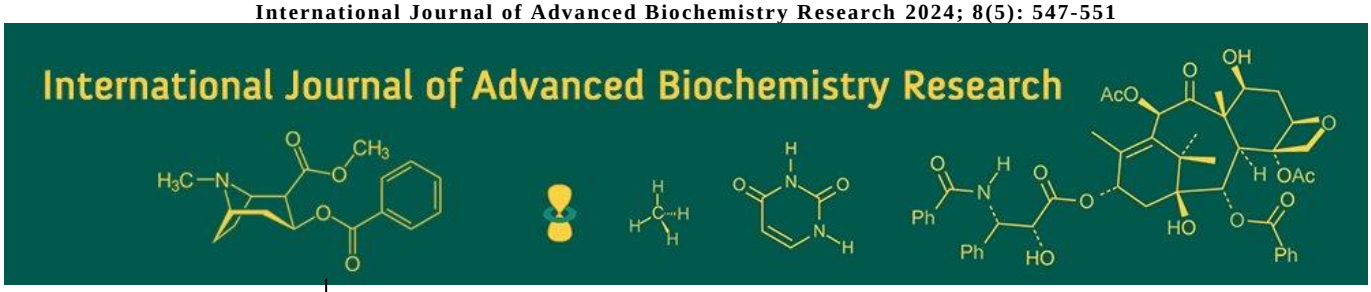

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Screening of germplasm against stem rot disease of tomato incited by *Sclerotinia sclerotiorum*

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Abstract
The tomato (*Solanum lycopersicum* L), is a highly valued and widely grown vegetable crop that is both economically and nutritionally significant. However, its susceptibility to various pathogens, including *Sclerotinia sclerotiorum*, poses a significant threat to its cultivation. The purpose of this study was to assess the resistance of 47 tomato germplasm lines against at the A.N.D.U.A.T. in Kumarganj, Ayodhya (Uttar Pradesh), sclerotinia stem rot disease is being observed in the field. The study utilized a comprehensive 0-9 scale for disease assessment, coupled with the calculation of percent disease index (PDI). Results indicated varying degrees of susceptibility among the germplasm lines, with none exhibiting complete resistance. Notably, five lines demonstrated moderate resistance, namely NDT-3, NDT-38, NDT-17, NDT-56, and NDT-6. These findings underscore the importance of breeding programs focused on developing resistant varieties to mitigate the impact of Sclerotinia stem rot. Given the limitations associated with fungicidal treatments, host plant resistance emerges as a promising strategy for disease management. The resistant lines that have been found provide important genetic resources for upcoming breeding projects that aim to increase tomato resistance to Sclerotinia Stem Rot. Ongoing field evaluations and further studies on tomato germplasm are recommended to sustainably address this persistent agricultural challenge.

Keywords: *Sclerotinia sclerotiorum*, tomato, germplasm, screened

Introduction
The tomato (*Solanum lycopersicum* L.), is regarded as the most popular and extensively grown vegetable crop worldwide, including in India. Owing to its widespread popularity, the crop ranks top among processing crops and second globally in terms of acreage after potatoes. Due to its unique nutritional value, it is also a protective meal and a crucial part of the kitchen diet when preparing Indian cuisine. It also has a great therapeutic value; in addition to being abundant in vitamins A and C, the pulp and juice are easily digested, encourage gastric secretion, and purify blood. Lycopene and beta-carotene pigments can be found in tomatoes (Rais and Sheoran 2015) [12]. One term for tomatoes is "poor man's orange."

Production share of Tomato by region in Asia 63%, Europe 12.9% Americas 12.5%, Africa 11.3 & and Oceania 0.2%. Globally, it was cultivated on 5,167,388 hectares of harvested land, yielding 189.13 million tonnes of tomatoes, or 36.6 tonnes per hectare (FAOSTAT, 2023). Tomatoes were planted on 8,45,000 hectares of harvested land in India, yielding a yield of 21.18 million tonnes, or 25.07 tonnes per hectare of land. (http://faostat.fao.org/, accessed on 20 May 2023).

One of the most widely grown, nutrient-dense, and popular food crops in the world is the tomato (*Lycopersicon esculentum* L.). According to Burton-Freeman and Reimers (2011), tomatoes are an excellent source of ascorbic acid and vitamin C, as well as antioxidants such lycopene (Di Matteo *et al.*, 2010) [3]. Fungal pathogens are one of the biotic variables that have affected tomato output (Terna and Simon 2017) [16]. *Sclerotinia sclerotiorum* L. DeBary is a filamentous ascomycete that is necrotrophic, phytopathogenic, and widespread. It has been found to have an impact on the yield of many crops (Hegedus and Rimmer 2005; Bolton *et al.*, 2006) [9, 1]. According to Sharma *et al.*, (2017) [15], it severely reduces the value of crops such as oilseeds, pulses, vegetables, feed legumes, and ornamentals.

