

Standardization of pre-storage seed treatment and different packaging material on seedling parameters of Indian mustard (*Brassica juncea* L)

Abhishek Kumar, Shivam Kumar Rai and Prashant Kumar Rai*

Department of Genetics and Plant Breeding, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj 211007, Uttar Pradesh, India

*Corresponding author: prashant.raai@shiats.edu.in

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Abstract

Indian mustard (*Brassica juncea* L) seed (variety SRM-777) stands as a pivotal agricultural asset, necessitating rigorous quality maintenance during storage. In our investigation spanning a three-month storage duration, we rigorously assessed various treatments and storage materials for their influence on seed quality parameters including germination rate, seedling growth, and vigour indices. Notably, seeds treated with *Rhizobium* at 5gm/kg displayed pronounced enhancements in several metrics, including a heightened germination percentage, accelerated germination rate, extended root and shoot lengths, and superior seedling vigour indices I and II. Simultaneously, the selection of storage material also had a significant impact on the seeds' preservation. Seeds stored in aluminum foil pouches consistently exhibited better results than those stored in cloth bags. In contrast, seeds treated with 3gm/kg of castor oil showed comparatively lower quality metrics when compared to untreated seeds. The findings indicated that the germination rate was 88.3%, with a seedling fresh weight of 127.6 mg, seedling dry weight of 18.4 mg, root length of 10.9 cm, shoot length of 15.2 cm, seedling length of 28.5 cm, seedling vigor I of 2500.7, and seedling vigor II of 41.4. This research highlights the twofold importance of rhizobium treatments and suitable storage materials, specifically aluminum foil pouches, in improving the quality of mustard seeds during storage. Although these findings offer a hopeful path towards enhancing mustard seed quality, it is crucial to conduct extensive research in various storage and environmental conditions to ensure comprehensive validation and wider applicability.

Keywords : Biofertilizers, Indian mustard, packaging materials, seed treatment, seedling parameters, seed storage

Introduction

Indian mustard (*Brassica juncea* L) is a pivotal edible oilseed crop within the Brassica family, Cruciferae. Originating from inter-specific crosses between *B. nigra* (n=8; B) and *B. rapa* (n=10; A), *B. juncea* emerged as an amphidiploid species. While, *B. rapa* spp. *Yellow Sarson* finds its roots in Southern Europe and *B. rapa* spp. brown sarson originates from China, black mustard is endemic to the Southern Mediterranean region. Notably, Indian mustard predominantly exhibits autogamous tendencies. However, the crop frequently undergoes out-crossing, varying between 5 to 30 percent, contingent upon environmental conditions and the activities of pollinating insects (Kumar *et al.*, 2013).

In terms of global significance, mustard seed ranks as the second most vital oilseed crop in India, following soybean. Furthermore, it stands as the third-largest source of edible vegetable oils worldwide, trailing behind soybean and oil palm (FAO, 2011). India emerges as a powerhouse in mustard production, ranking third in both area and yield after China and Canada. Statistics from 2017-2018 reveal a cultivation over 6.07

million hectares, yielding 7.92 million tonnes at a productivity rate of 1304 kg/ha (Anonymous, 2018). However, regional disparities exist; for instance, Uttar Pradesh reported a lower productivity of 1155 kg/ha in contrast to Gujarat's 1363 kg/ha. Within Uttar Pradesh, Mathura district demonstrates the highest metrics, with 0.053mha in area, 0.077mt in production, and 1453 kg/ha in productivity.

