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Biological Priming: An Eco-Friendly Alternative for Inducing Salinity Tolerance and Augmenting Plant Growth in *Brassica juncea*

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

High salinity injury is one of the critical factors that limit crop yields and quality internationally especially in hot and semi hot areas. *Brassica juncea* otherwise called as Indian mustard is a significant oilseed crop tender to saline stress. In this work, a possibility of the biological priming treatment application as the environmentally friendly method for increasing the plants' salt tolerance and growth rate of Brassica juncea plants is described. This study was carried out at Department of Genetics and Plant Breeding, Naini Agricultural Institute, Sam Higginbottom University of

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Agriculture Technology and Sciences, Prayagraj, Uttar Pradesh during rabi 2021-22. The experiment was carried out in factorial complete randomized design including 15 genotypes of mustard treated with 16 treatments of NaCl (20, 40 and 60%) and PGPR (*Bacillus cereus*, *Aeromonas* media and *Rhizobium alamii*). Various quantitative characters and qualitative characters were observed and studied. In this research we only highlighted the seed yield, chlorophyll content, proline and protein content as these observations are vital for salinity tolerance. The traits which exhibit positive effects on seed yield would be considered for the breeding programmes. Hence, RLM-619, RH-761, and P21-KANTI genotypes with PGPR-1, PGPR-2, and PGPR-3 treatments are most effective for increasing seed yield per plant, using strategies like plant breeding, genetic engineering, and seed biopriming for improving the tolerance against the salinity. Hence, this study clearly discusses the effectiveness of the biological priming strategy as a cost effective and eco-friendly method of combating the effect of salinity stress as well as enhancing plant growth and yield of *Brassica juncea* in salt affected zones of agriculture.

Keywords: Bio-priming; Brassica juncea; PGPR; salinity stress.

1. INTRODUCTION

Brassica juncea, or Indian mustard, is a vital oilseed crop grown in India. It is ranked second in Asia in terms of acreage and production, after rapeseed [1]. Its production and area are further increased by the fact that it is mostly grown in states like Gujarat, Rajasthan, Madhya Pradesh, Haryana, and Uttar Pradesh [2]. With its cultivation spanning over 6.2 million hectares and an annual production of 9.3 million tons of seeds, mustard plays a critical part in India's agricultural economy [3]. Approximately 85% of India's oilseed production comes from seven important states, including Madhya Pradesh, which accounts for 40% of the country's production and GDP [4]. Indian mustard is a valuable source of edible oil for cooking and other uses because of its oil content, which can range from 38 to 50% [5]. The crop's adaptability is demonstrated by the range of applications it may be used for; it can be used to make sauces, edible oil, animal feed, and even biodiesel. Moreover, Indian mustard is essential for improving both the economy and food security. The crop is quite profitable, but the crop is highly sensitive to salt stress. Studies have shown that salt stress in Indian mustard decreases a number of morpho-physio-seed-quality parameters, including root and shoot length, fresh weight, and seedling vigor [6]. Moreover, mustard plants' growth characteristics, metabolites, and antioxidant defense system are adversely affected by salt stress, which results in oxidative damage and stunted growth. In order to augment salt tolerance, we can opt for seed treatment such as biopriming. Biological priming, which involves treating seeds with different microorganisms, is a sustainable method of improving salt tolerance and stimulating development in *Brassica juncea*. Through improved antioxidant defenses, osmotic adjustment, gene expression modulation, and chloroplast integrity, these priming strategies have demonstrated promising outcomes in minimizing the detrimental effects of salinity stress, ultimately promoting plant development and productivity [7]. By improving growth, hydration status, and gas exchange management in plants, seed priming with biological agents not only activates the defense system against combined stress conditions but also increases stress resilience and production. In mustard plants, plant-growth-promoting rhizobacteria (PGPR) are essential for reducing salt stress. Research has demonstrated that applying PGPR strains to mustard cultivars can greatly improve photosynthesis and development while reducing ethylene and oxidative stress [8]. Furthermore, it has been shown that halotolerant PGPR strains, which were isolated from the rhizosphere of halophyte plants, can improve salt tolerance by stimulating certain growth metrics when exposed to salt stress [9]. Plant growth and stress tolerance in salty soils are enhanced by PGPR through mechanisms that include osmotic adjustment, regulation of antioxidant systems, ion homeostasis, and phytohormonal balance [10]. These results demonstrate the potential of PGPR as a long-term approach to reduce salt stress and increase mustard plant crop output. Indian mustard is a keystone of agricultural sustainability and economic progress since its productivity is critical to increasing the nation's total oilseed yield.

2. MATERIALS AND METHODS

The experiment was conducted at Department of Genetics and Plant Breeding, Naini Agricultural Institute, Sam Higginbottom University of Agriculture Technology and Sciences, Prayagraj, Uttar Pradesh. In this experiment 15 genotypes of diverse geographic and genetic origin of Indian mustard were taken under consideration.

Table 1. List of genotypes

Sl.No.		Genotypes
1.	G1	RH-761
2.	G2	P4-CS-54
3.	G3	P21-KANTI
4.	G4	P6-PBR-297
5.	G5	P20-KRISHNA
6.	G6	P28-ROHINI
7.	G7	P28-NDYS-08
8.	G8	P-8-PM-21
9.	G9	P20-PUSATARAK
10.	G10	P2-RB-50
11.	G11	RGN-298
12.	G12	PUSA VIJAY
13.	G13	P-2-RH-406
14.	G14	P-4-PATAN MUSTARD-67
15.	G15	RLM-619

Table 2. Experimental details

Season	Rabi *2021-22*
Design	CRD
Total Number of Genotypes	15
Total Number of Replications	02
Number of treatments (PGPR)	03
Number of treatments (NaCl)	03
Date of sowing	01/12/2022
Number of pots	480

Biological priming, also called bio-priming, is a method of treating seeds that includes hydrating the seeds after applying helpful microorganisms, such as *Trichoderma, Bacillus*, and *Pseudomonas*, to promote seed germination and early seedling growth [11]. Beneficial bacteria called Plant Growth-Promoting Rhizobacteria (PGPR) inhabit the rhizosphere of plants and stimulate growth by a number of processes, including the production of phytohormones, ion exchange, and antioxidant enzyme activation [12]. In this experiment, these fifteen genotypes were bio primed with NaCl at 20, 40 and 60 % and PGPR namely *Bacillus cereus, Aeromonas media* and *Rhizobium alamii.* These beneficial microorganisms used in biopriming serve as vital for enhancing plant health, nutrient cycling, stress tolerance, crop productivity, and seed germination. This practice also enhances soil fertility and health, demonstrating its potential for environmentally friendly agriculture [13]. When it comes to Indian mustard, PGPR can be quite important in lowering salinity stress. Research has demonstrated that the application of PGPR can reduce the negative effects of salinity by promoting salt tolerance and enhancing stressed plant development. In order to maintain ion homeostasis, increase food availability, and produce Osmo protectants, these bacteria cause the creation of volatile organic compounds and plant growth hormones, which in turn promotes improved growth, development, and yield in plants under salt stress [14].

Table 3. List of treatments

Treatment	Description
C	Control
S1	Control+S1 (20% NaCl)
S2	Control+S2 (40% NaCl)
S3	Control+S3 (60% NaCl)
T1	PGPR-1(Bacillus cereus)
T2	PGPR-2 (Aeromonas media)
T3	PGPR-3 (Rhizobium alamii)
T1S1	PGPR-1+S1
T1S2	PGPR-1+S2
T1S3	PGPR-1+S3
T2S1	PGPR-2+S1
T2S2	PGPR-2+S2
T2S3	PGPR-2+S3
T3S1	PGPR-3+S1
T3S2	PGPR-3+S2
T3S3	PGPR-3+S3

The various biochemical tests conducted in this experiment were:

1. **Chlorophyll content (mg/g)**

DMSO (Dimethyl sulfoxide): First 0.1 g of plant tissue was weighed and cut into smaller pieces and transferred to test tubes containing 10 ml of DMSO (Dimethyl sulfoxide) solvent. Test tubes were incubated in a water bath at 65°C for 37 1 hr until the 25 tissues became colourless. The test tubes were cooled for 30 min at room temperature and filtered. The absorption was measured at 665 nm and 648 nm using Thermo Scientific microplate reader. Blank determination was carried out with DMSO. The total chlorophyll concentration was expressed as mg/g fresh weight and determined by the following formula [15].

Total chlorophyll (mg/g FW) = (7.49 A665+ 20.34 A648)

(Where: A665: Absorption value at 665 nm A648: Absorption value at 648 nm)

2. **Protein (mg/g) By Lowerys Method**

- **Estimation of Protein Reagents:**
- Preparation of Protein Standard - 100mg of BSA was dissolved in 100 ml of distilled water (for 1 mg/ml concentration).

- Extraction from Plant Sample For extraction of protein
  First 0.5g of plant leaves were taken and grind with distilled water using a mortar and pestle. The homogenate was centrifuged at 5000 rpm for 10 mins and the supernatant was used for protein estimation.

- **Estimation of Protein**

Working standard solution was taken into a series of test tubes that is 0.02, 0.04, 0.06, 0.08, and 0.10ml using micropipette. 0.2ml of sample extract was pipette 38 out into separate test tube. The volume was made up to 1 ml with distilled water in all the tubes. A tube with 1 ml of distilled water served as blank. 5 ml of solution "C" was added to all tubes and mixed well and incubated at room temperature for 10 minutes. 0.5ml of solution 'D' was added, mixed well immediately and incubated at room temperature in dark for 30 minutes to develop blue color. O.D. was taken at 660 nm using Thermo Scientific microplate reader. The absorbance was read at 660 nm against the blank. Standard graph was drawn. The total amount of protein in the sample was calculated and expressed as the result as µg/ml sample [16].

3. **Proline content by Colorimetric Analysis**

Reagents:

- 3% Sulphosalicylic acid
- Acid Ninhydrin reagent – 0.625g of ninhydrin powder was dissolved in 15 ml glacial acetic acid and 10 ml 6M Phosphoric acid and agitated, until ninhydrin dissolves completely.
- Glacial acetic acid
- Toluene
- Preparation of Proline Standard - 100mg of proline was dissolved in 100 ml of distilled water (for 1 mg/ml concentration).

Procedure:

First 0.5 g of fresh plant shoot was weighed and then it was homogenized in 4 mL of 3% Sulphosalicylic acid using mortar and pestle. Then the homogenate was centrifuged for 10 min at 1000 rpm. The working standard solution was taken into a series of test tubes that is 0.02, 0.04, 0.06, 0.08, and 0.10ml using micropipette and final volume was made up to 1 mL. In another test tube 1 mL of the supernatant was taken. After that 2 mL of acid Ninhydrin reagent and 2 mL of glacial acetic acid was added to each test tube. Then the mixture was incubated in a water bath at 100 °C for 60 min. After that the mixture was cooled suddenly in an ice bath. After cooling, 4 mL of toluene was added to the solution mixture and vortex. The chromophore containing toluene (upper layer) was transferred to a new test tube. Finally, the absorbance was read at 520 nm using Thermo Scientific microplate reader and toluene was used as a blank. The concentration of proline was determined using the standard curve and expressed as µg mL-1.

