



Regulation of siliqua and seed quality in Indian mustard (*Brassica juncea*) by application of salicylic acid

Dhani Hansda and Amitava Dutta*

Department of Seed Science and Technology, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, 741 252, West Bengal, India

Corresponding author: amitavapors@gmail.com

<https://doi.org/10.56093/job.v17i2.4>

Received date : 08 April 2026; Revised date : 10 June 2026; Accepted date : 15 June 2026

Abstract

Heat stress is a severe problem for the agriculture, affecting crop growth and yield. Salicylic acid is an important plant growth regulator which not only promotes plant growth and development, but also induces stress resistance in plant cells. The present investigation was carried out during rabi 2023-24 at Instructional Farm of Bidhan Chandra Krishi Viswavidyalaya, West Bengal. The experiment was conducted with mustard variety TBM-143. Seeds were sown in three different dates D_1 , D_2 and D_3 . Spraying of Salicylic acid in different plots was done with Salicylic acid as control (T_1), @200 ppm (T_2), 400 ppm (T_3) and 600 ppm (T_4). Physiological and biochemical parameters viz. siliqua length (cm), siliqua width (mm), germination percent, siliqua fresh weight (mg), fresh weight of seed (mg), dry weight of seed (mg), seedling fresh weight (mg), seedling dry weight (mg), seedling length (cm), vigour index I, vigour index II, imbibition rate (12 hours), α -amylase activity ($\mu\text{g min}^{-1}\text{g}^{-1}$) (24 hours), Peroxidase activity ($\text{A min}^{-1}\text{g}^{-1}$) (24 hours) were estimated. D_1 was identified as optimum date for sowing of TBM-143 for most of the characters. In case of heat stress mitigating chemicals the higher physiological and biochemical characters were recorded when salicylic acid was applied @ 400ppm. Interaction effect between date of sowing and heat stress mitigating chemicals was also observed. As the sowing delayed, there was poor performance due to terminal heat stress. Thus by applying heat stress mitigating chemicals, the seed quality could be maintained even delaying in sowing by the month of middle of December.

Keywords: Indian mustard, biochemical quality, salicylic acid, TBM-143, terminal heat stress

Introduction

Two thousand years ago, the Greeks, Romans, Indians, and Chinese were aware of rapeseed-mustard. Some ancient texts and literature mentioned it, and were cultivated as early as 5000 BC. It was cultivated as early as the Neolithic era. Between 2300 and 1750 BC, mustard seeds were found at Channhu-daro, a part of the Harrapan civilization (Allchin, 1969). Aryan people used brassica species as oil and as sauces. Oil use, however, continued to be more common among non-Aryans. In botany, Indian mustard is called *Brassica juncea* ($2n=4x=36$) while rapeseed is called *Brassica napus* ($2n=4x=38$). The Middle East seems to be the origin of *Brassica juncea* (Mizushima and Tsunoda 1967; Olsson 1960). After that, it swiftly expanded throughout Asia, India, Africa, Europe, and the Far East (Hemingway 1976). It had appeared multiple times in different places and with different ancestors. Geographic centres of diversity now include the Caucasus, China, and Eastern India (Hemmingway 1976, Prakash & Hinata 1980). There are two geographical races of *Brassica juncea*, the Chinese and Indians- which is also corroborated by biochemical and molecular research.

According to the Economics & Statistics Division of the Department of Agriculture & Farmers Welfare, rapeseed-mustard cultivation in India occupies approximately 8.06 million hectares of land and yields 14.58 quintals per hectare. Our country contributes significantly to the global rapeseed and mustard market, producing approximately 11.75 million tons of rapeseed mustard (Fourth advance estimates, 2021–2022), fourth only to the European Union (19.5 million tons), Canada (19 million tons), and China (14.7 million tons). In West Bengal, rapeseed-mustard is grown on 6.1 lakh hectares, yielding 1250 kg/ha and 7.6 lakh tons (Anonymous 2021-22).

The diverse agro ecological condition of West Bengal is favourable for growing mustard crop (Dutta *et al.*, 2019). In Gangetic alluvial region, mustard and rapeseed are cultivated after the *Kharif* rice harvest. Late harvesting of *Kharif* rice, delays mustard sowing which leads to insufficient dry matter accumulation (Samanta and Dutta 2024) resulting low seed yield and reduced seed vigour. Moreover, higher temperatures in March and April encourage the seeds to mature forcefully, which prevent late planted mustard crops from bold sized seeds. High

