Impact of Weather parameters and Fungicides Strategies on the Management of Root & Stem Rot in Sesame caused by *Macrophominaphaseolina*

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ABSTRACT

Root & stem rot caused by *Macrophominaphaseolina* is an important disease. It spreads through seed and soil residual materials. In India root & stem rot disease can induce 5-100% yield losses under epidemic condition. The effect of various weather parameters on the development of root & stem rot in sesame was investigated during *Kharif* 2023 and 2024. The various weather parameters *viz*., temperature (max), temperature (min), relative humidity (morning), relative humidity (evening), soil temperature, soil moisture, rainfall and rainy days under natural condition.Two year data revealed that there is significantcorrelation between disease incidence and weather parameters.The weather parameters *viz*., temperature (minimum), relative humidity (evening), soil moisture, rainfall showed a significant negative correlation with disease incidence, while soil temperature showed a significant positive correlation during both years. Regression analysis revealed that all the weather parameters contributed 99.96% and 96.04% towards disease development during both years. Due to lack of resistance in sesame genotypes, disease is managed through fungicides.Management of root & stem rot disease in sesame was done under *in vitro* and *in vivo conditions.*Average pooleddata analysisrevealed that,seed treatment with Carbendazim 12% WP + Mancozeb 63% WP followed by two foliar application of Tebuconazole 50% WG + Trifloxystrobin 25% WG was found most effective in minimizing the disease incidence (20.49%) andper cent disease reduction over the control (59.51%) with yield 478.98 kg/ha and B:C ratio 1.69. The key benefit to use this fungicides against plant disease is that it provides both protective and curative activity, reduce risk of fungicide resistant development, it also offers broader spectrum of disease control, and it gives both quick action (trifloxystrobin) and extended protection (tebuconazole).

Keywords*: Sesame, Root & Stem rot, Per cent disease incidence, Weather parameters*

1. INTRODUCTION

Sesame (*Seasmumindicum* L.) is commonly known as 'Til' also called as 'Queen of oil seeds'. Sesame seeds contain a high amount of edible oil (46-52%), mainly oleic acid (47%) and linoleic acid (39%), which helps to lower cholesterol (Shyu and Hwang, 2002). In India, sesame is cultivated over an area of 15.23 lakh ha^{-1} in India, with a total production of 527 kg/ha during 2022-23 (Vishwakarma *et al*., 2024). The major sesame growing districts in India are primarily located in the states of Gujarat, Rajasthan, Madhya Pradesh, Uttar Pradesh, West Bengal, Tamil Nadu, and Andhra Pradesh. The primary reason for the low productivity of Sesame is the influence of several biotic and abiotic factors. Biotic factors include various pests and diseases*viz*., root& stem rot, *Alternaria* leaf spot, Bacterial blight, Powdery mildew, *Cercospora leaf* spot, and Sesame phyllody (Gupta *et al*., 2018). Among these are root & stem rot of Sesame, which is caused by *Macrophominaphaseolina* (Tassi.) Goid. (Sclertoial stage- *Rhizoctoniabataticola*), is one of the most devastating diseases. It affects the crop at almost all stages of its growth, particularly during the flowering to capsule initiation stage which drastically reduce germination and seedling stand (Indra, 2020). *M. phaseolina* was considered as very destructive pathogen in all sesame growing areas and causes 15-100% yield loss (Thirunarayanan*et al*., 2017). *Macrophominaphaseolina* (Tassi). Goid. soil inhabiting pathogen, attacks many host plants including oilseeds, pulses, vegetables and ornamentals (Bandopadhyay*et al*., 2022). The most common symptoms of the disease is sudden wilting of growing plant mainly after the flowering stage, stem portion near the ground level show dark brown and dark black lesion at the collar region show shredding and to destroy the vascular bundles leading to plant death. Stem portion can be easily pulled out leaving the rotten rot portion in the soil which helps pathogen to survive in debris over long period of time (Avila *et al*., 1999). The pathogen is usually soil borne but can also be found in seed testa, where microscopic sclerotia bodies adhere to it (Mishra *et al*., 2024).The fungus is greatly influenced by environmental factor and produce pycnidia when the soil temperature ranges from 25ºC to 35ºC. Under high soil temperature and moisture stress conditions the fungus cause maximum disease (Satpathi and Gohel (2018), Rathore *et al*. (2022), Khamari*et al.* (2022),). Management strategies used against stem and root rot of sesame is challenging for farmers due to its soil borne nature thus production of sclerotia and difficult to apply control measures (Nasari, 2008). The explosive pathogenicity of *M. phaseolina* in favorable conditions and the ability of its sclerotia to withstand adverse conditions, made a successful plant pathogen. The efficacy of various fungicides against *Macrophomina* species has been demonstrated under *in vitro* and *in vivo* conditions (Nagpure*et al*., 2023, Gea*et al*., 2024).However, there is lack of precise information on the influence of environmental factors on the development of root & stem rot of disease of sesame. Therefore, the present investigations were directed to assess the impact of epidemiological factors on the root & stem rot disease of sesame crop and its management during *kharif* 2023 and 2024.