Table 4. List of all the solutions used along with composition

Solution	Composition
Solution 'A'	4g of sodium hydroxide was dissolved in 800 ml of distilled water, then of 20 g sodium carbonate and 0.2g sodium potassium tartrate was added then make up the final volume 1000ml with distilled water and stored at room temperature.
Solution 'B'	0.5g $CuSO_4.5H_2O$ dissolved in 80 ml of distilled water and make up the volume 100ml.
Solution 'C'	Mix 98 ml of solution 'A' with 2 ml of solution 'B' and make the volume of 100ml.
Solution 'D'	1 part of Folin- Ciocalteau reagent was diluted with distilled water to 1N.

Table 5. List of all the characters under study

Sl. No.	Characters / traits
1.	Days to 50% flowering
2.	Plant height (cm)
3.	Number of primary branches per plant
4.	Number of secondary branches per plant
5.	Number of siliquae per plant
6.	Number of seeds per siliqua
7.	Length of siliqua (cm)
8.	Seed yield (gm)
9.	Biological yield (g)
10.	Harvest Index (%)
11.	Chlorophyll content
12.	Proline
13.	Protein

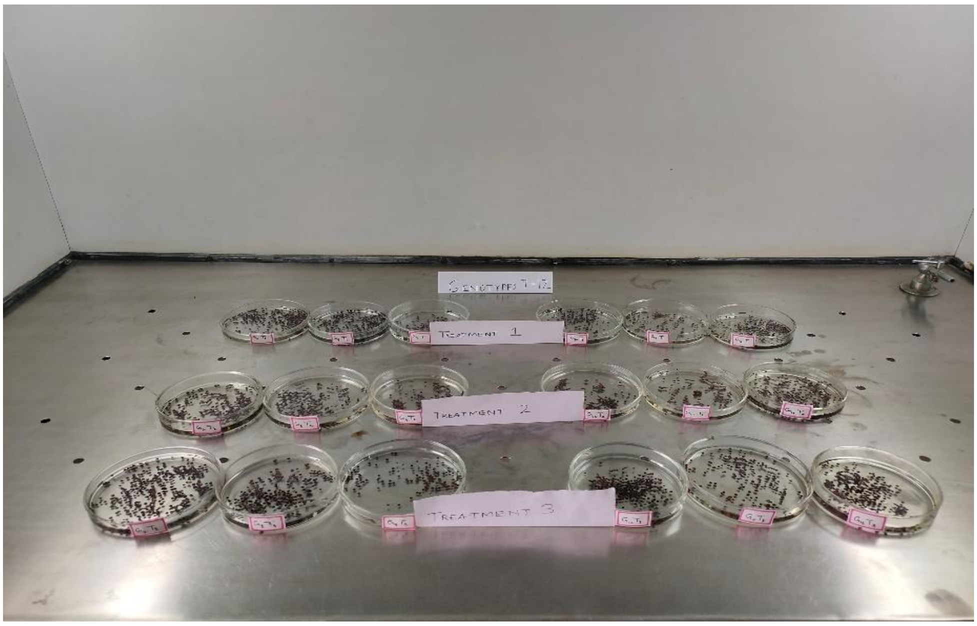

Fig. 1. Seeds treated with various biopriming agents

Observation for 13 primary characteristics were noted in order to analyse the effect of various biochemical test against the salinity stress. The 13 characters traits under study are mentioned in Table 5.

3. RESULTS AND DISCUSSION

In order to evaluate the performance of the 15 genotypes and to compare the effect of the treatment on them we need to calculate the mean of the observation. The mean value of each character was worked out by dividing the totals by the corresponding number of observations.

Arithmetic mean $X = \Sigma X / N$

(Where, ΣX = Sum of all the observations for each character in replication, N = Corresponding number of observations)

3.1 Quantitative Character

3.1.1 Seed yield per plant (g)

Among the treatments, PGPR-1 (12.46 g) showed significantly highest seed yield per plant followed by PGPR-2 (12.43 g) and PGPR-3 (12.36 g). While, Control+S1 (8.13 g), Control+S2 (7.60 g) and Control+S3 (7.35 g) were recorded lowest seed yield per plant. The seed yield per plant was significantly highest in RLM-619 (16.19 g) followed by RH- 761 (15.75 g) and P21- KANTI (11.53 g) whereas, P4-CS-54 (7.77 g) and RGN- 298 (7.72 g) recorded lowest seed yield per 59 plants among the selected genotypes. Among the genotypes and treatment interaction, the genotype RH-761 with PGPR-3 (19.75 g), RLM-619 with PGPR-3 (19.08 g) and RH-761 with PGPR-1 (19.50 g) showed significantly highest seed yield per plant, whereas, lowest seed yield per plant were noticed in P4-CS-54 with Control+S3 (6.13 g) and with Control+S1 (6.50 g).

3.2 Qualitative Characters

3.2.1 Chlorophyll content (%)

Among the treatments, S2+PGPR-1 (1.13 %) showed significantly highest chlorophyll content followed PGPR-2 and PGPR-3 (1.11 %). While, S1+PGPR-3 (0.83 %) S3+PGPR-3 (0.84 %) were recorded lowest chlorophyll content. The chlorophyll content was significantly highest in P4-CS-54 (1.33 %) followed by P6-PBR-297 (1.27 %) P-4-PATAN MUSTRAD- 67 and P21-KANTI (1.06 %) whereas, P20 - Krishna (0.84 %) and RLM-619 (0.86 %) recorded lowest chlorophyll content among the selected genotypes. Among the genotypes and treatment interaction, the genotype P4-CS-54 (1.88 %) and P6-PBR-297 (1.74 %) with PGPR-2 and P4-CS-54 with PGPR-3 (1.81 %) showed significantly highest chlorophyll content, whereas, lowest chlorophyll content was noticed in P20- Krishna (0.32 %) and RH-761 (0.37 %) with S1+PGPR-3.

Table 6. Mean performance of mustard genotypes, PGPR treatments and interactions for yield and yield contributing traits

Treatments	Days to 50% flowering	Plant height (cm)	Number of primary branches per plant	Number of secondary branches per plant	Number of siliqua per plant	Number of seeds per siliqua	Length of siliqua (cm)	Seed yield (gm)	Biological yield (g)	Harvest Index (%)	Chlorophyll content	Proline	Protein
G1T1	56.25	94.50	2.50	2.25	91.00	12.00	4.98	15.50	48.75	31.80	0.98	15.27	20.79
G1T2	52.50	77.50	1.75	1.25	71.00	10.50	4.38	8.50	38.25	22.23	0.98	24.39	20.37
G1T3	50.50	75.75	1.25	1.00	68.25	10.50	3.75	7.25	36.25	20.01	1.35	25.39	20.67
G1T4	49.00	75.50	1.00	0.25	66.00	9.75	3.63	7.00	33.25	21.07	1.26	28.87	21.34
G1T5	57.50	100.75	2.75	2.75	94.80	13.00	5.48	19.50	51.25	38.07	1.01	17.95	23.48
G1T6	54.75	97.75	2.50	3.00	95.25	12.25	5.13	17.75	49.25	36.07	1.37	15.94	20.43
G1T7	53.75	99.25	3.00	3.50	99.00	12.75	5.40	19.75	52.25	37.80	1.18	17.05	21.83
G1T8	50.75	94.00	2.25	2.00	86.00	12.25	4.88	17.50	49.00	35.71	0.85	18.34	24.64
G1T9	54.38	91.00	2.00	1.75	78.00	11.75	4.75	17.25	48.00	35.94	0.57	20.27	26.57
G1T10	51.50	90.00	1.50	1.00	74.25	11.25	4.50	16.25	44.25	36.85	0.37	23.83	28.53
G1T11	49.75	92.25	2.25	2.50	85.00	12.50	5.08	18.00	47.00	38.32	1.06	17.59	21.75
G1T12	53.25	94.25	2.00	2.25	80.75	12.50	4.25	17.75	45.25	39.34	0.80	19.56	23.40
G1T13	56.13	91.00	1.25	1.25	78.25	11.25	4.13	16.50	43.25	38.18	0.54	22.17	25.59
G1T14	54.25	97.75	2.50	2.25	89.00	12.00	5.08	18.25	47.75	38.23	0.94	17.33	22.91
G1T15	52.25	95.75	1.25	1.75	86.00	11.75	4.95	18.00	46.50	38.73	0.63	19.63	24.12
G1T16	52.57	89.00	1.25	1.00	77.25	11.25	4.65	17.25	45.50	37.92	0.51	21.85	25.88
G2T1	57.75	88.50	2.63	2.75	82.00	11.25	4.20	7.75	37.50	20.67	1.51	13.80	19.48
G2T2	56.25	77.25	1.25	2.25	69.25	10.50	3.63	6.50	33.00	20.00	1.17	14.74	15.69
G2T3	52.50	75.00	1.25	1.75	67.50	10.00	3.25	6.63	32.25	20.54	0.98	16.13	16.73
G2T4	49.00	73.25	1.00	1.75	62.00	9.75	3.13	6.13	30.00	20.42	1.11	18.32	17.66
G2T5	48.00	98.00	2.75	3.25	91.25	13.50	4.93	8.50	43.25	19.64	1.70	11.53	20.80
G2T6	54.75	98.75	2.75	3.00	87.00	12.75	4.93	8.50	45.25	18.79	1.88	12.71	18.11
G2T7	54.00	98.25	2.88	2.75	89.00	12.50	4.65	9.75	46.00	21.21	1.81	13.62	19.85
G2T8	51.50	93.25	2.25	2.63	84.00	12.25	3.88	7.93	39.00	20.34	1.54	15.02	21.18
G2T9	57.00	93.00	2.00	2.38	80.00	11.50	3.88	7.88	43.00	18.33	1.20	16.23	23.12
G2T10	54.38	89.25	1.75	2.25	81.00	12.00	3.63	7.65	38.25	20.00	0.79	18.34	24.33
G2T11	50.75	96.75	2.50	2.88	83.25	12.50	4.50	8.13	43.25	18.80	1.63	13.25	18.93
G2T12	48.50	95.50	2.08	2.28	79.25	12.00	4.13	8.13	39.25	20.71	1.45	14.80	20.32
G2T13	51.38	93.25	2.00	2.00	79.25	11.25	4.00	7.88	39.25	20.07	0.91	16.19	22.14
G2T14	54.38	97.25	2.00	2.38	75.00	12.00	3.50	7.88	44.00	17.92	1.40	14.00	19.84
G2T15	52.75	93.25	1.88	2.00	74.25	11.25	3.50	7.75	41.25	18.81	1.35	15.06	21.82
G2T16	54.25	91.00	1.75	2.13	72.25	11.00	3.25	7.38	39.25	18.81	0.89	17.02	23.51
G3T1	56.25	81.00	2.70	3.13	79.00	12.50	4.68	11.25	43.25	26.03	1.15	14.26	21.45

