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Efficacy of various chemicals spray in terminal heat stress condition on seed storability of mustard (*Brassica juncea* L.)

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Abstract
The experiment was conducted during two consecutive years 2019-20 & 2020-21 at Oil Seed Farm of C. S. Azad University of Agriculture & Technology Kanpur. Two varieties namely Kanti (V_1) and Maya (V_2) seeds were sown in *Rabi* season (October-April 2019 & 2020), seven chemicals concentrations were applied as foliar spray treatments at vegetative stage, at anthesis stage and at both stage which were as Salicylic acid @ 800 ppm (T_1, T_8 and T_{15}), Salicylic acid spray at vegetative stage @ 400 ppm (T_2, T_9 and T_{16}), Ascorbic acid @ 10 ppm (T_3, T_{10} and T_{17}), Potassium chloride @ 1% (T_4, T_{11} and T_{18}), thiourea @ 400 ppm (T_5, T_{12} and T_{19}), Cycocel @ 800 ppm (T_6, T_{13} and T_{20}), Cycocel @ 400 ppm (T_7, T_{14} and T_{21}) and T_0-Control (without spray). Freshly harvested seeds of each plot were stored under ambient condition in cotton bag for nine months and seed viability (%), seed germination (%), seedling length (cm) and seedling vigour index-I was recorded at every three month of interval. At the end of storage period significantly maximum seed viability (90.42%), seed germination (89.05%), seedling length (14.24cm) and SVI-I (1268) was found in sample collected from treatment T_{19}-Thiourea spray at vegetative + anthesis stage @ 400 ppm followed by treatment T_{16} irrespective of varieties. Within varieties, variety Maya was significantly superior over variety Kanti.

Keywords: Mustard, terminal eat stress, foliar spray, thiourea, storability

Introduction

Indian contribution to global rapeseed-mustard production is 19.8% in global acarease of 36.59 mha and 9.8% in production of 72.37 MT (Anonymous, 2018-19) [2]. Indian mustard is sown late due to delay in harvesting of rainy season crops like rice, cluster bean and cotton (Kumar *et al*., 2013) [17] Late sown Indian mustard is exposed to high temperature associated with high evaporative demand of the atmosphere during the reproductive stage which results in forced maturity, increased senescence and low productivity (Porter, 2005) [27]. High temperature stress negatively affects plant growth development and crop yield (Boyer, 1982) [5]. 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) [13, 36]. According to recent study (Lobel and Asner, 2003) [21] each degree centigrade increase in average growing season temperature reduce crop yield by 17%. Constantly high temperatures cause an array of morphological, physiological and biochemical changes in plants (Serraj *et al*., 1999) [30]. High temperature stress directly or indirectly affects plant photosynthesis rate by changing the structural organization and physio-chemical properties of thylakoid membrane (Lichtenthaler *et al*., 2005) [20], significant inhibition in the import of photosynthates was recorded by (Subrahmanyam and Rathore, 1994) [33]. (Hall, 1992) [12] 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 this reduction in crop yield associated with reduction in seed quality and storability also. (Keeling *et al*., 1994) [15] concluded that starch synthesis deactivate at high temperature during reproductive stage. Heat stress causes significant reduction in yield (Lallu and Dixit, 2008) [19] because of floral sterility (Morrison and Stewart, 2002) [23], floral abortion (Young *et al*., 2004) [37]. In general, seeds are considered to be of high quality when they exhibit fast and homogeneous germination. Germination is defined as the process in which seeds uptake water, followed by embryo elongation and radical penetration through the endosperm and seed coat (Bewley and Black, 1994) [4].