Despite the agricultural significance, storage remains a critical concern. In the North-East Plain Zone (NEPZ) of India, traditional farming practices predominate, with farmers retaining seeds post-harvest for subsequent Kharif seasons. Such prolonged storage not only impacts morphological traits but also disrupts seed genetic structures (Kumar and Rai, 2009). Given the temporal gap between harvest and sowing, maintaining optimal storage conditions becomes imperative to preserve seed viability. Exacerbated by factors like moisture, oxygen, sunlight, and pests, seed deterioration poses challenges, with membrane degradation identified as a primary ageing event (Rai *et al.*, 2011). Considering these challenges, the primary goal of this research is to assess the influence of pre-sowing seed treatments that

incorporate *Azotobacter*, *Trichoderma*, mycorrhiza, rhizobium, eucalyptus oil, and castor oil. The aim is to determine the most efficient treatment and ideal packaging material for mustard variety.

Materials and Methods

The study was executed at the Notified State Seed Testing Laboratory, Department of Genetics and Plant Breeding, Sam Higginbottom University of Agriculture, Technology and Sciences, Naini, Prayagraj, Uttar Pradesh, India, spanning during summer 2023.

A completely randomized design (CRD) with four replications was employed to standardize biofertilizer treatments and assess their efficacy on mustard seedling parameters. The treatments encompassed an untreated control group (T_0) and seeds treated with varying concentrations (10% and 15%) of *biofertilizers* such as *Azotobacter* (T_1 - T_2), *Trichoderma viride* (T_3 - T_4), *Mycorrhiza* (T_5 - T_6), Rhizobium (T_7 - T_8), Eucalyptus oil (T_9 - T_{10}), and Castor oil (T_{11} - T_{12}).

For each treatment group, 10 or 15 grams of the designated biofertilizer was dissolved in 100 ml of distilled water. Mustard seeds (variety SRM-777) were immersed in this solution for a 12-hour period at room temperature, followed by a six-hour drying phase. Subsequently, 250 grams of seeds from each treatment were stored in both aluminum foil pouches (C_1) and cloth bags (C_2) within the Seed Testing Laboratory. Storage conditions maintained a temperature of $20 \pm 5^\circ\text{C}$ and a relative humidity of 95% over a three-month period, with systematic monthly sampling for seed parameter evaluations.

Various seedling parameters were meticulously assessed, including germination percentage after 10 days using the Petri dish method as per ISTA, 2014 guidelines, seedling fresh weight, seedling dry weight determined after a 12-hour drying period at 85°C , shoot length, root length, seedling length, and seedling vigor indices I and II, as delineated by Baki and Anderson (1973). Data derived from the experimental procedures underwent rigorous statistical scrutiny using a factorial CRD. Results were subsequently tabulated and interpreted employing the OPSTAT statistical software.

Results and Discussion

Growth and quality parameters

Over the three-month storage period, a meticulous investigation of mustard seeds was conducted, focusing on growth and quality parameters. The results, presented in tables 1, 2 and 3, highlighted the substantial and variable influence of this interaction. The study employed various biofertilizers and two distinct packaging materials: aluminum foil pouches (C_1) and

cloth bags (C_2). Results revealed a significant influence of packaging materials on seed quality. Specifically, seeds stored in aluminum foil pouches consistently outperformed those in cloth bags. For instance, seeds in aluminum foil pouches exhibited an impressive germination percentage of 80.0%, seedling fresh weight of 2.05 g, seedling dry weight of 0.47 g, root length of 11.4 cm, shoot length of 13.2 cm, seedling length of 23.6 cm, seedling vigor I of 1895.6, and seedling vigor II of 37.7 by the end of the storage period. The impermeable nature of aluminum foil pouches effectively shielded the seeds from external adversities, aligning with prior research emphasizing the importance of impermeable materials for seed preservation (Gorechi, 1982; Paricha *et al.*, 1977; Roy *et al.*, 2023).