Treatments	Days to 50% flowering	Plant height (cm)	Number of primary branches per plant	Number of secondary branches per plant	Number of siliqua per plant	Number of seeds per siliqua	Length of siliqua (cm)	Seed yield (gm)	Biological yield (g)	Harvest Index (%)	Chlorophyll content	Proline	Protein
G3T2	52.50	69.00	2.00	2.25	69.00	12.25	3.98	10.63	39.25	27.11	1.15	19.74	14.26
G3T3	49.00	67.25	1.75	2.25	69.00	12.00	3.78	10.00	37.25	26.81	0.86	21.46	15.92
G3T4	48.00	65.00	1.50	2.00	65.00	12.25	3.88	9.75	37.25	26.18	0.93	15.64	17.55
G3T5	57.00	89.25	3.00	4.50	87.00	13.00	5.58	12.98	51.25	25.34	1.20	17.89	19.24
G3T6	54.75	86.50	3.05	3.75	95.00	14.00	5.23	12.25	45.25	27.25	1.59	15.14	21.15
G3T7	53.75	88.00	3.13	4.00	97.00	13.00	4.95	12.63	45.25	27.95	1.39	16.24	21.71
G3T8	51.50	87.50	2.63	4.13	83.25	12.75	5.13	12.13	44.00	27.60	1.05	18.84	24.17
G3T9	54.38	83.00	2.50	4.13	82.00	11.75	4.95	11.95	46.00	26.03	0.93	19.89	25.64
G3T10	50.75	82.25	2.38	4.00	81.00	11.25	4.65	11.80	39.00	30.28	0.71	21.37	27.35
G3T11	48.50	82.00	3.00	3.25	91.00	12.75	5.00	12.13	44.20	27.49	1.30	15.66	21.27
G3T12	52.50	80.25	2.93	3.13	89.00	12.50	4.73	12.00	43.20	27.80	1.13	17.78	23.11
G3T13	55.88	79.25	2.68	3.13	82.00	12.25	4.38	11.50	41.00	28.04	0.81	19.92	24.97
G3T14	54.25	88.00	3.00	3.88	92.25	12.50	5.00	11.50	43.25	26.58	1.14	16.67	23.04
G3T15	52.63	87.25	2.85	3.75	88.00	12.00	4.75	11.13	42.50	26.18	0.95	18.88	23.67
G3T16	52.94	86.00	2.38	3.50	87.00	11.50	4.63	10.88	41.00	26.57	0.63	20.99	25.94
G4T1	56.17	84.00	2.25	2.75	73.00	12.00	4.40	10.25	35.00	29.33	1.40	13.68	20.25
G4T2	52.50	73.00	1.25	1.25	68.20	10.50	3.70	8.38	29.00	28.87	0.90	14.40	21.51
G4T3	49.00	72.20	1.00	1.25	64.00	10.75	3.55	8.13	27.50	29.60	1.17	16.12	21.52
G4T4	48.00	71.00	1.00	1.00	64.00	10.50	3.58	7.63	25.75	29.63	1.10	14.62	21.74
G4T6	54.75	89.00	2.25	3.25	79.25	13.25	5.08	11.25	39.95	28.20	1.74	12.86	21.94
G4T7	53.75	88.25	2.50	3.50	78.75	13.00	4.83	11.75	43.00	27.36	1.68	13.61	20.47
G4T8	51.50	88.25	2.38	3.13	74.00	11.75	4.38	11.50	41.00	28.04	1.45	15.10	22.40
G4T9	54.34	85.25	2.13	2.75	73.25	12.00	4.30	11.65	39.50	29.52	1.27	16.63	23.61
G4T10	50.75	84.00	2.00	2.38	73.00	11.50	4.33	11.28	38.00	29.67	0.71	18.78	25.02
G4T11	48.50	85.00	2.13	2.75	77.00	12.00	4.18	10.88	36.50	29.83	1.58	13.40	19.36
G4T12	52.63	81.00	2.25	2.75	75.00	11.50	4.75	10.38	34.00	30.56	1.34	14.35	20.83
G4T13	56.00	80.00	1.88	2.50	71.00	11.00	4.63	10.40	33.50	31.06	0.99	16.03	23.05
G4T15	52.63	81.00	2.00	2.50	72.50	10.75	4.13	11.40	38.25	29.81	1.20	15.51	22.35
G4T16	52.92	79.25	2.00	2.13	71.00	11.50	4.00	11.00	35.75	30.78	0.86	17.17	24.25
G5T1	56.25	72.50	2.13	2.25	71.00	12.00	4.78	10.50	37.00	28.44	0.88	15.47	21.42
G5T2	52.50	68.00	1.50	1.50	65.25	10.75	4.08	7.83	30.00	26.16	1.07	23.10	14.91
G5T3	49.00	63.00	1.50	1.25	62.00	10.75	3.90	7.65	27.25	28.17	0.93	18.05	16.52
G5T4	48.00	60.00	1.25	1.50	60.25	10.75	3.70	7.13	26.00	27.40	0.88	20.14	18.08
G5T5	57.00	79.00	2.50	3.00	83.50	13.00	5.38	12.25	43.25	28.34	1.04	18.08	19.84
G5T6	54.75	77.50	2.25	2.75	80.50	12.75	5.28	12.25	40.75	30.06	1.23	16.37	21.00

Treatments	Days to 50% flowering	Plant height (cm)	Number of primary branches per plant	Number of secondary branches per plant	Number of siliqua per plant	Number of seeds per siliqua	Length of siliqua (cm)	Seed yield (gm)	Biological yield (g)	Harvest Index (%)	Chlorophyll content	Proline	Protein
G5T7	53.75	76.00	2.50	2.75	77.75	12.50	5.28	11.75	43.00	27.36	1.12	17.25	22.41
G5T8	51.50	77.50	2.25	2.25	80.50	12.25	4.63	12.00	41.00	29.29	0.77	18.99	25.22
G5T9	54.38	73.25	2.13	2.50	80.25	11.75	4.38	11.13	39.25	28.37	0.48	21.20	25.66
G5T10	50.75	72.75	1.75	2.25	79.00	11.25	4.30	11.00	36.50	30.15	0.32	23.97	27.18
G5T11	48.50	75.00	2.00	2.25	75.00	11.75	4.18	12.00	37.25	32.23	1.20	18.81	21.93
G5T12	52.50	74.00	1.75	2.00	74.25	12.25	4.00	11.88	38.25	31.05	0.79	20.09	23.76
G5T13	55.88	73.50	1.88	1.75	73.00	11.75	3.98	11.25	36.25	31.04	0.69	22.97	25.43
G5T14	54.25	75.50	2.13	2.50	76.00	11.25	4.63	11.50	37.50	30.69	0.89	17.99	23.04
G5T15	52.63	73.25	1.75	2.25	74.25	10.50	4.40	11.00	37.00	29.73	0.67	20.04	25.00
G5T16	52.94	71.00	1.50	2.00	73.50	10.25	4.10	10.75	35.00	30.76	0.52	22.36	26.47
G6T1	56.25	68.25	2.00	2.75	59.00	11.75	4.68	10.75	37.00	29.06	1.20	15.47	27.46
G6T2	52.50	63.75	1.00	1.00	55.05	11.25	3.80	7.75	29.50	26.30	0.70	17.77	21.23
G6T3	49.00	60.75	1.00	0.75	52.50	11.00	3.63	7.25	29.25	24.83	1.07	23.11	26.48
G6T4	48.00	63.25	1.00	0.75	52.00	10.50	3.55	7.25	28.25	25.66	0.77	15.50	25.80
G6T5	57.00	74.50	2.75	3.50	70.75	13.00	5.28	11.75	41.50	28.31	0.65	18.56	23.76
G6T6	54.75	75.50	2.75	3.75	73.00	13.00	5.10	11.25	41.25	27.28	0.92	20.11	23.57
G6T7	53.75	73.75	2.25	3.25	71.00	12.50	5.05	11.50	42.25	27.23	0.78	22.90	26.77
G6T8	51.50	73.00	2.50	3.25	66.50	11.75	4.75	10.75	40.00	26.88	0.96	15.12	27.52
G6T9	54.38	71.25	2.25	2.50	65.00	11.50	4.90	10.25	39.25	26.11	0.89	21.15	23.64
G6T10	50.75	69.75	1.75	2.50	63.50	10.50	4.75	10.50	38.25	27.46	0.94	18.28	24.29
G6T11	48.50	73.25	2.25	2.75	68.00	12.50	4.75	10.75	40.50	26.53	0.98	15.93	21.71
G6T12	52.50	73.75	2.00	2.50	67.00	12.00	4.63	11.00	38.75	28.39	0.91	15.30	22.39
G6T13	55.88	71.00	1.75	2.25	66.25	11.50	4.40	10.25	37.75	27.16	0.66	23.71	27.26
G6T14	54.25	72.00	1.75	2.75	69.00	11.25	5.00	10.88	37.50	28.98	0.69	22.87	26.67
G6T15	52.63	70.75	1.50	2.63	70.00	11.50	4.88	10.75	36.75	29.23	0.86	23.28	26.48
G6T16	52.94	70.00	1.50	2.25	68.00	11.00	4.63	10.13	36.25	27.93	1.03	23.01	22.57
G7T1	56.25	69.50	2.25	2.25	67.00	11.75	4.03	9.25	37.00	25.04	1.11	15.20	20.64
G7T2	52.50	58.25	1.50	1.50	56.50	11.50	3.93	7.75	31.00	25.06	0.89	23.35	27.56
G7T3	49.00	54.75	1.25	1.00	53.25	11.00	3.75	7.00	28.25	24.78	0.97	15.18	21.69
G7T4	48.00	54.25	1.00	0.75	51.25	10.75	3.70	6.75	28.00	24.17	0.69	15.96	20.50
G7T5	57.00	76.25	2.75	3.50	74.25	13.00	4.28	10.98	41.50	26.49	0.81	16.74	23.02
G7T6	54.75	77.00	2.75	3.25	74.20	13.25	4.38	11.50	41.00	28.04	0.97	15.03	20.36
G7T7	53.75	72.75	2.50	3.00	72.00	12.25	4.25	10.75	41.75	25.74	1.17	15.81	21.73
G7T8	51.50	73.50	2.63	2.75	68.00	12.00	4.08	10.25	39.75	25.87	1.12	17.40	23.82
G7T9	54.38	72.50	2.50	2.50	64.00	12.50	3.95	10.00	39.00	25.66	0.82	19.17	24.90