temperature stress can impact several aspects of plants, including their morphology, physiology, biochemistry, antioxidant enzyme activity, and the quality metrics of crops (Serraj *et al.*, 1999; Moradshahi *et al.*, 2004). When exposed to high temperatures, heat shock proteins (HSPs) and reactive oxygen species (ROS) are produced (Wahid *et al.*, 2007, Camejo *et al.*, 2006). According to a study, an increase of 1°C in the average growing season temperature could result in a crop yield decline of up to 17%, with the extent of the decline varying depending on the crop, growth stage, and environmental circumstances. Higher temperatures change the photosynthetic activity and have an impact on the physio-chemical characteristics and structure of the thylakoid membrane (Lichtenthaler 2005). This generates low yield as well as creates low vigour seed, lower plant population during next season. Various strategies have been employed; nevertheless, the foliar application of nutrients has proven to be more advantageous than the alternatives. It improves the yield and quality of the seeds. According to Hayat *et al.* (2007), salicylic acid (SA), an endogenous signalling molecule is crucial for controlling plant growth (by triggering mitotic activity), development, and interactions with other factors as well as reactions to a variety of abiotic stressors (Miura and Tada 2014). Since terminal heat stress is very common in areas where the duration of winter spell is short, the effect of heat stress may be minimised by planning the present investigation with the objective: effect of salicylic acid on physiological and biochemical parameter of siliqua and seeds under terminal heat stress condition.

Materials and Methods

The variety TBM-143 developed at Bidhan Chandra Krishi Viswavidyalaya by the second author in collaboration with Bhabha Atomic Research Centre

(BARC), collected from department of Seed Science of Technology, BCKV. The experiment was conducted during Rabi season 2023-24 at Jaguli Instructional Farm, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia. The research plot where the field investigation was under taken, is located 22.95°N latitude, 88.54°E longitude with an altitude of 9.73 m above the mean sea level. Monthly meteorological observation during experimental period 2023-24 (Table 1).The experiment was carried out in factorial RBD with the objective of assessment of siliqua and seed quality parameters under varying levels of Salicylic Acid and different date of sowing. Three dates of sowing such as D₁: Timely sowing; D₂: Late sowing; D₃: Very late sowing was considered as first factor. Four treatments such as T₁: Control, T₂: Salicylic acid @200 ppm, T3: Salicylic acid @400 ppm, T4: Salicylic acid @600 ppm was considered as second factor. Plot size was 3m x 1.2m with spacing of row to row: 30 cm and plant to plant: 10 cm replicated thrice. N: P₂O₅: K₂O was applied @ 100:50:50 kg/ha. 50% nitrogen and full doses of phosphate and potash were applied as basal and remaining 50% Nitrogen were applied in 2 splits at 30 DAS and 45 DAS (days after sowing). Thinning and intercultural operation were done 15 DAS. Seeds were sown by line sowing method at row-to-row distance 30 cm on 17.11.23 (D₁); 4.12.23 (D₂); 21.12.23 (D₃). It was followed by light irrigation. Spraying of Salicylic acid in different plots were done 20.01.24 (D₁), 27.01.24 (D₂), 04.02.24 (D₃). All biometric observations on the five chosen plants were recorded, and they were appropriately labelled. Physiological parameters related to siliqua and seed as well as biochemical quality were recorded following Factorial CRD under three replications. Analysis of data was conducted under OPSTAT software programme.

Table 1: Monthly meteorological observation during experimental period 2023-24 (November, 2023 to March, 2024)

Year (2023-24)	Month	Temperature (°C)		Relative humidity (%)		Total Rainfall (mm)
		Max.	Min.	Max.	Min.	
November, 2023	17 Nov-30 Nov	29.10	16.43	93.07	80.86	0.36
December, 2023	01 Dec-31 Dec	25.71	13.45	94.32	79.00	2.17
January, 2024	01 Jan-31 Jan	22.41	10.41	95.45	77.77	2.04
February, 2024	01 Feb-29 Feb	27.48	14.78	94.31	76.21	0.44
March, 2024	01 Mar-13Mar	30.71	15.47	92.92	73.38	0.00

Results and Discussion

Physiological parameter such as siliqua length, siliqua width, germination percent, siliqua fresh weight, fresh weight of seed, dry weight of seed, seedling fresh weight, seedling dry weight, seedling length, vigour index I, vigour index II, imbibition rate (12 hours), á- amylase activity

(µg min⁻¹ g⁻¹) (24 hours), Peroxidase activity (.A min⁻¹g⁻¹) (24 hours) were estimated in the laboratory. Details of results and observations noted are described below:

Growth parameters

Siliqua length, siliqua width and fresh weight

The mean values of siliqua length decreased progressively from timely sowing to very late sowing. There was significant variation due to treatments, sowing dates, and their interactions. From Table 2, it was evidenced that, T3 (Salicylic acid @ 400 ppm) had the largest mean siliqua length (5.05 cm), followed by T4 (Salicylic acid @ 600 ppm) and T2 (Salicylic acid @ 200 ppm) (4.71 cm and 4.65 cm). Timely sown (D1) crops produced maximum mean siliqua length (5.22 cm), followed by late sown (D2) and very late sown (D3) crops with 4.65 cm and 4.32 cm respectively. Maximum interaction effect on siliqua length (Fig 1) was shown by D1T3 (5.70 cm) followed by D1T4 (5.30 cm). Overall, the interaction effect was found promising in D2T3 and D3T3 also which indicates a positive influence of salicylic acid for this character. Further, T3 had highest siliqua width (1.24 mm), followed by T2 (1.12 mm), and T1 (1.12 mm).

Among the different date of sowing, late sowing i.e. D2

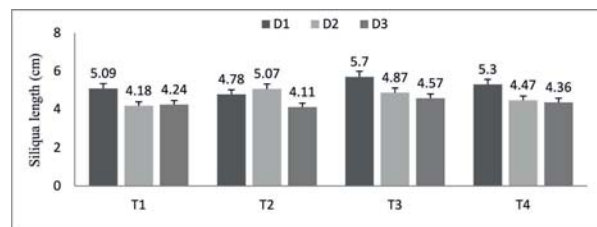


Fig. 1: Interaction effect of salicylic acid treatment and date of sowing on siliqua length

had maximum siliqua width (1.29 mm), followed by D1 (1.19 mm) and D3 (0.90 mm). With the delay of sowing, due to temperature rise siliqua length as well as width decreased. There was significant effect due to treatments, sowing dates and interaction between date of sowing and treatments (Table 2). Among the interaction effects (Fig 2), D2T3 exhibited the maximum effect (1.49 mm) followed by D2T1 (1.47 mm). Table 2 indicated that the siliqua fresh weight (mg) varied significantly depending on the treatment, date of sowing, but interaction between

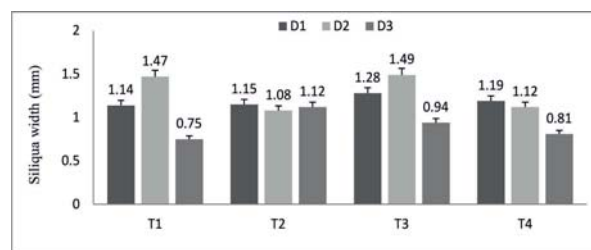


Fig. 2: Interaction effect of salicylic acid treatment and date of sowing on siliqua width (mm)

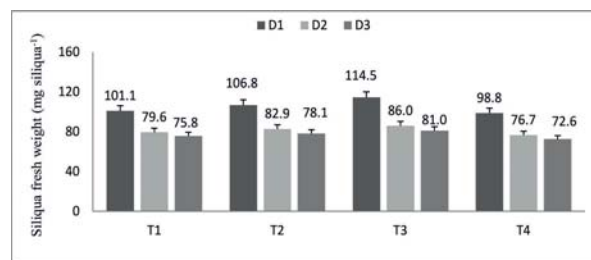


Fig. 3: Interaction effect of salicylic acid treatment and date of sowing on siliqua fresh weight (mg siliqua⁻¹)

Table 2: Siliqua and seed characters as influenced by salicylic acid and date of sowing

Treatments	Siliqua length (cm)	Siliqua width (mm)	Siliqua fresh weight (mg siliqua ⁻¹)	Fresh weight of seed (mg seed ⁻¹)	Dry weight of seed (mg seed ⁻¹)
Control (T1)	4.50	1.12	85.74	5.62	3.53
Salicylic acid@ 200 ppm (T2)	4.65	1.12	89.28	4.72	3.61
Salicylic acid@ 400 ppm (T3)	5.05	1.24	93.82	6.27	3.91
Salicylic acid@ 600 ppm (T4)	4.71	1.04	82.69	5.96	3.65
SEm (±)	0.03	0.02	0.89	0.06	0.09
LSD (P=0.05)	0.07	0.06	2.63	0.18	0.26
Date of sowing					
Timely sowing (D1)	5.22	1.19	105.30	6.46	3.99
Late sowing (D2)	4.65	1.29	81.28	5.37	3.68
Very late sowing (D3)	4.32	0.90	76.86	5.09	3.36
SEm (±)	0.02	0.02	0.77	0.05	0.08
LSD (P=0.05)	0.06	0.05	2.27	0.16	0.23
Interaction					
SEm (±)	0.04	0.03	1.54	0.11	0.15
LSD (P=0.05)	0.13	0.10	NS	0.31	NS

date of sowing and treatment were statistically non-significant. T3 produced highest siliqua fresh weight ($93.82 \text{ mg siliqua}^{-1}$) among the treatments. It was followed by T2 ($89.28 \text{ mg siliqua}^{-1}$) and T1 ($85.74 \text{ mg siliqua}^{-1}$).