Interaction of packaging and biofertilizer treatments

Diving deeper into the nuances of seed storage, the combined effects of packaging materials and biofertilizer treatments were analyzed. Among the various combinations tested, the pairing of Rhizobium @ 5% with aluminum foil packaging (T_8C_2) emerged as notably effective. Seeds subjected to this treatment showcased outstanding results: germination percentage at 88.25%, seedling fresh weight at 127.56 mg, seedling dry weight at 18.35 mg, root length of 10.85 cm, shoot length of 15.18 cm, seedling length of 28.5 cm, seedling vigor I at 2500.7, and seedling vigor II at 41.4. The synergistic effect of Rhizobium with the impermeable aluminum foil packaging underlines its pivotal role in enhancing mustard seed quality, corroborating insights from earlier studies like Singh *et al.* (2003), Kumar and Rai (2011) and Roy *et al.* (2023).

Moisture absorbance and seed quality

A critical determinant influencing seed quality is moisture absorbance. The study delved into the impact of different storage containers, revealing that rigid plastic containers, owing to their impermeable characteristics, offered superior moisture retention compared to permeable alternatives like gunny bags. Such observations resonate with established literature, highlighting the detrimental effects of elevated moisture on seed longevity and quality (Copeland, 1976; Tithi *et al.*, 2010). Therefore, ensuring optimal storage conditions, especially with impermeable containers, remains paramount to counteract the challenges associated with seed deterioration, as supported by findings from Barler *et al.* (1975) and Bhadauria *et al.* (2011).

Conclusion

During the assessment of SRM-777 mustard seed variety, it was observed that seeds treated with rhizobium at a concentration of 5gm/kg displayed exceptional performance in various seed quality

Table 1 : Effect of pre sowing seed treatment with selected biofertilizer, oils of eucalyptus and castor, and different packaging material on seedling parameters of Indian mustard (*B. juncea*)

Container	Germination (%)			Germination rate			Shoot length (cm)			Root length (cm)		
	March	April	May	March	April	May	March	April	May	March	April	May
C1- Aluminium Foi	80.6	78.1	75.6	83.4	78.9	75.4	11.9	11.0	11.0	7.8	6.9	6.8
C2- Cloth Bag	83.6	81.1	78.6	86.5	82.0	78.5	13.3	12.4	12.4	9.1	8.2	8.1
Mean	82.1	79.6	77.1	84.9	80.4	76.9	12.6	11.7	11.7	8.4	7.6	7.5
P=0.01%	0.2	0.1	0.3	0.2	0.3	0.3	0.2	0.3	0.4	0.3	0.2	0.1
Treatments												
T0- Control	68.5	66.0	63.5	72.5	68.0	64.5	10.8	9.9	9.8	10.8	9.9	9.8
T1- Azatobacter 3%	86.8	84.3	81.8	75.6	71.1	67.6	11.6	10.7	10.6	11.6	10.7	10.6
T2- Azatobacter 5%	89.1	86.6	84.1	93.1	88.6	85.1	14.2	13.3	13.2	14.2	13.3	13.2
T3- Trichoderma 3%	81.8	79.3	76.8	85.8	81.3	77.8	11.8	10.9	10.8	11.8	10.9	10.8
T4- Trichoderma 5%	88.3	85.8	83.3	92.3	87.8	84.3	13.7	12.8	12.8	13.7	12.8	12.8
T5- Mycorrhiza 3%	84.0	81.5	79.0	88.0	83.5	80.0	12.9	12.0	11.9	12.9	12.0	11.9
T6- Mycorrhiza 5%	87.4	84.9	82.4	91.4	86.9	83.4	12.1	11.2	11.1	12.1	11.2	11.1
T7- Rhizobium 3%	84.9	82.4	79.9	88.9	84.4	80.9	13.3	12.4	12.4	13.3	12.4	12.4
T8- Rhizobium 5%	91.5	89.0	86.5	95.5	91.0	87.5	15.3	14.4	14.3	15.3	14.4	14.3
T9- Eucalyptus oil 3%	71.6	69.1	66.6	75.6	71.1	67.6	12.1	11.2	11.1	12.1	11.2	11.1
T10- Eucalyptus oil 5%	76.8	74.3	71.8	80.8	76.3	72.8	11.8	10.9	10.9	11.8	10.9	10.9
T11- Castor oil 3%	78.4	75.9	73.4	82.4	77.9	74.4	12.2	11.3	11.2	12.2	11.3	11.2
T12- Castor oil 5%	78.4	75.9	73.4	82.4	77.9	74.4	12.5	11.6	11.5	12.5	11.6	11.5
Mean	82.4	79.9	77.4	85.1	80.6	77.1	12.6	11.8	11.7	12.6	11.8	11.7
P=0.01%	0.5	0.4	0.7	0.6	0.8	0.7	0.6	0.8	0.9	0.7	0.5	0.4
Interaction (T x C)												
T0xC1	67.0	64.5	62.0	71.0	66.5	63.0	9.9	9.0	8.9	5.6	4.7	4.6
T1xC1	85.08	2.5	80.0	74.0	69.5	66.0	10.9	10.0	9.9	6.6	5.7	5.6
T2xC1	87.5	85.0	82.5	91.5	87.0	83.5	12.8	11.9	11.8	8.5	7.6	7.5
T3xC1	80.5	78.0	75.5	84.5	80.0	76.5	11.0	10.1	10.0	6.6	5.7	5.7
T4xC1	86.8	84.3	81.8	90.8	86.3	82.8	13.6	12.7	12.6	9.1	8.2	8.1
T5xC1	82.8	80.3	77.8	86.8	82.3	78.8	12.5	11.6	11.5	8.2	7.3	7.2