Treatments	Days to 50% flowering	Plant height (cm)	Number of primary branches per plant	Number of secondary branches per plant	Number of siliqua per plant	Number of seeds per siliqua	Length of siliqua (cm)	Seed yield (gm)	Biological yield (g)	Harvest Index (%)	Chlorophyll content	Proline	Protein
G7T10	50.75	74.00	2.00	2.25	62.00	11.50	3.85	9.50	37.00	25.70	1.16	21.35	26.96
G7T11	48.50	74.25	2.50	3.00	69.50	12.50	4.08	11.25	40.00	28.13	0.99	14.95	21.09
G7T12	52.50	73.25	2.25	2.50	67.00	11.75	4.00	10.75	38.25	28.11	1.12	17.72	22.37
G7T13	55.88	71.00	2.00	2.25	67.50	11.25	4.00	10.50	37.00	28.44	1.14	19.35	24.61
G7T14	54.25	70.75	2.25	2.25	68.00	11.50	4.08	11.25	39.00	28.88	0.81	16.16	22.27
G7T15	52.63	70.50	2.00	2.25	66.00	11.75	3.83	10.75	37.00	29.02	0.88	18.53	22.98
G7T16	52.94	68.75	1.75	2.00	64.00	11.00	3.70	10.50	37.00	28.41	0.81	20.28	24.95
G8T1	57.75	68.50	2.25	2.75	70.50	11.50	4.05	9.75	32.00	30.54	1.14	17.50	24.11
G8T2	56.25	57.50	1.25	1.00	56.00	11.00	3.65	8.25	27.00	30.63	1.14	17.38	24.76
G8T3	52.50	55.25	1.00	0.75	55.00	10.75	3.55	7.40	25.25	29.36	0.98	15.48	24.49
G8T4	49.00	53.25	1.00	0.75	54.00	11.00	3.30	7.35	24.25	30.52	0.75	18.19	22.93
G8T5	48.00	72.75	2.75	3.50	77.25	12.25	4.63	11.75	39.00	30.13	1.19	16.34	23.04
G8T6	54.75	75.00	2.50	3.25	76.00	12.25	4.43	12.50	37.25	33.55	0.83	19.70	22.73
G8T7	53.75	71.75	2.50	3.50	78.00	12.00	4.50	11.50	37.25	30.86	0.82	19.75	25.87
G8T8	51.50	69.50	2.25	3.25	73.00	12.25	4.38	10.75	36.00	29.87	0.94	17.86	26.82
G8T9	57.00	70.00	2.25	2.75	72.00	12.00	4.10	10.50	33.00	31.80	1.12	15.93	24.31
G8T10	54.38	67.00	2.00	2.50	71.00	11.75	3.73	10.00	32.00	31.37	1.05	17.97	23.25
G8T11	50.75	73.25	2.00	3.00	70.00	12.00	4.13	11.75	35.25	33.40	0.82	21.47	27.08
G8T12	48.50	73.00	2.00	2.75	69.00	11.75	3.98	11.50	34.25	33.62	0.82	23.02	20.67
G8T13	51.38	71.00	1.75	2.63	69.00	11.00	3.85	10.50	32.50	32.29	1.06	19.17	23.25
G8T14	54.25	67.50	2.00	2.75	76.00	12.00	4.20	9.63	35.50	27.11	0.73	17.77	27.35
G8T15	52.63	66.00	1.75	2.75	75.00	12.00	4.10	9.50	33.75	28.15	0.90	22.29	26.53
G8T16	54.25	65.00	1.50	2.25	72.00	11.25	3.98	9.25	32.00	28.91	1.02	21.89	25.11
G9T1	56.00	67.50	2.00	2.50	67.00	12.50	4.70	9.75	30.75	31.66	0.66	15.41	20.64
G9T2	52.50	59.75	0.75	1.00	59.00	11.75	4.15	7.78	26.25	29.62	0.73	16.63	25.45
G9T3	49.00	58.00	1.00	1.00	57.00	11.50	4.00	7.24	22.50	32.15	0.99	22.14	21.68
G9T4	48.00	54.00	0.75	0.75	54.75	11.25	3.95	7.05	23.25	30.42	0.74	16.30	23.75
G9T5	57.75	78.25	2.75	3.25	80.50	12.75	5.05	11.75	38.25	30.77	1.13	18.41	25.85
G9T6	54.75	80.00	2.50	3.25	84.25	13.50	5.05	11.25	35.50	31.67	0.70	22.46	26.16
G9T7	53.75	78.00	2.75	3.00	80.00	13.25	5.05	10.75	36.00	29.83	0.96	17.76	23.09
G9T8	51.50	76.25	2.25	2.75	80.00	11.50	4.75	10.75	36.25	29.69	0.76	17.86	25.56
G9T9	54.25	74.00	2.50	3.00	78.00	12.25	4.73	10.75	34.75	31.06	0.83	22.37	24.51
G9T10	50.75	72.50	2.25	2.25	76.00	11.50	4.60	10.25	32.75	31.33	0.83	16.72	21.47
G9T11	48.50	78.00	2.25	2.50	82.00	12.00	4.88	11.50	34.75	33.11	1.20	16.20	23.84
G9T12	52.88	76.25	2.00	2.50	79.00	12.25	4.80	11.25	33.25	33.83	0.79	15.92	26.69

Treatments	Days to 50% flowering	Plant height (cm)	Number of primary branches per plant	Number of secondary branches per plant	Number of siliqua per plant	Number of seeds per siliqua	Length of siliqua (cm)	Seed yield (gm)	Biological yield (g)	Harvest Index (%)	Chlorophyll content	Proline	Protein
G9T13	56.25	72.00	1.75	2.25	74.00	11.50	4.63	10.75	34.50	31.16	1.11	20.21	25.35
G9T14	54.25	76.25	1.75	2.75	78.00	12.00	4.95	10.50	32.50	32.34	0.92	16.99	28.09
G9T15	52.63	74.00	1.50	2.50	75.00	11.50	5.00	10.50	33.25	31.63	0.94	15.51	23.47
G9T16	52.88	73.75	1.50	2.25	74.00	12.25	4.65	10.25	29.75	34.46	0.70	16.18	23.31
G10T1	56.25	83.50	2.25	3.00	68.00	12.00	4.98	11.00	40.00	27.64	0.77	18.05	27.66
G10T2	52.50	66.00	1.00	1.75	42.25	11.75	3.93	7.68	35.75	21.47	1.01	19.15	24.25
G10T3	49.00	64.00	1.00	1.50	36.50	11.50	3.80	7.00	33.25	21.07	1.16	21.02	22.00
G10T4	48.00	63.25	1.00	1.25	33.25	11.00	3.78	7.10	32.25	22.09	1.05	19.43	27.58
G10T5	57.75	95.50	2.75	4.25	74.75	13.25	5.50	12.83	54.25	23.65	0.68	17.02	27.92
G10T6	54.75	92.50	3.00	4.25	80.75	13.25	5.40	12.03	51.25	23.49	0.98	15.92	23.13
G10T7	53.75	96.50	2.75	4.75	85.00	12.75	4.93	12.00	48.78	24.63	1.20	21.12	26.74
G10T8	51.50	87.75	2.50	3.75	66.75	12.75	5.38	11.90	45.38	26.23	0.83	16.49	25.13
G10T9	54.38	86.50	2.25	3.50	64.00	12.00	4.95	11.95	45.25	26.42	0.77	18.48	20.70
G10T10	50.75	86.00	2.00	2.75	60.00	12.50	4.38	11.65	43.25	26.95	1.04	19.87	20.80
G10T11	48.50	94.00	2.75	3.50	74.25	13.00	4.98	11.00	44.25	24.85	0.87	16.84	26.65
G10T12	52.88	90.50	2.50	3.50	69.75	12.75	4.75	11.15	43.36	25.62	0.78	17.14	23.30
G10T13	56.25	90.50	2.25	3.00	69.00	11.50	4.38	11.75	47.00	25.00	1.11	21.29	22.51
G10T14	54.25	84.25	2.25	4.25	72.50	12.25	4.75	11.75	43.25	27.19	1.02	21.55	23.75
G10T15	52.63	85.00	2.25	3.75	70.25	12.25	4.40	11.75	43.25	27.21	0.66	23.01	20.82
G10T16	52.94	80.75	2.00	3.50	67.25	10.50	4.12	10.75	41.75	25.72	0.80	15.78	23.27
G11T1	56.25	86.00	2.00	2.75	67.00	12.00	4.20	7.19	33.00	21.79	0.97	18.43	24.45
G11T2	52.50	64.00	1.00	1.00	59.00	11.50	3.63	6.90	28.50	24.27	0.96	19.21	20.91
G11T3	49.00	59.00	1.00	1.00	53.00	11.50	3.63	6.65	25.50	26.10	0.74	20.61	26.65
G11T4	48.00	57.00	1.00	0.75	51.00	11.50	3.50	6.57	25.00	26.26	1.17	16.68	26.82
G11T5	57.00	88.00	2.75	4.00	71.00	14.50	5.15	8.05	40.00	20.16	0.78	16.64	21.38
G11T6	54.75	94.00	3.00	4.50	79.00	15.00	5.10	10.75	43.00	25.00	1.08	20.83	27.73
G11T7	53.75	95.50	3.25	4.75	84.00	13.00	5.30	9.65	39.50	24.43	0.90	15.71	21.08
G11T8	51.50	84.00	2.50	3.25	69.00	13.25	4.55	7.57	36.00	21.04	1.10	21.82	24.78
G11T9	54.38	80.50	2.25	2.75	69.00	12.50	4.25	7.74	35.00	22.10	0.85	18.14	27.39
G11T10	50.75	77.00	1.75	2.25	67.00	12.50	4.20	7.40	32.50	22.78	0.67	19.24	21.81
G11T11	48.50	87.50	2.50	3.25	74.00	13.50	4.50	8.53	39.00	21.86	1.06	18.97	24.24
G11T12	52.50	81.50	2.25	2.50	71.50	13.25	4.65	7.85	36.00	21.82	0.87	21.90	26.02
G11T13	55.88	67.00	2.00	2.25	70.50	12.50	4.35	7.28	32.00	22.77	0.76	20.06	23.96
G11T14	54.25	86.00	2.50	3.50	81.00	13.50	4.75	7.25	34.00	21.34	1.05	16.50	22.82
G11T15	52.63	85.00	2.00	3.25	80.00	12.00	4.70	7.10	29.50	24.08	0.92	15.81	22.40

