(77.6)	95.7(78)	91.3(73.2)	94.1	95.3(77.6)	93.0(74.8)	91.0(72.7)	93.1	93.6d
PEG	94.0(76)	93.3(75.1)	89.3(71.2)	92.2	94.0(76)	91.3(73.1)	89.0(70.8)	91.4	91.8bc
QR (IncoTec)	94.7(76.9)	92.7(74.4)	88.7(70.4)	92.0	94.7(76.9)	91.0(72.7)	88.3(70.1)	91.3	91.7bc
Genius Coat 172	94.0(75.9)	92.3(74.2)	87.3(69.3)	91.2	94.0(75.9)	90.3(72)	87.7(69.5)	90.7	90.9ab
IncoTec 220	94.0(76)	92.3(74.1)	88.0(69.9)	91.4	94.0(76)	90.7(72.3)	85.7(67.8)	90.1	90.8ab
Thiram	94.0(76)	91.3(73)	88.3(70.1)	91.2	94.0(76)	90.0(71.7)	86.3(68.4)	90.1	90.7ab
Mean (VXSL)	94.3	92.7	88.9		94.3	90.8	88.0		
Mean (Variety)		92.0				91.1			
Mean (SL)	94.3c	91.7b	88.4a						

CD (p=0.05%) VAR=6.52, STL=0.8, TREAT=1.46, VXSTL=1.13, VXT=NS, STLXT=NS, VXSTLXT=NS

* The figures in parenthesis are arc sine transformed values of per cent data.

Since the vigour index I & II are manifestation of seedling length and per cent dry weight respectively, so the data recorded has not been presented. In the two varieties studied, significant differences were observed in their vigour indices (i. Vigour Index I ii. Vigour index II). In variety PM 28 Vigour Index I was significantly higher (990) than that of variety Pusa Karishma. The vigour indices were found to be significantly decreased in increased temperature stress levels. It was noticed that the vigour indices I & II values were significantly lower (i. 803, ii. 178) at 35 °C than 30°C and control (with no temperature stress). Treatments also revealed significant variations. All the treatments were significantly higher in mean vigour index I over control (912) except thiram, which was at par with control. It was significantly higher in seeds treated with salicylic acid (1057) than all other treatments. KNO_3treated seeds conferred vigour index I (1020) at par with hydropriming seed treatment but significantly higher than other treatments. In case of Vigour Index II, out of ten treatments, six (salicylic acid, KNO_3, PEG, hydropriming, $CaCl_2$ and IncoTecQR) were found significantly higher over control (186). It was significantly higher in seeds treated with salicylic acid (205) which was at par with KNO_3 treated seeds (201) than all other treatment. All interaction (variety x stress level, variety x treatment, treatment x stress level and variety x stress level x treatment) effects were found to be non-significant (Tables 3 & 4). However, highest vigour index values (i. 1185 ii. 213) were observed in temperature stress tolerant variety PM 28 in salicylic acid treated seeds tested without any temperature stress whereas, it was lowest (i. 732 ii. 165) in temperature stress susceptible variety Pusa Karishma tested under conditions of 35 °C level.

The effect of different temperature stress levels and seed enhancement treatments on other quality parameters of mustard seeds has been given in tables 5 and 6 respectively. However, the data for individual variety has not been presented because of being non significant except for shoot length. Significantly lower abnormal seedling per cent was noticed without temperature stress (4.17%), whereas highest abnormal seedling per cent (8.73%) was observed at 35 °C temperature stress level. No significant differences with respect to abnormal seedling per cent was observed amongst the varieties evaluated. Significant variations amongst the treatments for abnormal seedling per cent were detected. Significantly lower abnormal seedling per cent than control (7.78%) was discerned in seeds treated with salicylic acid (4.72%) which was at par with halopriming (KNO_3), hydropriming and IncoTec QR treatment. Non significant differences in abnormal seedling per cent were observed in all other remaining treatments except PEG treatment (6.11%), as compared with control. Significantly lower hard seed per cent was noticed without temperature stress (0%) whereas highest hard seed per cent (0.75%) was observed at 35°C temperature stress level. No significant differences with respect to hard seed per cent was observed amongst the varieties evaluated. The mean hard seed per cent was found to be numerically more in variety PM 28(2.4%) than in Pusa Karishma (2.3%). No significant variations amongst the treatments for hard seed per cent were detected. Significantly lower dead

Table 3. Effect of seed quality enhancement treatments on vigour index I of different varieties under variable temperature levels.