T6xC1	85.8	83.3	80.8	89.8	85.3	81.8	10.7	9.8	9.7	9.3	8.4	8.3
T7xC1	83.5	81.0	78.5	87.5	83.0	79.5	13.2	12.3	12.2	8.8	7.9	7.9
T8xC1	89.8	87.3	84.8	93.8	89.3	85.8	14.4	13.5	13.4	10.0	9.1	9.1
T9xC1	70.0	67.5	65.0	74.0	69.5	66.0	10.7	9.8	9.7	6.3	5.4	5.4
T10xC1	75.0	72.5	70.0	79.0	74.5	71.0	11.6	10.7	10.6	7.2	6.3	6.3
T11xC1	76.8	74.3	71.8	80.8	76.3	72.8	11.9	11.0	10.9	7.5	6.6	6.6
T12xC1	77.0	74.5	72.0	81.0	76.5	73.0	12.2	11.3	11.2	7.9	7.0	6.9
T0xC2	70.0	67.5	65.0	74.0	69.5	66.0	11.7	10.8	10.7	7.3	6.4	6.4
T1xC2	88.5	86.0	83.5	77.2	72.7	69.2	12.2	11.3	11.2	7.9	7.0	6.9
T2xC2	90.8	88.3	85.8	94.8	90.3	86.8	15.5	14.6	14.5	11.2	10.3	10.2
T3xC2	83.0	80.5	78.0	87.0	82.5	79.0	12.7	11.8	11.7	8.3	7.4	7.4
T4xC2	89.8	87.3	84.8	93.8	89.3	85.8	13.9	13.0	12.9	10.2	9.3	9.2
T5xC2	85.3	82.8	80.3	89.3	84.8	81.3	13.3	12.4	12.3	8.9	8.0	8.0
T6xC2	89.0	86.5	84.0	93.0	88.5	85.0	13.6	12.7	12.6	9.5	8.6	8.6
T7xC2	86.3	83.8	81.3	90.3	85.8	82.3	13.5	12.6	12.5	9.2	8.3	8.2
T8xC2	93.3	90.8	88.3	97.3	92.8	89.3	16.2	15.3	15.2	11.8	10.9	10.9
T9xC2	73.2	70.7	68.2	77.2	72.7	69.2	13.6	12.7	12.6	9.2	8.3	8.3
T10xC2	78.5	76.0	73.5	82.5	78.0	74.5	12.1	11.2	11.1	7.8	6.9	6.8
T11xC2	80.0	77.5	75.0	84.0	79.5	76.0	12.6	11.7	11.6	8.2	7.3	7.3
T12xC2	79.8	77.3	74.8	83.8	79.3	75.8	12.8	11.9	11.8	8.4	7.5	7.5
Mean	82.1	79.6	77.1	86.1	81.6	78.1	12.8	11.9	11.8	8.4	7.6	7.5
P=0.01%	0.7	0.7	1.0	0,876	1.1	1.0	0.8	1.2	1.3	1.0	0.7	0.5