Treatments	Days to 50% flowering	Plant height (cm)	Number of primary branches per plant	Number of secondary branches per plant	Number of siliqua per plant	Number of seeds per siliqua	Length of siliqua (cm)	Seed yield (gm)	Biological yield (g)	Harvest Index (%)	Chlorophyll content	Proline	Protein
G11T16	52.94	79.50	2.00	2.50	69.00	12.00	4.25	7.04	29.50	23.90	0.78	22.06	20.51
G12T1	56.25	70.50	2.25	2.75	85.00	12.25	4.35	10.13	35.25	28.72	1.08	17.87	27.71
G12T2	52.50	63.00	1.00	1.75	66.50	10.50	3.80	8.20	29.50	27.83	0.82	23.01	28.04
G12T3	49.00	64.00	1.00	1.50	64.00	10.50	3.90	7.85	28.00	28.05	0.85	18.86	24.81
G12T4	48.00	54.00	1.00	1.50	61.00	10.50	3.40	7.58	26.00	29.13	1.11	14.94	21.19
G12T5	57.00	90.50	2.75	4.25	94.00	12.75	5.25	11.88	40.00	29.70	0.74	15.31	26.34
G12T6	54.75	85.50	2.75	4.50	100.00	13.25	5.65	12.25	42.50	28.84	1.01	21.41	26.71
G12T7	53.75	87.50	3.00	4.75	95.00	13.00	5.35	11.33	38.00	29.82	0.79	23.75	22.16
G12T8	51.50	82.50	2.25	2.75	89.50	12.25	4.63	11.35	39.25	28.92	0.68	18.07	23.92
G12T9	54.38	77.00	2.00	2.50	87.50	12.00	4.50	10.98	37.75	29.08	0.99	18.36	22.79
G12T10	50.75	75.50	1.75	2.50	86.50	11.50	4.35	10.88	35.50	30.65	0.79	22.19	22.68
G12T11	48.50	83.50	2.50	3.25	93.50	12.75	5.28	11.35	36.50	31.11	1.13	20.96	26.63
G12T12	52.50	82.50	2.25	3.00	86.50	12.75	5.00	10.63	34.00	31.25	1.14	20.70	27.65
G12T13	55.88	77.00	1.75	2.75	84.00	12.25	4.63	10.45	33.75	30.96	0.92	21.58	20.73
G12T14	54.25	82.50	2.75	3.50	86.50	13.50	5.38	11.20	39.00	28.72	0.91	19.40	27.15
G12T15	52.63	80.00	2.25	3.25	84.00	13.00	5.00	11.33	37.75	30.00	0.80	19.28	27.13
G12T16	52.94	80.00	1.75	2.75	82.50	12.50	4.50	11.33	36.50	31.03	0.92	21.70	23.46
G13T1	57.00	70.50	1.75	2.75	61.00	12.25	4.13	10.08	32.50	31.06	0.70	23.70	24.09
G13T2	56.25	58.50	1.00	1.50	46.50	10.50	3.88	8.20	27.50	29.84	0.66	22.48	22.14
G13T3	52.50	56.00	1.00	1.25	43.00	11.00	3.65	7.46	25.25	29.60	1.08	21.58	22.88
G13T4	49.00	51.00	1.00	1.00	39.00	11.25	3.13	7.20	23.58	30.55	1.15	18.36	21.66
G13T5	48.00	76.50	2.75	3.75	69.00	14.75	5.30	11.95	39.00	30.65	0.76	15.45	20.89
G13T6	54.75	80.50	2.50	3.50	72.50	13.50	5.13	12.28	39.25	31.28	0.75	23.73	19.89
G13T7	53.75	80.50	2.75	4.00	70.00	14.50	5.10	11.58	38.00	30.45	0.96	18.28	23.35
G13T8	51.50	69.50	2.25	2.75	65.00	12.25	5.13	11.70	37.50	31.21	1.11	21.38	21.53
G13T9	56.63	68.00	1.75	2.75	59.50	12.00	4.63	10.20	33.25	30.69	1.17	21.15	21.17
G13T10	54.38	66.00	1.50	2.50	55.00	11.75	4.25	10.48	31.50	32.33	1.20	22.28	21.14
G13T11	50.75	71.00	2.25	3.13	67.00	12.50	4.85	11.10	35.00	31.73	1.07	21.53	25.47
G13T12	48.50	70.50	2.00	2.88	59.00	12.75	4.38	10.85	34.50	31.47	0.69	18.21	20.33
G13T13	51.38	70.00	1.75	2.25	54.00	11.50	4.50	10.48	33.00	31.75	1.16	19.76	20.59
G13T14	54.25	71.00	2.50	3.38	64.00	12.00	4.98	10.13	32.00	31.66	0.80	22.66	27.90
G13T15	52.63	69.50	2.25	3.25	62.00	12.50	5.10	11.75	34.50	34.03	1.01	15.18	27.19
G13T16	54.07	66.00	2.00	2.25	59.00	11.75	4.50	10.33	32.00	32.27	1.12	17.41	24.21
G14T1	56.25	70.50	1.75	3.25	68.50	12.50	4.25	10.35	34.83	29.72	0.82	16.57	23.85
G14T2	52.50	59.50	1.00	1.75	51.50	11.50	3.60	8.55	29.25	29.22	1.09	21.29	24.43

Treatments	Days to 50% flowering	Plant height (cm)	Number of primary branches per plant	Number of secondary branches per plant	Number of siliqua per plant	Number of seeds per siliqua	Length of siliqua (cm)	Seed yield (gm)	Biological yield (g)	Harvest Index (%)	Chlorophyll content	Proline	Protein
G14T3	49.00	58.50	1.00	1.50	48.50	12.00	3.48	8.05	28.75	28.04	1.07	17.07	24.54
G14T4	48.00	56.50	1.00	1.50	48.00	11.50	3.38	7.44	25.83	28.80	1.21	15.45	26.82
G14T5	57.75	84.50	2.75	4.25	73.50	15.50	4.95	11.35	39.25	28.92	1.14	21.28	24.62
G14T6	54.75	79.00	2.50	4.50	76.50	14.50	5.25	11.85	42.00	28.23	0.84	18.41	28.13
G14T7	53.75	77.50	2.75	4.50	81.50	14.50	5.05	11.65	40.23	28.98	1.12	18.17	25.89
G14T8	51.50	80.50	2.00	3.13	67.50	12.50	4.55	11.50	38.50	29.84	1.18	21.63	21.05
G14T9	54.38	71.00	1.50	3.13	67.50	13.00	4.70	11.20	37.08	30.21	0.91	19.14	27.39
G14T10	50.75	73.00	1.50	2.50	59.50	12.50	4.38	9.98	34.08	29.30	1.13	19.54	20.15
G14T11	48.50	73.50	2.25	3.00	70.50	12.50	4.88	11.33	41.33	27.42	1.15	23.85	26.36
G14T12	52.88	72.00	1.75	3.00	67.00	12.00	4.75	10.88	37.05	29.37	1.06	17.32	25.67
G14T13	56.25	70.00	1.75	2.88	65.00	11.50	4.38	10.35	34.08	30.43	1.02	15.68	22.84
G14T14	54.25	73.50	2.50	3.88	70.50	13.25	4.38	9.88	36.08	27.39	0.91	20.78	25.89
G14T15	52.63	73.00	2.25	3.25	70.00	12.50	4.13	9.75	33.50	29.15	1.12	18.88	26.66
G14T16	52.94	70.00	1.75	2.75	64.00	12.25	3.95	9.28	32.25	28.78	1.10	18.57	25.24
G15T1	56.25	86.50	1.75	3.50	69.00	12.50	4.40	16.55	48.25	34.31	1.06	23.11	23.52
G15T2	52.50	66.50	1.00	2.25	57.50	11.50	3.93	9.05	37.88	23.90	0.72	20.46	23.54
G15T3	49.00	66.00	1.00	2.25	55.00	11.00	4.05	8.40	35.75	23.50	0.90	22.85	25.28
G15T4	48.00	62.50	1.00	2.00	51.00	10.00	3.50	8.25	33.25	24.83	0.97	21.86	25.29
G15T5	57.00	99.50	2.75	4.75	95.00	13.50	5.38	19.05	52.25	36.46	0.82	19.95	26.06
G15T6	54.75	90.00	2.50	4.63	90.00	12.50	5.08	18.70	50.25	37.22	0.76	21.18	21.37
G15T7	53.75	94.00	2.75	4.88	88.50	14.50	5.10	19.08	52.38	36.42	0.73	21.18	26.94
G15T8	51.50	85.00	2.00	3.88	71.00	12.50	4.66	18.35	49.75	36.89	0.89	15.54	26.24
G15T9	54.38	80.50	2.00	3.25	70.00	13.00	4.45	18.05	48.75	37.03	0.72	21.77	22.43
G15T10	50.75	79.50	1.75	2.75	68.00	12.50	4.25	17.65	48.28	36.57	0.76	21.42	23.21
G15T11	48.50	84.00	2.25	3.13	76.50	12.50	4.85	17.45	47.00	37.13	0.90	19.97	24.65
G15T12	52.50	82.50	2.25	2.75	72.50	12.75	4.75	17.23	45.50	37.86	0.67	18.71	25.18
G15T13	55.88	79.50	1.75	2.25	69.50	12.50	5.15	17.08	42.83	39.88	1.05	18.02	21.45
G15T14	54.25	79.00	2.00	3.00	73.50	12.50	4.50	18.20	47.75	38.12	0.87	15.15	20.28
G15T15	52.63	76.50	1.75	2.75	68.50	12.00	4.50	18.03	45.33	39.77	1.06	16.85	20.50
G15T16	52.94	74.00	1.50	2.25	70.50	11.50	4.13	17.85	44.85	39.81	0.86	15.36	21.65
S.Em ±	**1.39**	**1.38**	**0.21**	**0.27**	**1.36**	**0.54**	**0.16**	**0.33**	**1.04**	**1.06**	**0.02**	**0.29**	**0.38**
C.D. 5%	**3.87**	**3.85**	**0.58**	**0.76**	**3.80**	**1.49**	**0.44**	**0.93**	**2.91**	**2.94**	**0.05**	**0.82**	**1.07**
G1	53.07	91.00	1.94	1.86	82.49	11.71	4.69	15.75	45.36	34.14	0.90	20.34	23.27
G2	52.95	90.72	2.05	2.40	78.52	11.63	3.94	7.77	39.61	19.69	1.33	15.05	20.22
G3	52.79	81.35	2.60	3.43	83.54	12.40	4.71	11.53	42.69	27.08	1.06	18.15	21.90