Seed have maximum quality at physiological maturity and it deteriorate as increase in 0 time (Kurdikeri *et al*., 1994) [18]. Prolonging storage period reduced seed quality (Ebrahim *et al*. 2009), (Channabasanagowda *et al*., 2008) [9, 6], and (Prasad and Joshi, 2017). Seed deterioration is expressed the loss viability, quality and vigour due to natural aging or adverse of environmental factors such as high temperature, high humidity moisture and others (Sisman, Delibas, 2004), (Azadi, Younesi, 2013) [32, 3]. Antioxidants are key elements in the defense mechanism of plants (Moustafa-Farang *et al*. 2020) [24]. Sustainable yield and seed quality of Indian mustard under late sown condition is only possible through minimizing the effect of heat stress during reproductive stage with the use of heat tolerant genotypes of mustard and application of bio regulators (antioxidant chemicals) which may be organic or inorganic in nature. Poor seed quality, with low viability and vigor, results in uneven or erratic emergence and consequently, reduces plant stand and crop yields. Farmers often fail to recover from the hazardous effects of such substandard seeds (Finch-Savage and Bassel, 2015) [11]. Varietal response against heat stress may be varies in accordance with genotype of variety, it may that two variety respond differently in a same environmental conditions (Chauhan *et al.* 2009) [7], (Panda *et al*., 2004) [25] and (Singh and Singh, 1998) [31]. Considerable reduction in seed yield due to less production of dry matter was reported by (Kumar and Srivastava, 2003) [16]. Considering all these facts, the present experiment was planned to know the efficacy of various chemicals sprays in terminal heat stress condition on seed storability of mustard (*Brassica juncea* L.).

2. Material and Methods

The field experiment was conducted at Oil Seed Farm, Kalyanpur, C.S. Azad University of Agriculture and Technology, Kanpur (U.P.) during *Rabi*, 2019-20 and 2020-21. Geographically, Kanpur is situated in sub-tropical zone at 25°26' and 26°58' N latitude and 79°32' and 80°34' E longitude with an altitude of 125.90 m above mean sea level.
The experimental materials were consisted of two mustard varieties namely Kanti (V_1) and Maya (V_2). To mitigate terminal heat stress the following bio regulators (chemicals), their concentrations and stage of spray were appliedT_0-Control (without spray), T_1-Salicylic acid spray at vegetative stage @ 800 ppm, T_2-Salicylic acid spray at vegetative stage @ 400 ppm, T_3-Ascorbic acid spray at vegetative stage @ 10 ppm, T_4-Potassium chloride spray at vegetative stage @ 1%, T_5-Thiourea spray at vegetative stage @ 400 ppm, T_6-Cycocel spray at vegetative stage @ 800 ppm, T_7-Cycocel spray at vegetative stage @ 400 ppm, T_8-Salicylic acid spray at anthesis stage @ 800 ppm, T_9- Salicylic acid spray at anthesis stage @ 400 ppm, T_{10}-Ascorbic acid spray at anthesis stage @ 10 ppm, T_{11}-Potassium chloride spray at anthesis stage @ 1%, T_{12}- Thiourea spray at anthesis stage @ 400 ppm, T_{13}-Cycocel spray at anthesis stage @ 800 ppm, T_{14}-Cycocel spray at anthesis stage @ 400 ppm, T_{15}-Salicylic acid spray at vegetative + anthesis stage @ 800 ppm, T_{16}-Salicylic acid spray at vegetative + anthesis stage @ 400 ppm, T_{17}-Ascorbic acid spray at vegetative + anthesis stage @ 10 ppm, T_{18}-Potassium chloride spray at vegetative + anthesis stage @ 1%, T_{19}-Thiourea spray at vegetative + anthesis stage @ 400 ppm, T_{20}- Cycocel spray at vegetative + anthesis stage @ 800 ppm and T_{21}-Cycocel spray at vegetative + anthesis stage @ 400 ppm. The harvested seed of each plot were stored under ambient condition in cotton bags for nine months and following observations were recorded at every three months of interval.

2.1 Seed Viability (%)

Seed viability was tested through tetrazolium test (%). The tetrazolium viability test (Moore, 1973) based on three replication of 100-seeds each was followed. The seed were moistened for 16 h at room temperature. After peeled off the seed coat, the seeds were stained in 0.5 per cent tetrazolium chloride solution, pH 7.0 for 4-5 at 38^0C. The number of seeds stained entirely red were considered as viable seeds and expressed in percentage.