Among different date of sowing D1 had maximum siliqua fresh weight with $105.30 \text{ mg siliqua}^{-1}$, followed by D2 with $81.28 \text{ mg siliqua}^{-1}$ and D3 with $76.86 \text{ mg siliqua}^{-1}$. Among all the interactions the highest siliqua fresh weight was recorded by D1T3 with $114.48 \text{ mg siliqua}^{-1}$ and D3T4 produced lowest value with $72.56 \text{ mg siliqua}^{-1}$ (Fig 3).

Fresh weight and dry weight of seed

T3 had maximum siliqua fresh weight ($6.27 \text{ mg seed}^{-1}$), followed by T4 and T1 with $5.96 \text{ mg seed}^{-1}$ and $5.62 \text{ mg seed}^{-1}$ respectively. In case of date of sowing, timely sowing (D1) produced the maximum fresh weight of seed with $6.46 \text{ mg seed}^{-1}$, followed by D2 ($5.37 \text{ mg seed}^{-1}$) and D3 ($5.09 \text{ mg seed}^{-1}$). Table 2 determined that the treatment, the date of sowing, and the interaction between treatment and date of sowing had significant impact on the fresh weight of the seed. Among all interactions, D1T3 with $6.89 \text{ mg seed}^{-1}$ exerted the maximum effect (Fig 4) on seed fresh weight, followed by D1T4 with $6.69 \text{ mg seed}^{-1}$. There was significant influence due to treatment, date of sowing but there was non-significant impact due to interaction on dry weight of seed (mg seed^{-1}). It was revealed that (Table 2), T3 produced maximum seed dry weight ($3.91 \text{ mg seed}^{-1}$) which was followed by T4 and T2 with 3.65 and $3.61 \text{ mg seed}^{-1}$, respectively. At timely sowing i.e. D1 generated maximum seed dry weight ($3.99 \text{ mg seed}^{-1}$), followed by D2 ($3.68 \text{ mg seed}^{-1}$) and D3 ($3.36 \text{ mg seed}^{-1}$). D1T3 with $4.24 \text{ mg seed}^{-1}$ exhibited the maximum

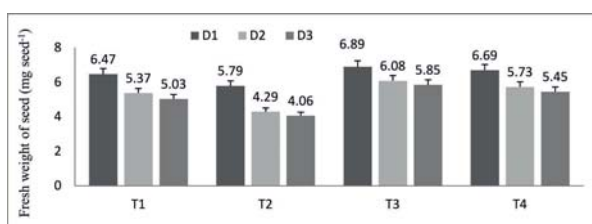


Fig. 4: Interaction effect of salicylic acid treatment and date of sowing on fresh weight of seed (mg seed^{-1})

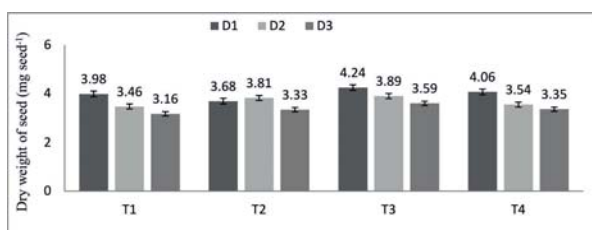


Fig. 5: Interaction effect of salicylic acid treatment and date of sowing on dry weight of seed (mg seed^{-1})

interaction effect on seed dry weight (Fig 5).

Germination percent

Table 3 showed that treatment (T) and interaction between date of sowing and treatment were significant. T1 had the greatest average germination rates among the treatments (95.67%), followed by T2 and T3 (94.11 and 91.89%). Both timely sowing (D1) produced consistently high germination rate with 100% preceded by D2 (90.9%) and D3 (88.17%). There was slight decrease in germination (88.17%) under very late sowing conditions (D3). Under very late sowing (D3) condition (Fig 6) D3T1 (92.33%) recorded higher interaction effect.