2. MATERIAL AND METHODS

2.1 Influence of weather parameter on root & stem rot disease of sesame

The effect of different weather parameters like soil temperature, soil moisture, atmospheric temperature, relative humidity, rainfall (mm), &number of rainy days on the per cent disease incidence and development of root & stem rot of sesame were studied at the research farm of PC Unit (Sesame & Niger), ICAR, Jawaharlal Nehru Krishi Vishwavidyalaya, Jabalpur. This study was conducted during *Kharif* 2023 & 2024. All the other agronomical and pest control practices were followed as per recommended in package of practices of sesame. To perform this study RT-351 genotype which is susceptible to root & stem rot of sesame was grown in three replications of 2.4 x 3 m^2 area. The observations were recorded as soon as the first symptom of root & stem rot was seen in the field till harvesting on the basis of standard meteorological week (SMW) as shown in Table-1 & Table-2. The incidence of root & stem rot disease was correlated with weather parameters and hence determine the correlation and regression coefficient. Stepwise multiple regression analysis was performed to find out the subset of environmental variable for the purpose of forecasting. The meteorological observation at Meteorology observatory, Jawaharlal Nehru Krishi Vishwavidyalaya, Jabalpur was used for this study purpose.

2.2 Statistical analysis

Year and season of experiment- *Kharif* 2023 and *Kharif* 2024

(A) – Correlation coefficient:

Correlation coefficient between percent disease incidence and weather parameters were worked out;

$$r\ (xy) = \frac{COV.\ (xy)}{\sqrt{Var.\ (x) Var.\ (y)}}$$

where,
r (xy) = correlation coefficient between character x and y
COV (xy) = covariance between character x and y
V (x) = variance of x character

Test of significance of "r"

$$t = \frac{r}{\sqrt{1 - r^2}} \sqrt{n} - 2$$

where,
r = correlation coefficient
n = number of observations
df = (n-2)

(B)Regression coefficient:

Percent disease incidence of root & stem rot was subject to regression and step down multiple regression analyses with weather parameter *viz.,* soil temperature, soil moisture, atmospheric temperature, rainfall, relative humidity and number of rainy days. The prediction equation/model was derived. The model can be defined as $\boldsymbol{Y = a + b_1X_1 + b_2X_2 + \ldots\ldots\ldots}$where, Y = percent disease incidence (PDI), a = constant, b = regression coefficient of independent variables, X = different weather parameters

2.2 Meteorological data

Table 1. Progression of root & stem rot disease incidence and its correlation with different weather parameters (*Kharif* 2023).

Date of observation	SMW	PDI	Temperature (ºC)		Relative Humidity (%)		Soil		Rainfall (mm)	Number of Rainy days
			Maximum	Minimum	Morning	Evening	Temperature (ºC)	Moisture (%)		
10 Sept. 2023	36	7.32	32.0	24.5	88.1	77.4	27.00	49.9	23.2	4
17 Sept. 2023	37	9.98	29.9	24.3	92.7	81.1	25.33	43.6	23.9	5
24 Sept. 2023	38	15.95	31.6	24.0	87.4	66.1	26.00	44.2	23.1	2
1 Oct. 2023	39	20.22	32.3	23.6	88.4	64.9	27.00	36.5	22.5	0
8 Oct. 2023	40	23.84	31.9	20.6	83.0	56.6	27.66	38.2	19.0	0
15 Oct. 2023	41	30.91	33.9	20.6	80.6	43.3	30.00	33.4	16.7	0
22 Oct. 2023	42	33.18	31.9	18.4	84.3	47.7	27.33	37.6	16.1	0
29 Oct. 2023	43	35.46	30.0	13.9	73.4	40.6	26.66	36.7	12.4	0
5 Nov. 2023	44	37.21	30.5	14.0	79.0	42.0	28.33	31.2	13.2	0
12 Nov. 2023	45	48.86	31.6	14.1	85.9	36.0	30.00	33.5	12.3	0

***SMW**- Standard meteorological week; **PDI**- Percent Disease Incidence*

Table 2. Progression of root & stem rot disease incidence and its correlation with different weather parameters (*Kharif* 2024).