Treatments	PM 28 Temperature stress level (SL) 20°C	30°C	35°C	Mean (VXT)	PUSA KARISHMA Temperature stress level (SL) 20°C	30°C	35°C	Mean (VXT)	Mean (Treatment)
Control	1062	947	751	920	1057	922	732	904	912a
Hydropriming	1139	1096	842	1026	1127	1048	828	1001	1013de
CaCl2	1119	1043	813	991	1103	997	783	961	976c
KNO3	1149	1111	844	1035	1138	1057	824	1006	1020e
Sal. Acid	1185	1139	883	1069	1172	1091	871	1045	1057f
PEG	1119	1052	822	998	1104	1016	818	980	989cd
QR (IncoTec)	1121	1027	795	981	1108	1002	794	968	975c
Genius Coat 172	1096	1031	783	970	1077	991	801	956	963bc
IncoTec 220	1093	1026	788	969	1083	984	765	944	956bc
Thiram	1070	983	781	944	1069	966	747	927	936ab
Mean (VXSL)	1115	1045	810		1104	1008	796		980
Mean (Variety)		990a				969b			
Mean (SL)	1109c	1026b	803a						

CD (p=0.05%) VAR=12.88, STL=15.7, TREAT=28.5 VXSTL=NS, VXT=NS, STLXT=NS, VXSTLXT=NS

Table 4. Effect of seed quality enhancement treatments on vigour index II of different varieties under variable temperature levels.

Treatments	PM 28 Temperature stress level (SL) 20°C	30°C	35°C	Mean (VXT)	PUSA KARISHMA Temperature stress level (SL) 20°C	30°C	35°C	Mean (VXT)	Mean (Treatment)
Control	206	189	169	188	206	184	165	185	186a
Hydropriming	209	203	183	198	209	197	180	195	197cd
CaCl2	208	196	181	195	207	192	177	192	194bc
KNO3	210	207	190	202	210	201	186	199	201de
Sal. Acid	213	214	194	207	212	206	193	204	205e
PEG	208	201	181	196	207	196	178	194	195bcd
QR (IncoTec)	209	200	177	195	209	196	175	193	194bcd
Genius Coat 172	207	198	173	193	207	194	172	191	192abc
IncoTec 220	207	198	174	193	207	193	166	189	191abc
Thiram	206	194	174	191	207	190	167	188	190ab
Mean (VXSL)	208	200	180		208	195	176		
Mean (Variety)		196a				193b			
Mean (SL)	208c	197b	178a						

CD (p=0.05%) VAR=2.18, STL=2.7, TREAT=4.9 VXSTL=NS, VXT=NS, STLXT=8.5, VXSTLXT=NS

seed per cent was noticed incontrol (1.5%), where as highest dead seed per cent (2.03%) was observed at 35°C temperature stress level. No significant differences with respect to dead seed per cent was observed amongst the varieties evaluated. Also, non-significant differences amongst the treatments for dead seed per cent were detected. Significantly higher root length was noticed in control (without temperature stress) (7.3 cm) whereas lowest root length was observed at 35°C temperature stress level (5.71 cm). The mean root length per cent was found to be more in variety Pusa Karishma (6.73) than PM 28 (6.69). Significant variations amongst the treatments for root length were observed. Significantly higher root length was discerned in seeds treated with salicylic acid (7.03 cm) which was at par with halopriming (KNO_3) and hydro priming treatment. Hydro priming was also at par with haloprimed ($CaCl_2$), PEG and genius coat treatment, whereas control was at par with thiram (6.53 cm) treatment.

Significantly higher shoot length was noticed in control (without moisture stress) (4.5 cm) whereas lowest shoot length (3.35 cm) was observed at 35 °C temperature stress level. Significant difference with respect to shoot length was observed amongst the varieties evaluated. The mean shoot length per cent was found to be significantly higher in variety PM 28 (3.82 cm) than Pusa Karishma (3.69 cm). Significant variations amongst the treatments for shoot length were detected. Significantly higher shoot length was discerned in seeds treated with salicylic acid (4.24 cm), which was at par with halopriming (KNO_3) and hydro priming treatment was at par with halo primed ($CaCl_2$)

Table 5. Effect of different temperature stress level on other quality parameters of mustard seeds.

Stress levels	Abnormal seedling(%)	Hard seed (%)	Dead seed (%)	Shoot length(cm)	Root length(cm)
Control (20°C)	4.17a(11.7)	0.0a(0.0)	1.50a(4.9)	4.5c	7.3c
Temperature (30°C)	6.17b(15.5)	0.58b(6.9)	1.5a(6.9)	4.04b	7.13b
Temperature (35°C)	8.73c(17.0)	0.75b(7.5)	2.03b(7.5)	3.35a	5.71a

* The figures in parenthesis are arc sine transformed values of per cent data.

Mean followed by the same letter in each column for each seed fraction do not differ statistically among each other according to the Duncan's Test of Homogeneous Subsets (Level of significance:0.05).