Table 2: Effect of pre sowing seed treatment with selected biofertilizer, oils of eucalyptus and castor, and different packaging material on seedling parameters of Indian mustard (*B. juncea*)

Containers	Seedling length (cm)			Seedling fresh wt. (mg)			Seedling dry wt.(g)		
	March	April	May	March	April	May	March	April	May
C1- Aluminium Foil	18.2	17.3	17.3	125.2	122.6	123.7	14.9	14.7	14.3
C2- Cloth Bag	19.5	18.6	18.5	127.4	124.6	125.7	16.2	15.9	15.6
Mean	18.9	18.0	17.9	188.9	184.9	124.7	15.5	15.3	15.0
P=0.01%	0.4	0.2	0.4	0.4	0.4	0.5	0.2	0.3	0.2
Treatments									
T0- Control	16.9	16.0	15.9	122.5	119.7	121.0	13.5	13.3	13.0
T1- Azatobacter 3%	17.6	16.7	16.7	125.3	122.4	123.8	14.3	14.1	13.8
T2- Azatobacter 5%	20.2	19.3	19.3	128.2	125.3	126.7	16.9	16.7	16.4
T3- Trichoderma 3%	17.9	17.0	16.9	126.1	123.2	124.5	14.6	14.3	14.0
T4- Trichoderma 5%	20.0	19.1	19.1	128.0	125.1	126.4	16.7	16.5	16.2
T5- Mycorrhiza 3%	19.0	18.1	18.0	127.1	124.3	125.6	15.6	15.4	15.1
T6- Mycorrhiza 5%	18.2	17.3	17.2	125.9	123.0	124.3	16.5	16.3	15.9
T7- Rhizobium 3%	19.4	18.5	18.4	127.6	124.7	126.0	16.1	15.9	15.5
T8- Rhizobium 5%	21.3	20.4	20.4	128.5	125.6	127.0	18.0	17.8	17.5
T9- Eucalyptus oil 3%	19.8	18.9	18.8	126.9	124.0	125.4	14.9	14.6	14.3
T10- Eucalyptus oil 5%	17.9	17.0	16.9	125.1	122.2	123.5	14.6	14.4	14.0
T11- Castor oil 3%	18.3	17.4	17.3	125.0	122.1	123.4	15.0	14.7	14.4
T12- Castor oil 5%	18.6	17.7	17.6	121.1	122.9	124.2	15.2	15.0	14.7
Mean	18.9	18.0	17.9	125.9	123.4	124.7	15.5	15.3	15.0
P=0.01%	1.0	0.5	0.9	0.9	0.4	0.5	0.5	0.8	0.6
Interaction (T x C)									
T0xC1	16.0	15.1	15.0	119.7	116.8	118.1	12.7	12.4	12.1
T1xC1	17.0	16.1	16.0	123.7	120.8	122.1	13.7	13.4	13.1
T2xC1	18.9	18.0	17.9	128.2	125.3	126.6	15.6	15.3	15.0
T3xC1	17.0	16.1	16.1	124.7	121.8	123.2	13.7	13.5	13.2
T4xC1	19.5	18.6	18.5	127.6	124.7	126.1	16.2	15.9	15.6
T5xC1	18.6	17.7	17.6	126.3	123.4	124.7	15.3	15.0	14.7