2.2 Seed Germination (%)

Three replication with100 seeds per replication from each variety were placed on the top of filter papers (T.P.) in 18 cm diameter Petri plates containing 15 ml of water. The petri plates were then kept in the germinator at 20± 10C. The counting of normal seedling was made on final count at 7th day (ISTA 1985) and normal seedlings were expressed as per cent germination.

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

2.3 Seedling Length (cm)

Seedling length was measured on 7^{th} days at final count. Ten seedling were randomly selected from each replication seedling length were immediately measured in cm and averaged.

2.4 Seedling Vigour Index-I

Seedling vigour index-I was calculated by formula of (Abdul Baki and Anderson, 1973) [1].

$$\text{Seedling Vigour Index} - I = \text{Seed germination (\%)x Seedling length (cm)}$$

The recorded data of individual years was analyzed statistically and error variance was tested for homogeneity by F-test. Further, if year ware found homogeneous, the data were subjected for pooled analysis. However, interpretation of the results have been made on the pooled data basis only.

3. Results and Discussion

In present experiment seed quality showed significant decline at 3^{rd} 6^{th} and 9^{th} month of storage. Maximum decline was recorded at 9^{th} month of storage in all chemicals spray treatments and both of the varieties *viz*., Kanti and Maya. This decline may be due to oxidative reaction in seeds, oxidative reaction led to severe cellular damage that eventually resulted in the loss of viability and vigor in several types of seeds (Halliwell and Gutteridge, 2007), (Varghese and Naithani, 2008) [34] and (Sahu *et al.*, 2017) [29]. Seed stored longer duration resulted in delayed and decreased germination (Garoma *et al*., 2017) [10].

Table 1: Effect of Chemicals sprays (T) on seed viability % of mustard varieties (V) during storage

	At 3rd month of storage			At 6th month of storage			At 9th month of storage		
Treatments	**V_1**	**V_2**	**Mean**	**V_1**	**V_2**	**Mean**	**V_1**	**V_2**	**Mean**
T_0	85.35	86.08	85.71	85.01	85.56	85.29	83.40	84.14	83.77
T_1	87.71	88.58	88.15	86.83	88.06	87.45	84.92	86.65	85.78
T_2	87.97	89.08	88.53	87.00	88.55	87.78	85.31	87.14	86.23
T_3	87.31	87.06	87.19	86.18	86.55	86.36	84.59	85.13	84.86
T_4	87.45	87.86	87.65	86.60	87.34	86.97	84.52	85.92	85.22
T_5	88.73	89.61	89.17	87.69	89.08	88.38	86.21	87.67	86.94
T_6	87.94	87.92	87.93	87.10	87.40	87.25	85.12	85.99	85.55
T_7	88.04	88.06	88.05	86.80	87.53	87.17	85.22	86.12	85.67
T_8	87.94	89.04	88.49	86.97	88.52	87.74	85.12	87.11	86.11
T_9	88.07	89.89	88.98	87.06	89.36	88.21	85.41	87.94	86.67
T_{10}	87.54	87.66	87.60	86.60	87.14	86.87	84.85	85.73	85.29
T_{11}	88.24	88.05	88.15	87.33	87.53	87.43	85.31	86.12	85.72
T_{12}	89.26	90.61	89.94	88.25	90.08	89.16	86.67	88.67	87.67
T_{13}	88.27	88.05	88.16	87.16	87.53	87.35	85.25	86.12	85.69
T_{14}	89.07	88.95	89.01	88.05	88.42	88.24	86.10	87.01	86.56
T_{15}	90.32	91.44	90.88	89.30	90.98	90.14	87.69	89.58	88.63
T_{16}	90.82	91.62	91.22	89.56	91.08	90.32	88.05	89.68	88.86
T_{17}	88.34	89.04	88.69	87.30	88.52	87.91	85.38	87.11	86.25
T_{18}	89.14	89.31	89.23	88.55	88.78	88.66	86.30	87.37	86.84
T_{19}	91.94	93.36	92.65	90.74	92.82	91.78	89.43	91.41	90.42
T_{20}	89.35	90.96	90.15	88.26	90.43	89.35	86.50	89.02	87.76
T_{21}	89.46	91.44	90.45	88.34	90.82	89.58	86.93	89.41	88.17
Mean	88.56	89.26		87.58	88.73		85.83	87.32	
	V	T	VxT	V	T	VxT	V	T	VxT
S.E.(d)	0.17	0.57	0.81	0.14	0.46	0.65	0.09	0.29	0.41
C.D. at 5%	0.34	1.14	N.S.	0.28	0.92	N.S.	0.172	0.57	0.81