Treatments	Days to 50% flowering	Plant height (cm)	Number of primary branches per plant	Number of secondary branches per plant	Number of siliqua per plant	Number of seeds per siliqua	Length of siliqua (cm)	Seed yield (gm)	Biological yield (g)	Harvest Index (%)	Chlorophyll content	Proline	Protein
G4	52.81	82.35	2.00	2.49	72.88	11.66	4.36	10.60	36.36	29.25	1.27	15.11	21.92
G5	52.79	72.61	1.93	2.18	74.13	11.60	4.44	10.75	36.58	29.33	0.84	19.68	22.37
G6	52.79	70.29	1.88	2.45	64.79	11.66	4.61	10.18	37.13	27.34	0.88	19.51	24.85
G7	52.79	69.46	2.12	2.32	65.28	11.83	4.00	9.92	37.04	26.72	0.97	17.64	23.09
G8	52.92	67.27	1.93	2.51	69.61	11.68	4.04	10.12	32.90	30.76	0.96	18.86	24.52
G9	52.86	71.79	1.90	2.35	73.66	12.08	4.69	10.13	32.15	31.55	0.88	17.94	24.31
G10	52.88	84.16	2.16	3.27	64.65	12.19	4.65	10.83	43.27	24.95	0.92	18.89	24.14
G11	52.79	79.47	2.11	2.77	69.69	12.75	4.42	7.72	33.63	23.11	0.92	18.92	23.94
G12	52.79	77.22	2.07	2.96	84.13	12.21	4.69	10.55	35.58	29.62	0.92	19.84	24.95
G13	52.84	68.44	1.94	2.68	59.10	12.30	4.54	10.36	33.02	31.29	0.96	20.20	22.78
G14	52.88	71.41	1.88	3.05	65.60	12.75	4.38	10.21	35.26	28.99	1.06	18.98	24.97
G15	52.79	80.35	1.88	3.15	71.63	12.33	4.55	16.19	45.63	34.98	0.86	19.59	23.60
S.Em ±	**0.35**	**0.35**	**0.05**	**0.07**	**0.34**	**0.13**	**0.04**	**0.08**	**0.26**	**0.26**	**0.00**	**0.07**	**0.10**
C.D. 5%	**0.97**	**0.96**	**0.15**	**0.19**	**0.95**	**0.37**	**0.11**	**0.23**	**0.73**	**0.74**	**0.01**	**0.20**	**0.27**
T1	56.48	77.45	2.17	2.76	71.87	12.05	4.46	10.67	37.48	28.39	1.03	16.92	23.17
T2	53.25	65.44	1.22	1.54	59.50	11.15	3.87	8.13	31.45	26.17	0.93	19.81	21.94
T3	49.80	63.30	1.14	1.34	56.57	11.05	3.71	7.60	29.49	26.18	1.01	19.67	22.12
T4	48.27	60.92	1.04	1.17	54.17	10.82	3.54	7.35	28.13	26.48	0.99	18.02	22.58
T5	55.40	86.44	2.74	3.72	81.11	13.42	5.18	12.46	43.94	28.26	1.01	17.07	23.21
T6	54.75	85.24	2.64	3.68	82.88	13.27	5.08	12.43	42.92	29.00	1.11	18.12	22.83
T7	53.77	85.17	2.75	3.80	83.10	13.07	4.99	12.36	42.91	28.67	1.11	18.15	23.33
T8	51.45	81.47	2.33	3.05	74.94	12.29	4.65	11.73	40.83	28.50	1.02	17.97	24.27
T9	54.87	78.45	2.14	2.81	72.67	12.10	4.50	11.44	39.93	28.56	0.90	19.33	24.26
T10	51.53	77.24	1.85	2.45	70.45	11.72	4.28	11.09	37.41	29.43	0.83	20.34	23.88
T11	49.04	81.55	2.36	2.95	77.10	12.49	4.68	11.81	40.12	29.46	1.13	17.96	23.40
T12	51.84	80.05	2.15	2.69	73.77	12.32	4.51	11.55	38.33	30.06	0.96	18.17	23.45
T13	55.08	77.07	1.88	2.36	71.49	11.64	4.36	11.13	37.18	29.88	0.93	19.74	23.58
T14	54.26	80.29	2.29	3.05	76.22	12.17	4.63	11.41	39.28	28.92	0.96	18.03	24.11
T15	52.61	78.72	1.95	2.80	74.39	11.82	4.49	11.37	38.01	29.70	0.93	18.52	24.07
T16	53.16	76.27	1.75	2.37	71.42	11.44	4.21	10.93	36.56	29.74	0.84	19.44	24.02
S.Em ±	0.36	0.36	0.05	0.07	0.35	0.14	0.04	0.09	0.27	0.27	0.00	0.08	0.10
C.D. 5%	1.00	0.99	0.15	0.20	0.98	0.39	0.11	0.24	0.75	0.76	0.01	0.21	0.28
C.V. %	3.72	2.54	14.64	14.51	2.68	6.29	4.98	4.36	3.91	5.23	2.39	2.24	2.33