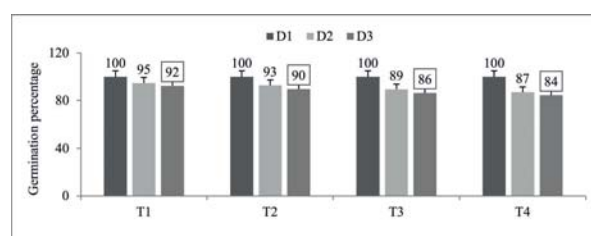


Fig. 6: Interaction effect of salicylic acid treatment and date of sowing on germination percent

Seedling weight and length

Mean values as presented in Table 3, revealed that, there was significant variation in the fresh weight of seedlings among treatment of spraying and date of sowing. T3 had maximum fresh weight of seedlings ($52.76 \text{ mg seedling}^{-1}$), followed by T4 ($51.17 \text{ mg seedling}^{-1}$) and T1 ($46.58 \text{ mg seedling}^{-1}$). Late sown plants (D2) had maximum seedling fresh weight with $49.01 \text{ mg seedling}^{-1}$, preceded by D1 with $48.89 \text{ mg seedling}^{-1}$ and D2 with $46.99 \text{ mg seedling}^{-1}$. Greatest seedling fresh weight was recorded under the interaction effect of D1T3 (Fig 7) with $53.48 \text{ mg seedling}^{-1}$ in normal date of sowing. Whereas in very late sown condition, greatest interaction effect on seedling fresh weight was noted in D3T3 with $51.48 \text{ mg seedling}^{-1}$. Dry weight provides a precise measurement of biomass, avoiding changes caused by varying environmental and physiological variables. Therefore, dry weight is thought to be a more useful metric than fresh weight for revealing information about treatment productivity and efficiency. Table 3 demonstrated that the dry weight of seedlings varied significantly. T3 produced maximum value ($13.06 \text{ mg seedling}^{-1}$) followed by T4 ($12.07 \text{ mg seedling}^{-1}$). The treatment T2 displayed minimum dry weight of seedlings ($10.65 \text{ mg seedling}^{-1}$). Among different dates of sowing, timely sowing (D1) produced the greatest dry seedling weight with $13.14 \text{ mg seedling}^{-1}$, followed by D2 and D3 with (11.53 and $10.52 \text{ mg seedling}^{-1}$ respectively). Among the interactions D1T3 recorded the maximum dry weight

Table 3: Physiological and biochemical characters as influenced by salicylic acid and date of sowing

Treatments	Germination percent (Angular transformed value)	Seedling fresh weight (mg seedling ⁻¹)	Seedling dry weight (mg seedling ⁻¹)	Seedling length (cm)	Vigour index I	Vigour index II	Imbibition rate (12 hr)	α -amylase activity ($\mu\text{g min}^{-1}\text{g}^{-1}$) (24 hr)	Peroxidase activity ($\Delta\text{A min}^{-1}\text{g}^{-1}$) (24 hr)
Control (T1)	95.67 (80.39)	46.58	11.14	12.04	1201.72	1112.04	153.11	87.30	1.25
Salicylic acid@ 200 ppm (T2)	94.11 (78.59)	42.68	10.65	13.10	1307.70	1062.31	149.55	79.31	1.14
Salicylic acid@ 400 ppm (T3)	91.89 (76.43)	52.76	13.06	16.14	1607.52	1300.92	146.67	75.41	1.16
Salicylic acid@ 600 ppm (T4)	90.44 (75.20)	51.17	12.07	14.59	1452.75	1202.64	144.00	68.16	1.21
SEm($\pm$)	0.48	0.13	0.04	0.08	8.47	4.90	0.80	0.41	0.02
LSD (P=0.05)	1.43	0.38	0.11	0.23	24.99	14.48	2.36	1.21	0.06
Date of sowing									
Timely sowing (D1)	100 (90)	48.89	13.14	15.06	1506.92	1314.17	155.50	91.04	1.28
Late sowing (D2)	90.92 (72.85)	49.01	11.53	14.41	1441.08	1152.58	138.49	78.72	1.11
Very late sowing (D3)	88.17 (70.11)	46.99	10.52	12.42	1229.27	1041.68	150.99	62.87	1.18
SEm($\pm$)	0.42	0.11	0.03	0.07	7.33	4.25	0.69	0.35	0.02
LSD (P=0.05)	1.24	0.33	0.09	0.19	21.65	12.54	2.05	1.05	0.05
Interaction									
SEm($\pm$)	0.84	0.22	0.07	0.13	14.67	8.49	1.39	0.71	0.04
LSD (P=0.05)	2.47	0.65	0.19	0.39	43.30	25.07	4.09	2.09	NS