Table 2: Effect of Chemicals sprays (T) on seed germination % of mustard varieties (V) during storage

	At 3rd month of storage			At 6th month of storage			At 9th month of storage		
Treatments	**V_1**	**V_2**	**Mean**	**V_1**	**V_2**	**Mean**	**V_1**	**V_2**	**Mean**
T_0	84.89	85.63	85.26	83.72	84.43	84.08	82.18	82.89	82.53
T_1	86.35	88.11	87.23	85.20	86.91	86.05	83.65	85.34	84.49
T_2	86.74	88.60	87.67	85.59	87.39	86.49	84.03	85.82	84.93
T_3	86.02	86.61	86.31	84.88	85.41	85.14	83.33	83.86	83.59
T_4	85.95	87.39	86.67	84.81	86.19	85.50	83.26	84.63	83.94
T_5	87.62	89.12	88.37	86.47	87.91	87.19	84.91	86.34	85.62
T_6	86.54	87.46	87.00	85.39	86.25	85.82	83.84	84.70	84.27
T_7	86.64	87.59	87.12	85.49	86.38	85.94	83.94	84.82	84.38
T_8	86.54	88.57	87.55	85.39	87.36	86.38	83.84	85.79	84.82
T_9	86.84	89.40	88.12	85.69	88.19	86.94	84.13	86.62	85.37
T_{10}	86.28	87.19	86.74	85.13	85.99	85.56	83.58	84.44	84.01
T_{11}	86.74	87.59	87.16	85.59	86.38	85.99	84.03	84.82	84.43
T_{12}	88.08	90.12	89.10	86.92	88.90	87.91	85.36	87.33	86.34
T_{13}	86.67	87.59	87.13	85.52	86.38	85.95	83.97	84.82	84.40
T_{14}	87.52	88.47	88.00	86.37	87.26	86.82	84.81	85.70	85.25
T_{15}	89.09	90.85	89.97	87.93	89.63	88.78	86.36	88.05	87.21
T_{16}	89.45	91.12	90.28	88.29	89.90	89.09	86.71	88.31	87.51
T_{17}	86.80	88.57	87.69	85.65	87.36	86.51	84.10	85.80	84.95
T_{18}	87.72	88.83	88.27	86.56	87.62	87.09	85.00	86.05	85.53
T_{19}	90.82	92.84	91.83	89.65	91.61	90.63	88.07	90.02	89.05
T_{20}	87.92	90.46	89.19	86.76	89.25	88.00	85.20	87.67	86.43
T_{21}	88.34	91.02	89.68	87.18	89.80	88.49	85.61	88.21	86.91
Mean	87.25	88.78		86.10	87.57		84.54	86.00	
	V	T	VxT	V	T	VxT	V	T	VxT
S.E.(d)	0.12	0.39	0.55	0.10	0.32	0.46	0.09	0.28	0.40
C.D. at 5%	0.23	0.77	N.S.	0.19	0.64	0.91	0.17	0.56	0.79