T6xC1	16.7	15.8	15.8	124.4	121.5	122.9	16.4	16.1	15.8
T7xC1	19.2	18.3	18.3	126.9	124.0	125.4	15.9	15.7	15.4
T8xC1	20.4	19.5	19.5	127.9	125.0	126.4	17.1	16.9	16.6
T9xC1	19.7	18.8	18.7	126.6	123.7	125.0	13.4	13.2	12.9
T10xC1	17.6	16.7	16.7	123.9	121.0	122.3	14.3	14.1	13.8
T11xC1	17.9	17.0	17.0	124.3	121.4	122.8	14.6	14.4	14.1
T12xC1	18.3	17.4	17.3	124.0	124.6	122.4	15.0	14.7	14.4
T0xC2	17.7	16.8	16.8	125.4	122.5	123.9	14.4	14.2	13.9
T1xC2	18.3	17.4	17.3	127.0	124.1	125.4	15.0	14.7	14.4
T2xC2	21.6	20.7	20.6	128.3	125.4	126.7	18.3	18.0	17.7
T3xC2	18.7	17.8	17.8	127.4	124.5	125.9	15.4	15.2	14.9
T4xC2	20.6	19.7	19.6	128.4	125.5	126.8	17.3	17.0	16.7
T5xC21	9.3	18.4	18.4	128.0	125.1	126.5	16.0	15.8	15.5
T6xC2	19.6	18.7	18.7	127.3	124.4	125.8	16.6	16.4	16.1
T7xC2	19.6	18.7	18.6	128.3	125.4	126.7	16.3	16.0	15.7
T8xC2	22.2	21.3	21.3	129.1	126.2	127.6	18.9	18.7	18.4
T9xC2	19.9	19.0	19.0	127.3	124.4	125.7	16.3	16.1	15.8
T10xC2	18.2	17.3	17.2	126.3	123.4	123.4	14.9	14.6	14.3
T11xC2	18.6	17.7	17.7	125.6	122.7	124.1	15.3	15.1	14.8
T12xC2	18.8	17.9	17.9	127.5	125.7	126.0	15.5	15.3	15.0
Mean	18.9	18.0	17.9	126.3	123.4	124.7	15.5	15.3	15.0
P=0.01%	1.4	0.7	0.6	1.3	1.3	2.0	0.7	1.1	0.8

Table 3: Effect of pre sowing seed treatment with selected biofertilizer, oils of eucalyptus and castor, and different packaging material on seedling parameters of Indian mustard (*B. juncea*)

Containers	Seed Vigour Index I			Seed Vigour Index II		
	March	April	May	March	April	May
C1- Aluminium Foil	1477.6	1362.5	1312.9	1209.2	1397.1	1330.2
C2- Cloth Bag	1633.4	1512.6	1459.9	1355.0	1552.7	1481.0
Mean	1555.5	1437.5	1386.4	2.69	1474.9	1405.4
P=0.01%	31.7	16.0	26.3	16.0	26.6	23.1
Treatments						
T0- Control	1156.3	1055.4	1009.8	928.2	1086.7	1025.7
T1- Azatobacter 3%	1263.3	1157.7	1110.5	1024.9	1191.2	1127.2
T2- Azatobacter 5%	1805.2	1677.5	1622.4	1508.4	1716.2	1641.7
T3- Trichoderma 3%	1462.8	1347.5	1298.9	1190.5	1381.5	1315.8
T4- Trichoderma 5%	1751.0	1625.4	1571.0	1460.1	1663.7	1590.0
T5- Mycorrhiza 3%	1592.7	1472.8	1421.3	1313.0	1508.9	1439.3
T6- Mycorrhiza 5%	1748.0	1622.2	1568.2	1454.1	1659.9	1587.0
T7- Rhizobium 3%	1647.2	1525.4	1472.7	1364.6	1562.4	1491.2
T8- Rhizobium 5%	1953.3	1820.7	1762.7	1648.6	1861.6	1783.1
T9- Eucalyptus oil 3%	1579.7	1459.2	1409.5	1290.8	1493.8	1426.7
T10- Eucalyptus oil 5%	1374.7	1263.9	1215.6	1119.1	1297.9	1232.5
T11- Castor oil 3%	1433.3	1320.0	1270.7	1172.3	1354.8	1288.0
T12- Castor oil 5%	1453.9	1339.9	1289.9	1192.9	1395.1	1326.4
Mean	1555.5	1437.5	1386.4	1282.1	1474.9	1405.7
P=0.01%	80.9	40.8	67.1	40.8	67.9	58.783
Interaction (T x C)						
T0xC1	1071.4	974.1	930.2	848.3	1003.0	945.2
T1xC1	1189.4	1086.8	1041.4	956.3	1119.0	1057.4
T2xC1	1652.0	1529.2	1477.6	1360.6	1565.1	1495.5