More than half of the yield issues are caused by the tomato infectious microorganism *Sclerotinia sclerotiorum* (Gomaa *et al.*, 2016) [6]. It is distinguished by the production of hard, blackish-brown sclerotia, which, upon germination, create cup-shaped, brown apothecia. The junction between the stem and the root becomes brittle and starts to rot. On the white-infected section of the plant, there is whitish fungal growth that changes from white to dark brown sclerotia. The majority of *S. sclerotiorum* habitat is found in temperate, subtropical, and chilly climates (Saharan and Mehta 2008) [14].

The disease begins with water-soaked regions in stem joints, at or above soil level, and is primarily caused by a pathogen that strikes early in the flowering stage (Rodríguez *et al.*, 2004) [13]. The fruit and stem gradually develop white, fluffy mycelium that resembles cotton once the disease has taken hold of the host tissues. Later, the water-soaked area turns hard, discolored, and dry, and the plant finally wilts, collapses, and dies (reviewed in Bolton *et al.*, 2006) [1]. Soilborne sclerotia, a pigmented, multi-hyphal structure, helped the pathogen survive over the long term in the agricultural area. Up to ten years might pass while the sclerotia are alive on the soil's surface (Harper *et al.*, 2002) [8]. They can germinate carpogenically or myceliogenically to start an infection (Duncan *et al.*, 2006) [5]. Water-soaked areas developed and became light to dark brown. On the surface of the infected stem and branch as well as in the pith of the stem, a white mass of mycelium with embedded black sclerotia emerged. Fruits that were impacted rotted (Hansda *et al.*, 2014) [7].

A valuable method for comparing genotypes and their ability to resist disease in the wild is to evaluate germplasm at the field level. Therefore, this is mostly helpful for breeding programmes that aim to produce cultivars resistant to sclerotinia stem rot. In light of this, the current study was carried out to assess the germplasm's resistance to early blight disease in field settings and to determine the state of disease prevalence in the vegetable farms of A.N.D.U.A.T., Kumarganj, Ayodhya (Uttar Pradesh).

Materials and Methods

Tomato germplasm is field-screened for the tomato Stem Rot Disease

The Experimental Site

The experimental site, situated at A.N.D.U.A.T., Kumarganj, Ayodhya (U.P), lies along Raibareli Road, approximately 46 km away from Ayodhya. Positioned within the Indo-Gangetic plains, its geographical coordinates are 26.47 N latitude and 82.12 E longitude, with an altitude of 113 m above mean sea level. The region experiences a sub-humid and sub-tropical climate, characterized by an average annual rainfall of around 1200 mm.

Germplasm

The resistance or susceptibility of tomato germplasm to *Sclerotinia sclerotiorum* caused Stem rot disease was assessed under field conditions. A total of 47 tomato germplasm samples were acquired from the Department of Vegetable Science, College of Horticulture, A.N.D.U.A.T., Kumarganj, Ayodhya (U.P.). These tomato germplasm samples, utilized in the experimental screenings, are listed below.

Table 1: List of evaluated germplasm

NDT-2, NDT-7, NDT-4, NDT-P, 2013/TODHYB 6-6-2-1, 2013/TODVAR-2-2, S5 × NDT-3-2-1-1, 2019/TOLCURES-2, 2019/TOLCURES-4, 2019/TOLCURES-6, 2019/TOLCURES-8, S5 × NDT-3-2-2-1, NDTH-11W22-1-2-2, NDT-5, NDT-5-1-1, NDT-6, NDT C-1, NDT-8, NDT-45, NDT-4-1, NDT-67, NDT-27, NCT-2, NCT-1, NDT-56, NDT-17, NDT-15, NDT-52, NDT-25, NDT-47, NDT-38, 2012/TOLCVRES-1-2-1-1, NDT-Sel-3, NDT-P-1, 2012/TOLCV Res-1, NDT -Sel-2, 2019/TOLCV Res-2, 2019/TOLCV Res-4, 2019/TOLCV Res-6, NDT-3, NDT-3-1, NDT-1-1, NDT-7-1, NDT-11-3-2, NDT-11-5-1-1, NDT-6-1, NDT-6-2

Land preparation and layout plan

The land underwent thorough preparation, starting with a single deep ploughing using a soil-turning plough, followed by two cross-harrowings. The entire field was demarcated with ropes to facilitate sowing in rows spaced at 60 cm intervals. To help with drainage and irrigation, the field was also divided into blocks and plots. Following these preparations, the recommended fertilizer dose (N: P: K-150:100:50 kg/ha) was applied, consisting of urea, single superphosphate, and muriate of potash. During planting, half of the nitrogenous fertilizer and the full dose of phosphorus and potash were incorporated into furrows as basal dressing. Divided into three equal doses, the remaining half of the nitrogenous fertilizer was applied one and a half months after transplanting, one month after the initial application, and three and a half months after transplantation.