Table 3: Effect of Chemicals sprays (T) on seedling length of mustard varieties (V) during storage

	At 3rd month of storage			At 6th month of storage			At 9th month of storage		
Treatments	**V_1**	**V_2**	**Mean**	**V_1**	**V_2**	**Mean**	**V_1**	**V_2**	**Mean**
T_0	11.78	13.09	12.43	11.75	13.06	12.40	11.60	12.89	12.25
T_1	12.44	13.92	13.18	12.41	13.89	13.15	12.25	13.71	12.98
T_2	12.56	13.96	13.26	12.53	13.93	13.23	12.35	13.76	13.05
T_3	11.95	13.48	12.72	11.91	13.45	12.68	11.76	13.28	12.52
T_4	12.08	13.62	12.85	12.04	13.59	12.81	11.89	13.42	12.66
T_5	12.74	14.19	13.47	12.70	14.16	13.43	12.55	13.98	13.26
T_6	12.31	13.85	13.08	12.28	13.82	13.05	12.12	13.65	12.89
T_7	12.61	13.93	13.27	12.57	13.90	13.23	12.42	13.73	13.07
T_8	12.41	14.08	13.24	12.38	14.04	13.21	12.23	13.87	13.05
T_9	12.71	14.09	13.40	12.68	14.06	13.37	12.52	13.88	13.20
T_{10}	12.12	13.66	12.89	12.08	13.63	12.86	11.93	13.46	12.70
T_{11}	12.35	13.77	13.06	12.31	13.74	13.03	12.16	13.57	12.86
T_{12}	12.98	14.47	13.72	12.94	14.09	13.52	12.78	14.22	13.50
T_{13}	12.47	13.93	13.20	12.43	13.89	13.16	12.28	13.72	13.00
T_{14}	12.74	14.05	13.40	12.71	14.02	13.36	12.55	13.84	13.20
T_{15}	13.01	14.41	13.71	12.98	14.43	13.70	12.81	14.21	13.51
T_{16}	13.07	14.58	13.83	13.04	14.51	13.78	12.88	14.34	13.61
T_{17}	12.78	14.23	13.50	12.75	14.16	13.46	12.58	13.99	13.29
T_{18}	12.84	14.45	13.65	12.81	14.39	13.60	12.65	13.92	13.28
T_{19}	13.80	15.13	14.46	13.77	15.06	14.41	13.60	14.87	14.24
T_{20}	13.01	14.16	13.58	12.98	14.35	13.66	12.81	14.17	13.49
T_{21}	13.07	14.49	13.78	13.04	14.43	13.74	12.88	14.25	13.57
Mean	12.63	14.07		12.59	14.03		12.44	13.85	
	V	T	VxT	V	T	VxT	V	T	VxT
S.E.(d)	0.4	0.15	0.21	0.04	0.14	0.20	0.05	0.16	0.22
C.D. at 5%	0.09	0.29	N.S.	0.09	0.28	N.S.	0.09	0.31	N.S.

Table 4: Effect of Chemicals sprays (T) on SVI-I of mustard varieties (V) during storage