T3xC	11370.9	1258.9	1212.5	1102.9	1291.2	1228.6
T4xC1	1670.4	1547.6	1494.7	1384.9	1584.8	1513.2
T5xC1	1537.5	1419.6	1369.2	1261.9	1455.0	1386.8
T6xC1	1707.	21583.1	1529.5	1418.4	1620.6	1548.3
T7xC1	1605.7	1485.5	1433.4	1327.7	1522.2	1451.7
T8xC1	1833.6	1704.9	1649.2	1534.7	1744.0	1668.7
T9xC1	1422.1	1306.8	1260.8	1139.0	1338.5	1276.6
T10xC1	1322.3	1213.7	1166.2	1072.5	1247.1	1182.9
T11xC1	1376.1	1265.2	1216.9	1120.6	1299.3	1233.8
T12xC1	1449.9	1336.5	1285.9	1192.3	1372.4	1303.8
T0xC2	1241.1	1136.7	1089.4	1008.0	1170.4	1106.2
T1xC2	1337.2	1228.6	1179.7	1093.6	1263.4	1197.0
T2xC2	1958.4	1825.9	1767.3	1656.2	1867.3	1787.9
T3xC2	1554.6	1436.1	1385.3	1278.2	1471.8	1403.0
T4xC2	1831.6	1703.2	1647.2	1535.3	1742.6	1666.9
T5xC2	1647.9	1525.9	1473.4	1364.0	1562.8	1491.8
T6xC2	1788.7	1661.2	1606.9	1489.9	1699.3	1625.8
T7xC2	1688.8	1565.3	1512.1	1401.6	1602.7	1530.7
T8xC2	2073.0	1936.6	1876.2	1762.4	1979.3	1897.5
T9xC2	1737.3	1611.6	1558.1	1442.6	1649.1	1576.8
T10xC2	1427.1	1314.0	1264.9	1165.7	1348.6	1282.2
T11xC2	1490.4	1374.9	1324.5	1224.0	1410.3	1342.2
T12xC2	1457.8	1343.4	1293.9	1193.5	1417.8	1349.1
Mean	1555.5	1437.5	1386.4	1282.1	1474.9	1405.7
P=0.01%	114.2	57.7	94.8	57.7	96.0	83.1

measurements. Parameters including germination percentage, germination rate, root length, shoot length, seedling length, fresh weight, dry weight, as well as vigour indices I and II exhibited significant enhancements compared to the control group after a storage period of three months. On the other hand, the effectiveness of castor oil in enhancing these seed quality parameters was found to be the lowest at a concentration of 3gm/kg of seed. These findings highlight the potential of applying rhizobium at the specified concentration as a promising strategy to improve mustard seed quality and extend its storage viability. However, it is important to acknowledge that these conclusions are based on a three-month experimental period, emphasizing the need for additional comprehensive investigations to strengthen and broaden these recommendations.

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