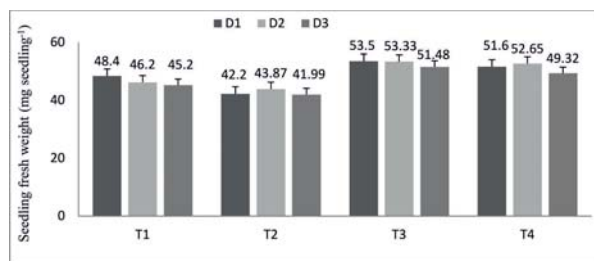


Fig. 7: Interaction effect of salicylic acid treatment and date of sowing on seedling fresh weight (mg seedling⁻¹)

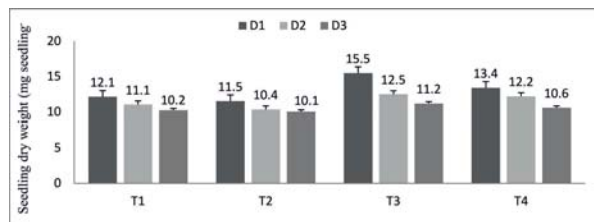


Fig. 8: Interaction effect of salicylic acid treatment and date of sowing on seedling dry weight (mg seedling⁻¹)

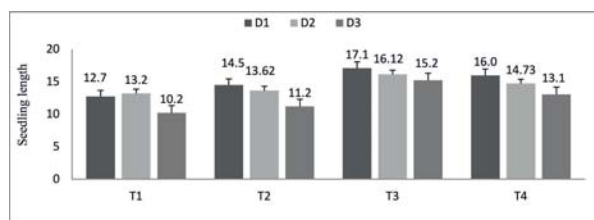


Fig. 9: Interaction effect of salicylic acid treatment and date of sowing on average seedling length (cm)

of seedlings with 15.49 mg seedling⁻¹. Under very late sown condition, D3T3 had the greatest interaction effect (Fig 8) on seedling dry weight (11.19 mg seedling⁻¹). Since average seedling length is a component of vigour index I, it is a crucial metric for assessing seed deterioration. Considering average performance of the genotype TBM-143 due to effect of date of sowing, treatment and their interactions it was found that treatment T3 had the longest seedlings, measuring 16.14 cm, followed by T4 and T2 with 14.59 cm and 13.10 cm respectively (Table 3). During timely sowing, D1 generated the longest seedling length with 15.06 cm, followed by D2 with 14.41 cm and D3 with 12.42 cm. Among the interactions D1T3 produced the longest seedlings with 17.09 cm (Fig 9). Under very late sowing (D3), D3T3 produced highest interaction effect on seedling length (15.22 cm).

Vigour index

Mean values of vigour index I for Indian mustard seed treated with varying doses of salicylic acid is shown in Table 3. Significant differences were noted due to the effects of treatment, sowing date, and their interactions.

Among the treatments, T3 had noticeably higher vigour index I (1607.52), followed by T4 and T2 (1452.75 and 1307.70 respectively). Whereas treatment T1 (Control) had the lowest seed vigour index I (1201.72). Seeds harvested under D1 recorded maximum value (1506.92) followed by D2 and D3 (1441.08 and 1229.27 respectively). Among the interactions, D1T3 had the highest vigour index I with 1709.00, followed by D1T4 with 1597.67. D3T1 had lowest vigour index I with 1015.17. Under very late sown condition (D3), D3T3 produced highest vigour index I with 1501.88 (Fig 10). Table 3 displayed mean values of vigour index II. The treatments, sowing dates, and their interactions all had significant effect on vigour index II. Among all treatments, T3 had highest seed vigour index II with 1300.92, preceded by T4 with 1202.64 and T1 with 1112.04. Treatment T2 showed considerably lower seed vigour index II with 1062.31. Among different date of sowing, D1 (1314.17) produced the highest vigour index II during timely sowing condition, followed by D2 (1152.58) and D3 (1041.68). Among interactions (Fig 11) D1T3 exhibited the maximum vigour index II with 1549.00, followed by D1T4 with 1340.67. During very late sowing (D3) condition, D3T3 recorded highest vigour index II with 1104.76.

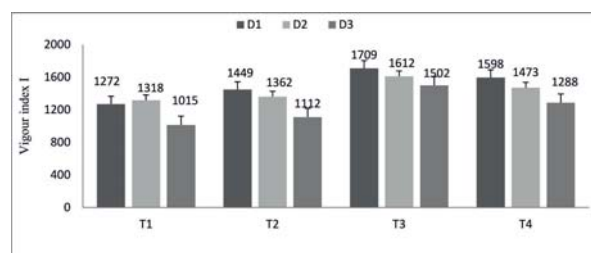


Fig. 10: Interaction effect of salicylic acid treatment and date of sowing on vigour index I