Table 6. Effect of seed enhancement treatments on other quality parameters of mustard seeds

Stress levels	Abnormal seedling(%)	Hard seed (%)	Dead seed (%)	Shoot length(cm)	Root length(cm)
Control	7.78d(15.9)	0.61a(2.76)	1.72a(7.28)	3.67a	6.43a
Hydropriming	5.72ab(13.6)	0.39a(2.23)	1.72a(7.25)	4.12de	6.85def
CaCl2	6.89bcd(15.0)	0.61a(3.32)	1.44a(6.40)	4.01cd	6.68bcd
KNO3	5.56ab(13.4)	0.39a(2.23)	1.44a(6.03)	4.11de	6.88ef
Sal. Acid	4.72a(12.3)	0.28a(1.60)	1.39a(5.92)	4.24e	7.03f
PEG	6.11bc(14.0)	0.39a(2.05)	1.67a(7.15)	4.00cd	6.74cde
QR (IncoTec)	6.00abc(13.8)	0.28a(1.60)	2.06a(7.94)	3.94c	6.66bcd
Genius Coat 172	6.83bcd(14.9)	0.44a(2.37)	1.78a(7.09)	3.88bc	6.68bcd
IncoTec 220	6.72bcd(14.7)	0.50a(2.50)	2.00a(8.03)	3.88bc	6.62bc
Thiram	7.22cd(15.4)	0.56a(3.00)	1.56a(6.32)	3.76ab	6.53ab

* The figures in parenthesis are arc sine transformed values of per cent data.

and PEG. Control (3.67cm) was at par with thiram treatment.

The response of all treatments under various stresses influenced various seed quality parameters in mustard. The maximum first count per cent, germination per cent, root length, shoot length, seedling dry weight, vigour index I and II and minimum percentage of abnormal seedling, hard seeds and dead seeds were observed in salicylic acid, KNO_3 and hydropriming seed treatments in all stress conditions. The significantly higher per cent germination and normal seedling were observed in seeds treated with salicylic acid and KNO_3 than untreated seeds, where the effect of salicylic acid was found to be more pronounced than KNO_3 primed seeds. Shoot weight (fresh and dry) and root fresh weight were increased in seedlings raised from seeds primed with 50 ppm salicylic acid. It was also found that salicylic acid application increased the dry mass of brassica seedlings under water stress [11]. The protective and growth promoting effect of salicylic acid are presumably due to increased level of cell division within the apical meristem of seedling root, which caused an increase in plant growth. Seed priming with salicylic acid in barley leads to plant resistance under salinity [12]. Previous results suggest that salicylic acid could be a promising compound for the reduction of abiotic stress sensitivity in plants, since under certain conditions it has been found to mitigate the damaging effects of various stress factors in plants. These positive effects are probably due to the stimulatory effects of priming on the early stages of germination process by mediation of cell division in germinating seeds [13-14].

Effect of seed quality enhancement treatments on speed of emergence (SoE) and percentage of seedling establishment (PoSE) under different temperature stress levels

Between the two varieties studied, significant differences were observed in their (i) SoE *i.e.* number of seedlings emerged per day after sowing and PoSE (ii). In variety PM 28 it was significantly higher (i. 14.7 ii. 73.0) than variety Pusa Karishma. The values were found to be significantly decreased at increased temperature stress levels. It was noticed that they were significantly lower (i. 13.6 ii. 66.5) at 35 °C temperature than 30°C temperature and control (with no temperature stress). Treatments also revealed significant variations in SoE and PoSE. All the three treatments resulted in significantly higher values over control (i. 13.70 ii. 69.2). It was significantly higher in seeds treated with Salicylic Acid (i. 15.10 ii. 74.7) than all other treatments. All interaction (variety x stress level, variety x treatment, treatment x stress level and variety x stress level x treatment) effects were found to be non-significant (Table 7 & 8). However, highest speed of emergence and percentage seedling establishment (i. 15.6 ii. 79.8) were found in temperature-stress tolerant variety PM 28 in salicylic acid treated seeds grown without any temperature stress whereas, it was lowest (i. 12.5 ii. 63.3) in temperature stress susceptible variety Pusa Karishma grown under conditions of 35 °C.

Rapid and uniform field emergence is critical to optimize stand establishment, especially under suboptimum conditions. Effect of seed enhancement on field performance was investigated and it was concluded that with increased level of stress the speed of emergence and percentage of seedling establishment significantly decreased under stress conditions. Significantly higher speed of emergence and per cent seedling establishment was observed in high temperature tolerant mustard variety than the susceptible one. On the other hand, priming with salicylic acid and KNO_3 significantly improved the speed of emergence and per cent seedling establishment than hydropriming and control. Salicylic acid treatment had significantly improved speed of emergence and per cent seedling establishment than KNO_3. Basra *et al.* [4] and Salinas [15] reported improvement in germination per cent, emergence and seedling stand, by using seed priming techniques. In fact priming induces a range of biochemical changes in the seed that is required for initiating the germination process *i.e.*, breaking of dormancy, hydrolysis or metabolism of inhibitors, imbibition and enzyme activation [16]. Previous research indicated that some or all the processes that precede the germination are triggered by priming and persist following the re-desiccation of the seed [17]. Thus upon sowing, primed seed can rapidly imbibe and revive the seed metabolism, resulting in higher germination percentage and a reduction in the inherent physiological heterogeneity in germination [18]. The probable reason for early emergence of the primed seed may be due to the completion of pre-germination

Table 7. Effect of seed quality enhancement treatments on speed of emergence of different varieties under variable temperature levels.