Fig. 2. Seed yield in various genotype after treatment application

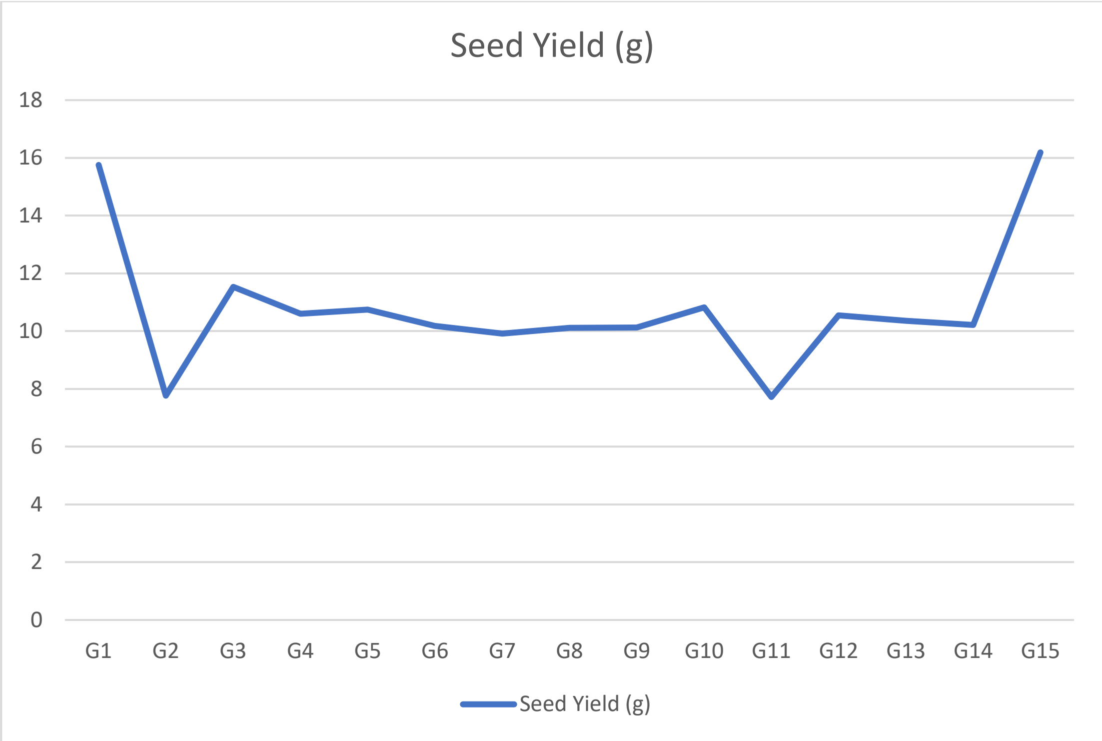

Fig. 3. Seed yield on the basis of genotypes

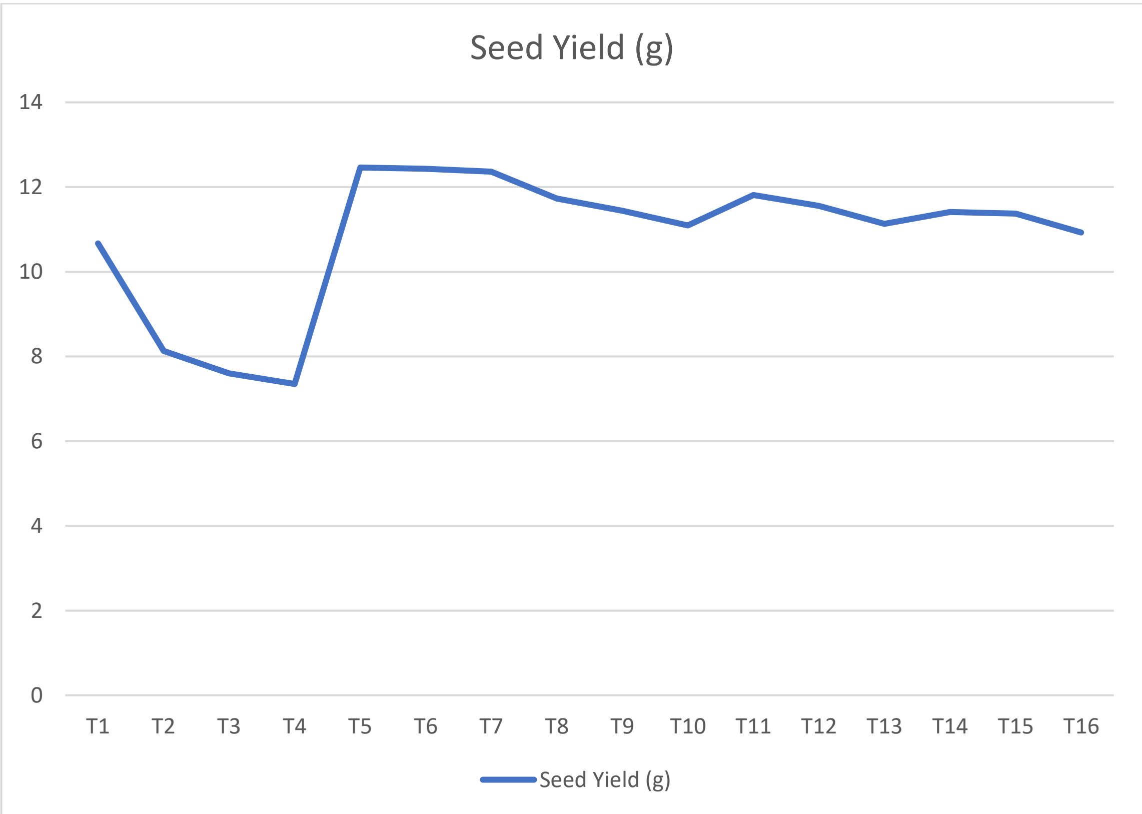

Fig. 4. Seed yield on the basis of treatments

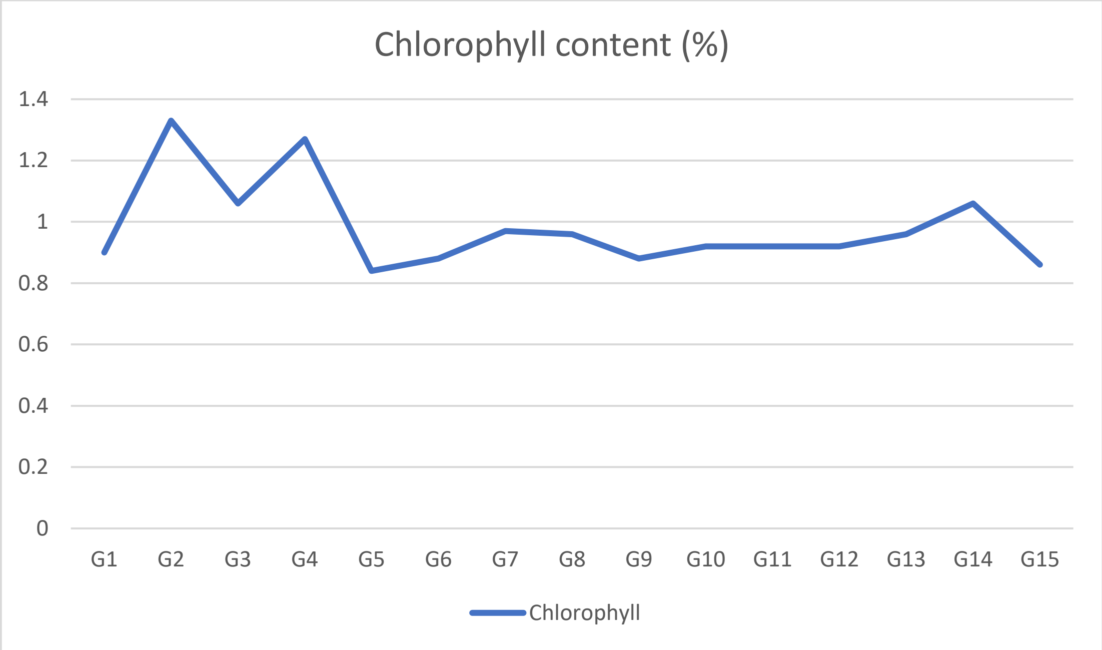

Fig. 5. chlorophyll content on the basis of genotypes

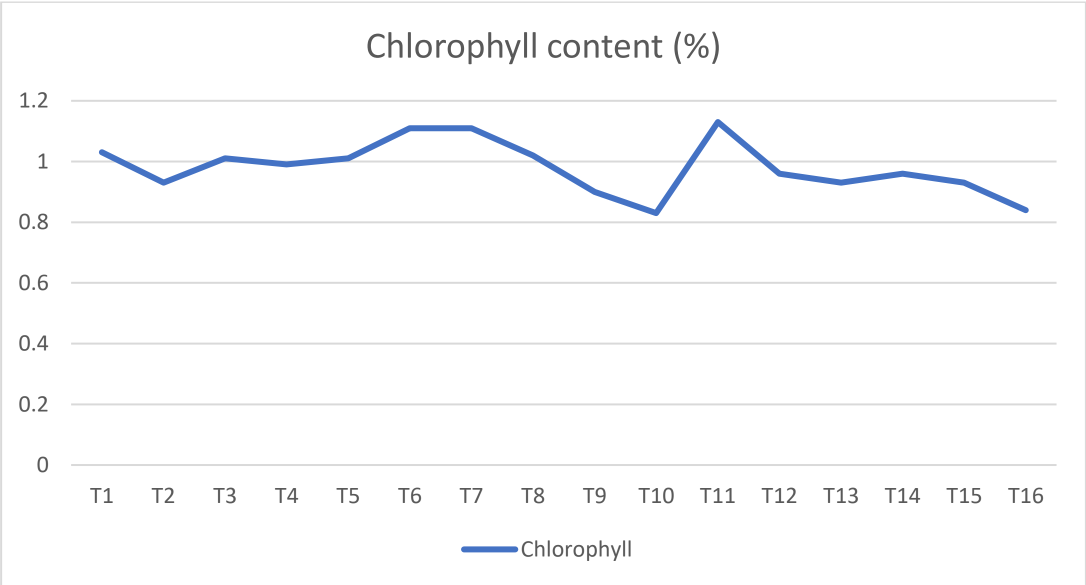

Fig. 6. chlorophyll content on the basis of treatments

3.2.2 Proline content (%)

Among the treatments, S1+PGPR-3 (20.34 %) showed significantly highest proline content followed Control+S1 (19.81 %) and S2+PGPR-3 (19.74 %). While, PGPR-1 (17.07 %), S2+PGPR-1 (17.96 %) were recorded lowest proline content. The proline content was significantly highest in RH- 761 (20.34 %) followed by P-2-RH-406 (20.20 %) and PUSA VIJAY (19.84 %) whereas, P4-CS-54 (15.05 %) and P6-PBR-297 (15.11 %) recorded lowest proline content among the selected genotypes. Among the genotypes and treatment interaction, the genotype RH-761 with Control+S3 (28.87 %) with Control+S2 (25.39 %) and with Control+S1 (24.39 %) showed significantly highest proline content, whereas, lowest proline content was noticed in P4-CS-54 with PGPR-1 (11.53 %) and PGPR-2 (12.71 %).

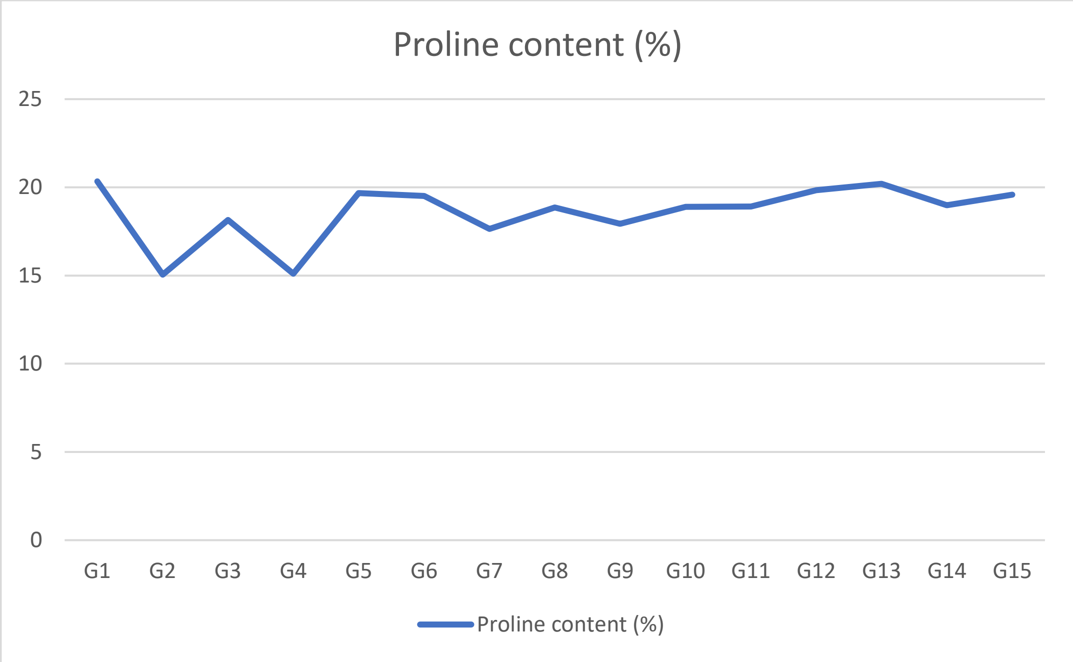

Fig. 7. Proline content on the basis of genotypes

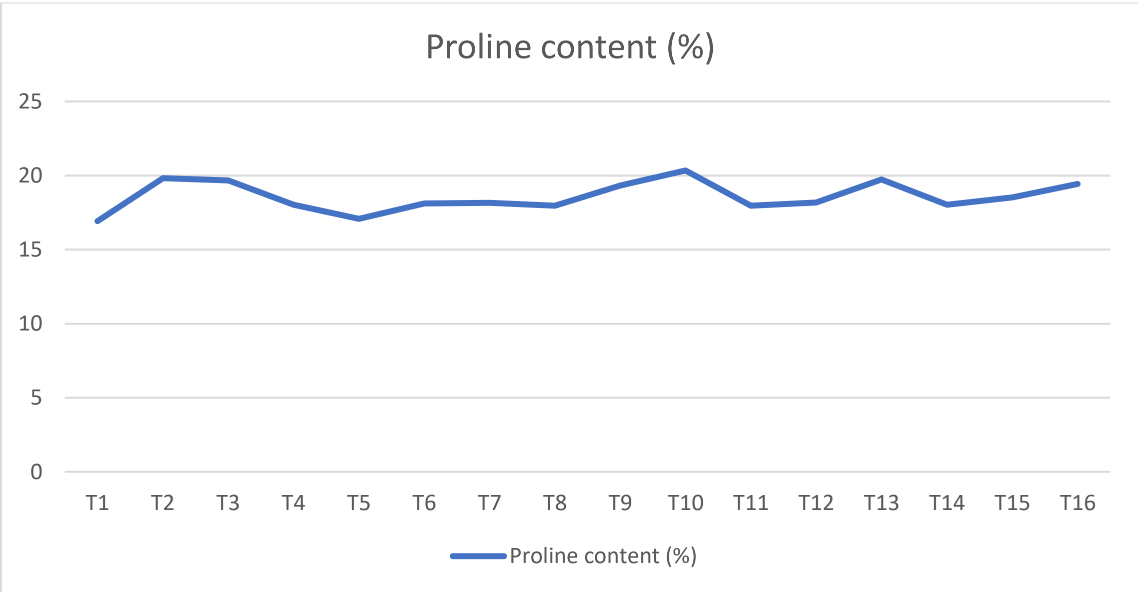

Fig. 8. Proline content on the basis of treatments

3.2.3 Protein (%)

Among the treatments, S1+PGPR-1 (24.27 %) showed significantly highest protein content followed by S1+PGPR-2 (24.26 %) and S3+PGPR-1 (24.11 %). While, Control+S1 (21.94 %) and Control+S2 (22.12 %) were recorded lowest protein content. The protein content was significantly highest in P-4-PATAN MUSTRAD-67 (24.97 %) followed by PUSA VIJAY (24.95 %) and P28-Roshini (24.85 %) whereas, P4-CS-54 (20.22 %) and P21- KANTI (21.90 %) recorded lowest protein content among the selected genotypes. Among the genotypes and 61 treatment interaction, the genotype RH-761 with S1+PGPR-3 (28.53 %) and P-4- PATAN MUSTRAD-67 with PGPR-2 (28.13 %) showed significantly highest protein content, whereas, lowest protein content were noticed in P21-KANTI (14.26 %) P20-Krishna (14.91 %) with Control+S1.