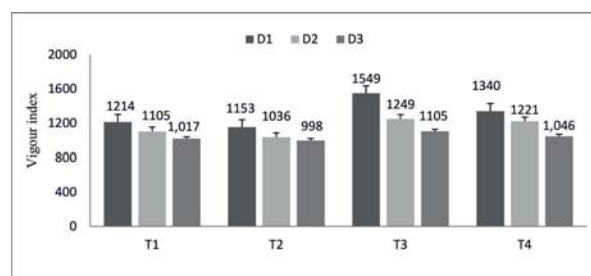


Fig. 11: Interaction effect of salicylic acid treatment and date of sowing on vigour index II

Imbibition rate

Significant variation in imbibition rate across treatments, sowing dates, and interactions between treatments and dates of sowing was observed (Table 3) when seeds were soaked for 12 hours. Treatment T1 recorded highest

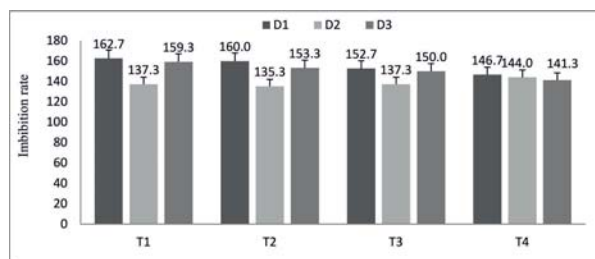


Fig. 12: Interaction effect of salicylic acid treatment and date of sowing on imbibition rate

imbibitions rate (153.11) proceeded by T2 and T3 (149.55 and 146.67 respectively). Treatment T4 had the lowest imbibitions rate (144.00). During timely sowing, D1 had highest imbibitions rate with 155.50, followed by D3 and D2 with 150.99 and 138.49 respectively. Interactions (Fig 12) between treatments and dates of sowing, revealed maximum value by D1T1 with 162.67, which was followed by D1T2 (160.0) and D3T1 (159.33).

α -amylase activity and peroxidase content

There were significant variation between treatments, date of sowing and among their interactions. Notable differences in the date of sowing, treatment and interactions were observed (Table 3). Among the treatments, T1 had highest α -amylase activity ($87.30 \mu\text{g min}^{-1} \text{g}^{-1}$), followed by T2 and T3 (79.31 and $75.41 \mu\text{g min}^{-1} \text{g}^{-1}$ respectively). T4 showed lowest α -amylase activity ($68.16 \mu\text{g min}^{-1} \text{g}^{-1}$). Under date of sowing, D1 showed highest α -amylase activity with $91.04 \mu\text{g min}^{-1} \text{g}^{-1}$, preceded by D2 and D3 with 78.72 and 62.87 respectively.

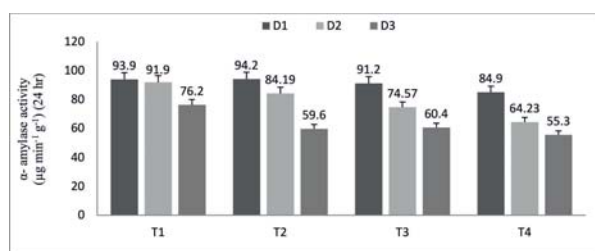


Fig. 13: Interaction effect of salicylic acid treatment and date of sowing on α -amylase activity ($\mu\text{g min}^{-1} \text{g}^{-1}$)

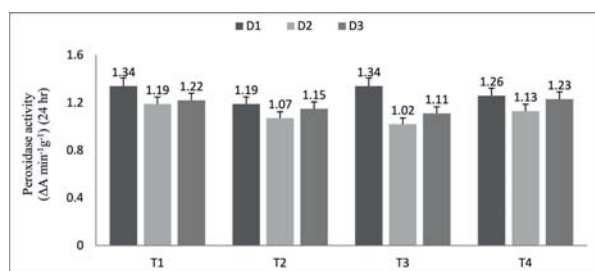


Fig. 14: Effect of salicylic acid treatment and date of sowing on Peroxidase activity ($\Delta\text{A min}^{-1} \text{g}^{-1}$)