Observations to be recorded

After artificial inoculation, observation was recorded regularly for up to 15 days for the appearance of Sclerotinia stem rot symptoms and severity. Screening of Tomato genotype for the source of resistance against Sclerotinia Stem rot of Tomatoes in field conditions by using a 0-9 scale (Abawi and Pastor-Corrales, 1990) [17].

Percent Disease Index (PDI) was calculated using the formula of Mckinney (1923) [10] as given here.

$$PDI = \frac{\text{Sum of all numerical ratings}}{\text{number of leaves} \times \text{maximum disease rating}} \times 100$$

Results and Discussions

At the Vegetable Farm, Department of Vegetable Science, College of Horticulture and Forestry, 47 tomato germplasm samples were screened regarding their response to sclerotinia stem rot in a naturally occurring ecosystem. The germplasm was screened by following a 0-9 scale. The germplasm was grouped into various categories of resistant and susceptible based on the percentage of infected plants as described and the results are summarized in (Tables 3 and 4).

Out of 47 germplasm, 2 germplasm *viz.*, NDTH-11W22-1-2-2, NDT-6-1 were found Highly Susceptible, 20 germplasm *viz.*, 2013/TODHYB 6-6-2-1, 2013/TODVAR-2-2, S5 × NDT-3-2-1-1, 2019/TOLCURES-4, 2019/TOLCURES-6, S5 × NDT-3-2-2-1, NDT-8, NDT-45, NCT-2, NCT-1, NDT-52, NDT-25, NDT-47, 2012/TOLCVRES-1-2-1-1, 2012/TOLCV Res-1, 2019/TOLCV Res-4, 2019/TOLCV Res-6, NDT-3-1, NDT-1-1, NDT-11-3-2 were found susceptible, 20 germplasm

viz., NDT-2, NDT-7, NDT-4, NDT-P, 2019/TOLCURES-2, 2019/TOLCURES-8, NDT-5, NDT-5-1-1, NDT-C-1, NDT-4-1, NDT-67, NDT-27, NDT-15, NDT-Sel-3, NDT-P-1, NDT-Sel-2, 2019/TOLCV Res-2, NDT-7-1, NDT-11-5-1-1, NDT-6-2 were found Moderately Susceptible, 5 germplasm *viz.*, NDT-3, NDT-38, NDT-17, NDT-56, NDT-6 were found Moderately Resistant. None of the germplasm was found Resistant and Immune to Sclerotinia stem rot. Nagesh *et al.*, (2020) [11] also reported a similar outcome.

Table 2: Details of 0-9 SES rating scale (Abawi and Pastor-Corrales, 1990) [17]

S. No.	Scale's	Description	Reaction
1	0	No incidence	Immune
2	1	Infected florets less than 1%	Resistant
3	3	Infected florets (1-5%)	Moderately Resistant
4	5	Infected florets (6-25%)	Moderately Susceptible
5	7	Infected florets (26-50%)	Susceptible
6	9	Infected florets (51-100%)	Highly susceptible

Table 3: Disease reaction and rating scale of tomato germplasms against Sclerotinia Stem Rot of Tomato

No. of germplasm	Rating scale	Name of the germplasm	Disease reaction
0	0	Nil	Immune
0	1	Nil	Resistant
5	3	NDT-3, NDT-38, NDT-17, NDT-56, NDT-6	Moderately Resistant
20	5	NDT-2, NDT-7, NDT-4, NDT-P, 2019/TOLCURES-2, 2019/TOLCURES-8, NDT-5, NDT-5-1-1, NDT-C-1, NDT-4-1, NDT-67, NDT-27, NDT-15, NDT-Sel-3, NDT-P-1, NDT-Sel-2, 2019/TOLCV Res-2, NDT-7-1, NDT-11-5-1-1, NDT-6-2	Moderately Susceptible
20	7	2013/TODHYB 6-6-2-1, 2013/TODVAR-2-2, S5 × NDT-3-2-1-1, 2019/TOLCURES-4, 2019/TOLCURES-6, S5 × NDT-3-2-2-1, NDT-8, NDT-45, NCT-2, NCT-1, NDT-52, NDT-25, NDT-47, 2012/TOLCVRES-1-2-1-1, 2012/TOLCV Res-1, 2019/TOLCV Res-4, 2019/TOLCV Res-6, NDT-3-1, NDT-1-1, NDT-11-3-2	Susceptible
2	9	NDTH-11W22-1-2-2, NDT-6-1	Highly susceptible