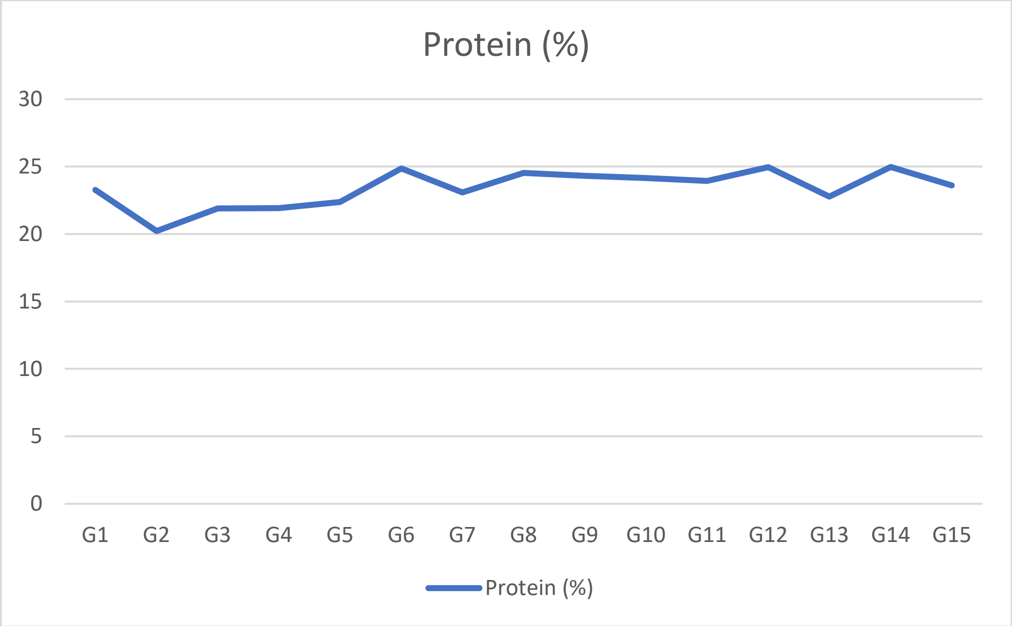

Fig. 9. Protein (%) on the basis of genotypes

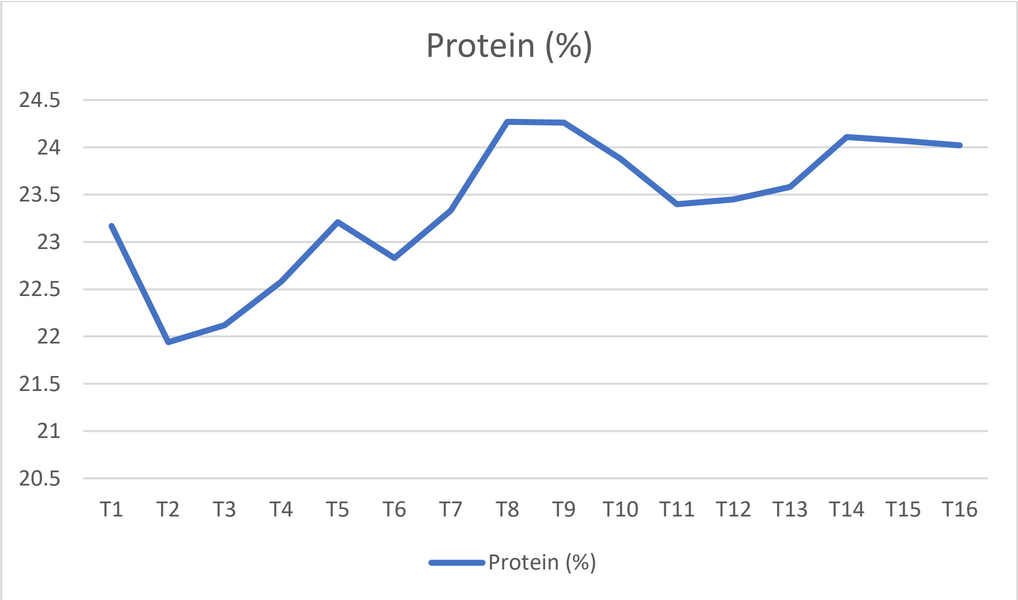

Fig. 10. Protein (%) on the basis of treatments

3.3 Genetic Parameters

A fundamental requirement of every crop improvement program is the presence of sufficient genetic variety. To guarantee appropriate genotype selection, it is essential to consider the heritability and genetic progression of genotypes. The degree of genetic variability within the population under study is measured by the genotypic coefficient of variation (GCV) and the phenotypic coefficient of variation (PCV). The percentage of variability that can be inherited is represented by heritability (h2). Estimating genetic gain (GAM) also aids in forecasting the beneficial gains that can be attained by selection. PCV values typically exceed GCV values, suggesting that environmental variables as well as genotypes contribute to variation. The GCV and PCV were categorized as low (less than 10%), moderate (10-20%) and high (more than 20%) [17]. Analysis of the genetic parameters in mustard genotypes- GCV, PCV, h 2 (Broad Sense), GA and GAM.

a. Coefficient of variation

Genotypic and phenotypic coefficients of variation were computed based on the estimate of genotypic and phenotypic variances as follows.

GCV = √GV x̅ x100
PCV = √PV x̅ x100

(Where, GCV = Genotypic coefficient of variation; PCV = Phenotypic coefficient of variation; GV = Genotypic variance; PV = Phenotypic variance; X = General mean of character).

List 1. The PCV and GCV were classified [18]

0-10%	Low
10 – 20%	Moderate
More than 20%	High

b. Heritability

Heritability in broad sense refers to the proportion of genetic variance to the total observed variance in the population. It has been estimated as per the formula given by Lush (1940).

h 2 (broad sense) = Genotypic variance (σ 2 g)

Phenotypic variance (σ 2 p) x100

(Where, σ 2 g and σ 2 p are the genotypic and phenotypic variances).

List 2. the range of heritability in broad sense was classified [19]

Less than 30%	Low
30 – 60%	Moderate
More than 60%	High

c. Genetic Advance (GA)

The expected genetic gain or advance for each character was estimated by using the following method [19]

GA = k x

(Where σ 2g = Genotypic variance σ 2p = Phenotypic variance k = Selection differential at 5 per cent selection intensity i.e. 2.06).

d. Genetic Advance as per cent Mean (GAM)

Genetic advance as per cent mean was worked out for each character adopting the formula [19].

GAM = GA x 100 X

(Where, GA = Genetic advance X = General mean).

List 3. The range of genetic advance as per cent of mean was classified

Less than 10%	Low
10 – 20%	Moderate
More than 20%	High

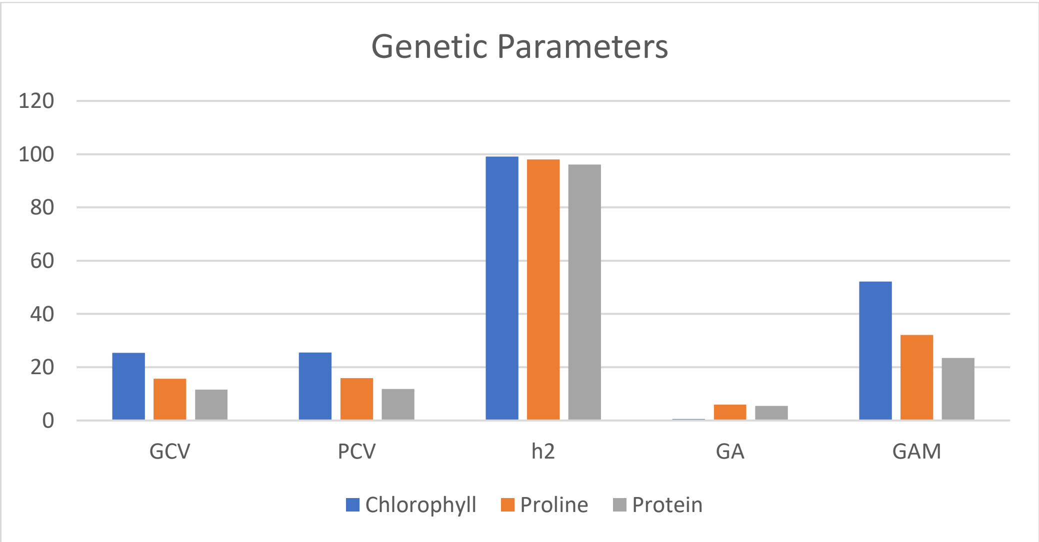

Fig. 11. Comparison among all the genetic parameters

Table 7. List of genetic parameters under consideration

	GCV	PCV	h2 (Broad Sense)	GA	GAM
Chlorophyll content	25.44	25.55	99.10	0.51	52.17
Proline	15.72	15.88	98.00	5.96	32.07
Protein	11.62	11.85	96.10	5.49	23.47

4. CONCLUSION

This study analysed the chlorophyll content, proline content, and protein content of various genotypes and treatments. Among the treatments, the highest chlorophyll content was observed in S2+PGPR-1, PGPR-2 and PGPR-3, however, S1+PGPR-3 and S3+PGPR-3 were recorded lowest chlorophyll content. The chlorophyll content was significantly highest in P4-CS-54 P6- PBR-297, P-4-PATAN MUSTRAD-67 and P21- KANTI, whereas, P20 - Krishna and RLM-619 recorded lowest chlorophyll content among the selected genotypes. Among the genotypes and treatment interaction, the genotype P4- CS-54 and P6-PBR-297 with PGPR-2 and P4-CS-54 with PGPR-3 showed significantly highest chlorophyll content, whereas, lowest chlorophyll content was noticed in P20-Krishna and RH-761 with S1+PGPR-3. The study also reported that S1+PGPR-3, Control+S1 and S2+PGPR-3 had the highest proline content, whereas the lowest proline content was recorded in PGPR-1 and S2+PGPR-1. The highest proline content was found in RH-761, P-2-RH-406 and PUSA VIJAY. The highest proline content was observed in RH-761 with Control+S3 and Control+S1. Among the treatments, S1+PGPR-1, S1+PGPR-2 and S3+PGPR-1 showed significantly highest protein content. While, Control+S1 and Control+S2 were recorded lowest protein content. The protein content was significantly highest in P-4-PATAN MUSTRAD- 67, PUSA VIJAY (24.95 %) and P28-Roshini (24.85 %) whereas, P4-CS-54 and P21-KANTI recorded lowest protein content among the selected genotypes. Among the genotypes and treatment interaction, the genotype RH-761 with S1+PGPR-3 and P-4-PATAN MUSTRAD-67 with PGPR-2 showed significantly highest protein content, whereas, lowest protein content was noticed in P21-KANTI P20-Krishna with Control+S1. According to variability studies of the present investigation, PCV was higher than the GCV, high PCV and GCV estimates in traits like chlorophyll content, moderate, proline and protein. The study found high estimates of heritability in traits such as chlorophyll content, proline, and protein. The low estimates of genetic advancement were recorded in proline, protein and chlorophyll content. Hence, RLM-619, RH-761, and P21-KANTI genotypes with PGPR-1, PGPR-2, and PGPR-3 treatments are most effective for increasing seed yield per plant, using strategies like plant breeding, genetic engineering, and seed biopriming for improving the tolerance against the salinity. The study demonstrated that the biological priming remarkably enhanced physiological and biochemical responses to salinity stress of Indian mustard (*Brassica juncea*) through a complicated mechanism. The involvement of beneficial microorganisms and bioactive compounds in the biological priming of seeds enhances advance defense systems in plants. This enzymatic activation decreases the oxidative stress and restores the intracellular equilibrium arising from saline stress. Altogether, these physiological and biochemical changes revealed the level of salinity stress tolerance in Brassica juncea after biological priming, and suggested that the biological priming could be a feasible, effective and environment friendly biotechnological management intervention for enhancing the productivity of crops under salt affected field conditions.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

I, Ajay, hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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