Treatments	PM 28 Temperature stress level (SL)			Mean	PUSA KARISHMA Temperature stress level (SL)			Mean	Mean
	20°C	30°C	35°C	(VXT)	20°C	30°C	35°C	(VXT)	(Treatment)
Control	14.6	14.3	13.3	14.0	14.0	13.7	12.5	13.4	13.7a
Hydropriming	15.5	15.0	13.5	14.7	14.7	14.4	13.3	14.1	14.2b
KNO3	15.1	14.8	13.8	14.6	14.3	14.1	13.2	13.9	14.3c
Sal. Acid	15.6	15.5	15.2	15.4	15.6	15.2	14.1	15.0	15.1d
Mean (VXSL)	15.2	14.9	13.9		14.7	14.3	13.3		
Mean (Variety)	14.7a				14.1b				
Mean (SL)	14.9c	14.6b	13.6a						

CD (p=0.05%) V=0.23, Stl=0.28, Treat=0.32, VXSTL=NS, VXT=NS, STLXT=NS, VXSTLXT=NS

Table 8. Effect of seed quality enhancement treatments on percentage of seedling establishment of different varieties under variable temperature levels.

Treatments	PM 28 Temperature stress level (SL)			Mean	PUSA KARISHMA Temperature stress level (SL)			Mean	Mean
	20°C	30°C	35°C	(VXT)	20°C	30°C	35°C	(VXT)	(Treatment)
Control	77.5 (61.7)	72.7(58.5)	63.0(52.6)	71.1(57.5)	70.8(57.3)	68.3(55.8)	63.3(52.7)	67.5(55.3)	69.2a(56.3)
Hydropriming	78.2(62.2)	74.3(59.6)	66.7(54.8)	73.1(58.8)	72.5(58.4)	70.0(56.8)	65.0(53.8)	69.2(56.3)	71.1b(57.5)
KNO3	77.2(61.5)	73.7(59.2)	66.7(54.8)	72.5(58.4)	73.2(58.9)	70.7(57.3)	65.7(54.2)	69.8(56.7)	71.1b(57.5)
Sal. Acid	79.8(63.3)	75.0(60.0)	71.7(57.9)	75.5(60.4)	77.2(61.5)	74.7(59.8)	70.0(56.8)	73.9(59.3)	74.7c(59.8)
Mean (VXSL)	78.2(62.2)	73.9(59.3)	67.0(55.0)		73.4(59.0)	70.9(57.4)	66.0(54.4)		
Mean (Variety)		73.0a(57.4)				70.1b(56.9)			
Mean (SL)	75.7c(60.5)	72.4b(58.3)	66.5a(54.6)						

CD (p=0.05%) V=0.42, STL=1.02, TREAT=1.09, VXSTL=NS, VXT=NS, STLXT=NS, VXSTLXT=NS

* The figures in parenthesis are arc sine transformed values of per cent data.

metabolic activities making the seed ready for radicle protrusion, whereby the primed seed germinates sooner after planting than untreated dry seed [19]. However, more energy is required for germination in high density of Salicylic acid and high level of drought stress and in addition, the time needed for germination will be more. Seed vigour decreases in high density of Salicylic acid and high level of drought stress [20]. Therefore, priming mustard seeds for 18 h/20 °C in salicylic acid beyond concentration of 1500µM could be deleterious for enhancing planting value.

CONCLUSIONS

The results of the study validated the potential of seed enhancement treatments for improving seed quality and vigour and thereby reducing the ill effects of different types of stresses. The maximum first count per cent, germination per cent, root length, shoot length, vigour index I and II and minimum percentage of abnormal seedling, hard seeds and dead seeds were observed in salicylic acid, KNO_3 and hydropriming seed treatments. Salicylic acid had significant effect on all above parameter than KNO_3 and hydropriming in all stress conditions. Pre-sowing seed enhancement treatments namely priming in salicylic acid and halopriming with KNO_3 were effective in improving seedling vigour of mustard under temperature stress conditions in both the varieties of Indian mustard under study. The information emanating from this study shall help in combating the effect of elevated temperatures, a consequence of climate change, by improving the plant stand and ultimately the productivity of Indian mustard.

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