Among all interactions (Fig 13), D1T2 produced greatest interaction effect with $94.15 \mu\text{g min}^{-1} \text{g}^{-1}$, followed by D1T1 with $93.86 \mu\text{g min}^{-1} \text{g}^{-1}$. Table 3 displayed mean values of peroxidase activity as impacted by the date of sowing and foliar spray of salicylic acid. Treatments, dates of sowing had significant impact but their interaction had non-significant impact on peroxidase content. Among treatments, peroxidase activity was highest in T1 ($1.25 \Delta\text{A min}^{-1} \text{g}^{-1}$), followed by T4 and T3 (1.21 and $1.16 \Delta\text{A min}^{-1} \text{g}^{-1}$) while T2 registered lowest peroxidase activity ($1.14 \Delta\text{A min}^{-1} \text{g}^{-1}$). Among different dates of sowing, D1 produced highest peroxidase activity with $1.28 \Delta\text{A min}^{-1} \text{g}^{-1}$, followed by D3 and D2 with 1.18 and $1.11 \Delta\text{A min}^{-1} \text{g}^{-1}$, respectively. D1T1 had highest interaction effect on peroxidase content ($\Delta\text{A min}^{-1} \text{g}^{-1}$) with $1.34 \Delta\text{A min}^{-1} \text{g}^{-1}$. D3T4 recorded greatest peroxidase activity ($1.23 \Delta\text{A min}^{-1} \text{g}^{-1}$) during very late sowing (Fig 14).

Conclusion

Oil seed production increased significantly from 1990 due to increase in area and adoption of improved variety. Since seed is a low-cost input, the quality of seed is an important factor as it directly influences plant health, yield and overall productivity. Among the different seed quality parameters studied under laboratory condition, significant variation was found due to treatments and date of sowing. Seed harvested from normal sown crop produced higher value for most of the seed quality parameters except α -amylase activity ($\mu\text{g min}^{-1} \text{g}^{-1}$). Among the treatments T3 (Salicylic acid @ 400ppm) produced maximum value for different seed quality parameter in most of the characters except imbibitions rate, α -amylase activity, Peroxidase activity where T1 (control) produced maximum value. The interaction effect of the seed quality parameter was significant for all the characters except peroxidase activity. Since T3 (Salicylic acid @ 400ppm) produced higher value in seed quality parameters, it can be adopted to mitigate higher temperature stress during the reproductive phases of rapeseed-mustard.

References

- Allchin FR. 1969. Early cultivated plants in India and Pakistan. *Domestication Exploit Plants Anim* 6: 323-329.
- Anonymous. 2021-22. Fourth advance estimates, 2021-22, source: Economics & Statistics Division, Department of Agriculture & Farmers Welfare. <https://www.statista.com/statistics/263930/worldwide-production-of-rapeseed-by-country/>
- Camejo D, Jimenez A, Alarcon JJ, Torres W, Gomez JM and Sevilla F. 2006) Changes in photosynthetic parameters and antioxidant activities following heat-shock treatment in tomato plants. *Funct Plant Biol* 33: 177-187.

- Dutta A, Jambhulkar SJ, Rai AN, Bhujbal S, Banerjee H, Das R, Dewanjee S, Sarkar S, Pramanik M and Mandal S. 2019. Trombay Bidhan Mustard-204 (TBM-204): A high yielding yellow seed coat mustard [*Brassica juncea*(L.) Czern. &Coss.] variety notified for West Bengal. *J Oilseeds Res* **36**: 220-224.
- Hayat S, Ali B and Ahmad A. 2007. Salicylic acid-A plant hormone. *Springer Dordrecht, The Netherlands*.
- Hemingway JS. 1976. Mustards: *Brassica spp.* and *Sinapsis alba* (Cruciferae). *Evolution of Crop Plants*. (ed. Simmonds, N. W.)
- Lichtenthaler YF. 2005. Effect of environment on changing the structural organization and physio-chemical properties of thylakoid membrane. *Ind J Agric Sci* **92**: 43-90.
- Miura K and Tada Y. 2014. Regulation of water, salinity, and cold stress responses by salicylic acid. *Front Plant Sci* **5**: 213-27.
- Mizushima U, Tsunoda S. 1967. A plant exploration in Brassica and Allied Genera. *Tohoku J Agric Res* **17**: 249-276.
- Moradshahi A, Eskandari BS, Kholdebari B. 2004. Some physiological responses of canola (*Brassica napus* L.). *Iran J Sci Technol* **28**: 43-50.
- Olsson G. 1960. Species crosses within the genus Brassica II. *Artificial Brassica napus* L. *Hereditas* **46**: 351-396.
- Prakash S and Hinata K. 1980. Taxonomy, cytogenetics and origin of crop Brassica, a review. *Opera Bot* **55**: 11-57.
- Samanta S and Dutta A. 2024. Impact of storage containers on seed quality and longevity of yellow sarson. *J AgriSearch* **11**: 53-57.
- Serraj R, Sinclair TR and Purcell LC. 1999. Symbiotic N₂ fixation response to drought. *J Exp Bot* **50**: 143-155.
- Wahid A, Gelani S, Ashraf M and Foolad MR. 2007. Heat tolerance in plants: An overview. *Environ Exp Bot* **61**: 199-223.