	At 3rd month of storage			At 6th month of storage			At 9th month of storage		
Treatments	**V_1**	**V_2**	**Mean**	**V_1**	**V_2**	**Mean**	**V_1**	**V_2**	**Mean**
T_0	1000	1121	1060	984	1102	1043	953	1069	1011
T_1	1075	1226	1150	1057	1207	1132	1025	1170	1098
T_2	1090	1237	1163	1072	1217	1145	1038	1180	1109
T_3	1028	1168	1098	1011	1149	1080	980	1114	1047
T_4	1038	1190	1114	1022	1171	1096	991	1135	1063
T_5	1117	1265	1191	1099	1244	1171	1066	1207	1136
T_6	1066	1212	1139	1048	1192	1120	1016	1156	1086
T_7	1092	1220	1156	1075	1200	1138	1042	1164	1103
T_8	1074	1247	1160	1057	1227	1142	1025	1190	1107
T_9	1103	1260	1182	1086	1240	1163	1053	1203	1128
T_{10}	1045	1191	1118	1029	1172	1100	997	1137	1067
T_{11}	1071	1206	1139	1054	1187	1120	1022	1151	1086
T_{12}	1143	1304	1223	1125	1253	1189	1091	1242	1167
T_{13}	1080	1220	1150	1063	1200	1132	1031	1164	1098
T_{14}	1115	1243	1179	1098	1223	1161	1065	1186	1126
T_{15}	1159	1310	1234	1141	1293	1217	1107	1251	1179
T_{16}	1169	1328	1249	1152	1305	1228	1117	1266	1191
T_{17}	1109	1260	1185	1092	1237	1165	1058	1200	1129
T_{18}	1126	1284	1205	1109	1261	1185	1075	1198	1136
T_{19}	1254	1404	1329	1234	1380	1307	1198	1339	1268
T_{20}	1144	1281	1212	1126	1281	1203	1092	1243	1167
T_{21}	1155	1319	1237	1137	1296	1216	1103	1257	1180
Mean	1102	1250		1085	1229		1052	1192	
	V	T	VxT	V	T	VxT	V	T	VxT
S.E.(d)	4	12	17	4	13	18	4	14	20
C.D. at 5%	7	24	N.S.	8	25	N.S.	9	29	N.S.

Significant decline in seed quality of mustard varieties was recorded during storage period. Maximum seed quality parameters were recorded at 3rd month of storage which declined with increase in storage period and minimum seed quality was found at 9th month of storage. However, maximum seed quality parameters were recorded in variety Maya in which seed viability percent 87.32%, seed germination percent 86.00%, seedling length 13.85cm and seedling vigour index-I 1191.94 at 9th month of storage. This effect may be due to more initial quality of variety *viz.* food reserve, higher 1000 seed weight etc. Our finding was corroborated with the findings of (Verma *et al*. 2003) [35], Decrease in seedling length might be due to reduction in mobilization of reserve substances during germination of seeds (Dhakal and Pandey, 2001) [8].

All treatments significantly influenced the seed quality parameters of mustard varieties during nine month of storage period and seed quality declined progressively. Maximum seed quality parameters were recorded from treatment T_{19} - thiourea spray at vegetative + anthesis stage @ 400 ppm in wchich seed viability percent was 90.42%, seed germination percent 890.05%, seedling length 14240cm and seedling vigour index-I 1306.91 followed by treatment T_{16} - salicylic acid spray at vegetative + anthesis stage @ 400 ppm (seed viability 8.86%, seed germination 87.51%, seedling length 13.83cm ans SVI-I 1228.15) at 9th month of storage. This may be due to higher accumulation of photosynthets that cause better initial seed quality or antioxidant properties of chemicals that reduced rate of deterioration. The foliar application of thiourea on the abiotically stressed plants is much effective. Improvement in plant growth and development under different stresses due to application of thiourea has been observed in crops like maize (Perveen *et al*., 2015) [26].

The interaction effect of varieties and chemicals spray treatments were found to be non-significant for seed quality parameters at all storage period except seed viability % and seed germination % at 9th month of storage. However, maximum numeric value was recorded from treatment combination of V_2T_{19} – variety Maya and Thiourea spray at vegetative + anthesis stage @ 400 ppm in which seed viability 91.41%, seed germination 90.02%, seedling length 14.87cm and seedling vigour index-I 1379.54 at 9th month of storage was recorded.

4. Conclusion

Significant decline in seed quality of mustard varieties was recorded during storage of both mustard varieties cultivated under terminal heat stress condition. Maximum seed quality parameters were recorded at 3rd month of storage which declined with increase in storage period and minimum seed quality was found at 9th month of storage, but the rate of deterioration can be reduced by foliar spray of Thiourea at vegetative + anthesis stage @ 400 ppm. However, variety maya showed better seed quality after nine month of storage.

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