Table 4: Tomato Germplasm Screened Against Stem Rot Disease

S. No.	Name of germplasm	Percent disease Incidence			Score 90 days after transplanting	Host reaction
		2022-23	2023-24	Mean		
1.	NDT-2	20.88	21.39	21.13	5	MS
2.	NDT-7	15.14	18.27	16.70	5	MS
3.	NDT-4	16.65	18.69	17.67	5	MS
4.	NDT-P	23.20	22.45	22.83	5	MS
5.	2013/TODHYB 6-6-2-1	46.07	47.62	46.84	7	S
6.	2013/TODVAR-2-2	46.46	23.72	35.09	7	S
7.	S5 × NDT-3-2-1-1	36.48	38.36	37.42	7	S
8.	2019/TOLCURES-2	25.21	23.44	24.33	5	MS
9.	2019/TOLCURES-4	48.62	50.57	49.59	7	S
10.	2019/TOLCURES-6	23.74	26.74	25.24	7	S
11	2019/TOLCURES-8	25.56	23.44	24.49	5	MS
12.	S5 × NDT-3-2-2-1	31.09	34.25	32.67	7	S
13	NDTH-11W22-1-2-2	61.33	60.74	61.03	9	HS
14.	NDT-5	19.64	18.63	19.14	5	MS
15.	NDT-5-1-1	15.56	18.45	17.00	5	MS
16.	NDT-6	5.41	5.36	5.39	3	MR
17.	NDT C-1	21.75	20.66	21.21	5	MS
18.	NDT-8	30.67	36.55	33.61	7	S
19.	NDT-45	27.78	28.60	28.19	7	S
20.	NDT-4-1	19.16	22.35	20.75	5	MS
21	NDT-67	23.29	26.44	24.86	5	MS
.22	NDT-27	15.04	18.57	16.81	5	MS
.23.	NCT-2	23.47	27.49	25.48	7	S
24.	NCT-1	33.79	37.62	35.71	7	S
25.	NDT-56	5.70	5.01	5.35	3	MR
26.	NDT-17	5.83	5.10	5.47	3	MR
27.	NDT-15	17.26	19.36	18.31	5	MS
28.	NDT-52	26.20	25.48	25.84	7	S
29.	NDT-25	35.72	30.51	33.12	7	S
30.	NDT-47	27.79	28.47	28.13	7	S
31.	NDT-38	5.72	5.64	5.68	3	MR
32.	2012/TOLCVRES-1-2-1-1	27.42	30.49	28.95	7	S
33.	NDT-Sel-3	13.13	16.78	14.96	5	MS
34.	NDT-P-1	17.79	18.48	18.13	5	MS
35.	2012/TOLCV Res-1	29.72	30.52	30.12	7	S
36.	NDT -Sel-2	12.37	15.41	13.89	5	MS
37.	2019/TOLCV Res-2	11.62	16.45	14.03	5	MS
38.	2019/TOLCV Res-4	46.48	48.44	47.46	7	S
39.	2019/TOLCV Res-6	46.72	46.58	46.65	7	S
40.	NDT-3	5.58	5.18	5.38	3	MR

41.	NDT-3-1	25.10	29.20	27.15	7	S
42.	NDT-1-1	48.45	46.52	47.48	7	S
43.	NDT-7-1	20.52	22.41	21.46	5	MS
44.	NDT-11-3-2	36.47	32.57	34.52	7	S
45.	NDT-11-5-1-1	22.44	26.43	24.44	5	MS
46.	NDT-6-1	61.52	58.47	59.99	9	HS
47.	NDT-6-2	21.68	24.55	23.12	5	MS
48.	Mean	27.63	28.49			
49.	C.D. @5% (Years)	-	-	0.21		
50.	C.D. @5% (Genotypes)	-	-	7.79		

Conclusion

Growing concerns about air pollution and its effects on health have put a strain on the usage of fungicides. Furthermore, their effectiveness is further restricted by the emergence of fungicidal resistance. As a result, the most promising method of treating the disease is for the host plant to become resistant to it. Based on our findings, a total of five germplasm lines exhibited moderate resistance, specifically NDT-3, NDT-38, NDT-17, NDT-56, and NDT-6. These genotypes may be used in breeding initiatives to create tomato cultivars resistant to stem rot caused by *Sclerotinia*. Additionally, ongoing field evaluations and periodic assessments of tomato germplasm are advocated for future research endeavors.

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