Date of observation	SMW	PDI	Temperature (ºC)		Relative Humidity (%)		Soil		Rainfall (mm)	Number of Rainy days
			Maximum	Minimum	Morning	Evening	Temperature (ºC)	Moisture (%)		
8 Sept. 2024	36	10.36	32.7	25.4	91.1	67.7	28.66	41.6	17.2	2
15 Sept. 2024	37	15.28	30.0	24.2	91.7	76.0	25.00	52.6	184.8	3
22 Sept.2024	38	25.51	30.6	24.2	93.6	67.7	25.33	48.4	93.8	2
29 Sept.2024	39	29.95	31.6	25.2	91.1	71.1	27.33	39.3	10.8	2
6 Oct. 2024	40	34.82	33.5	24.2	87.9	58.9	29.66	40.2	0	0
13 Oct. 2024	41	39.62	32.5	23.1	88.6	59.6	29.00	37.2	0	0
20 Oct. 2024	42	42.15	31.5	21.0	90.4	56.6	28.66	42.8	14.4	1
27 Oct. 2024	43	44.26	31.2	18.3	90.0	50.0	27.66	37.6	0	0
3 Nov. 2024	44	49.58	32.8	17.5	86.6	48.0	31.33	33.0	0	0
6 Nov. 2024	45	52.36	30.9	16.1	88.8	46.2	27.66	35.8	0	0

***SMW**- Standard meteorological week; **PDI**- Percent Disease Incidence*

2.3 Management of root & stem rot disease

2.3.1 *In vitro* evaluation of fungicides

The experiment was laid out as per details given below-
Design- CRD, *Replication*- 3, *Treatments*- 10 (9+1), *Method*- Poisoned food Technique, *Dose* (ppm)- 100, 250, 500
In the present study nine fungicides *viz*., Mancozeb, Tebuconazole + Trifloxystrobin, Fluxapyroxad + Pyraclostrobin, Carbendazim + Mancozeb, Hexaconazole, Pyraclostrobin + Epoxiconazole, Mancozeb + Thiophenate methyl, Chlorothalonil, Difenoconazole & control (Table-3) having PDA alone were evaluated against *Macrophominaphaseolina*by poisoned food technique advocated by **Morton and Straube (1955)**. The required quantity of each fungicide was thoroughly mixed with 100 ml of sterilized PDA medium contained in 200 ml flakes. It was then mixed thoroughly and was poured in petriplates and allowed to solidity. Each treatment replicated thrice. The control petriplates having PDA alone were inoculated in the same manner. Five mm diameter of pathogen colony from seven days old culture of *M. phaseolina* was cut with the help of cork borer and inoculated at the centre in each Petridish. The inoculated Petri-dishes were incubated at 28±2ºC. Observations on mean colony diameter at 3, 5 & 7 days, sclerotia production & per cent inhibition of average radial growth was calculated as suggested by Vincent (1947).
I = C-T/C X 100

I = per cent inhibition
C= radial growth measurement of the pathogen in control plate
T= radial growth measurement of the pathogen in treatment plate

2.3.2 *In vivo*evaluation of fungicides

The experiment was laid out as per details given below-
Variety- RT 351, *Design*- RBD, *Replication*- 3, *Treatments*- 10 (9+1), *Plot Size*- 3x2.4 m², *Method*- seed treatment (Carbendazim12% WP + Mancozeb63% WP @ 2g/kg seed); foliar application at 45 & 60 DAS (Table-3).
The field trial of chemical management was conducted during *Kharif* 2023 and 2024 at research farm, PC unit Sesame & Niger, ICAR, JNKVV, Jabalpur in a Randomized Block Design (RBD) with three replications. The field trial was conducted under irrigated, sandy loam soil conditions. RT 351 variety of sesame which is susceptible to root & stem rot disease was seed treated with Carbendazim 12% WP + Mancozeb 63% WP @ 2g/kg seed prior to sowing, mixed well & sown on 12th August, 2023; 5th August, 2024in a plot size of 7.2 m^2 with row to row distance of 40 cm and plant to plant distance 10 cm. Recommended dose of fertilizer and IPM measures were followed accordingly from time to time. Observations on per cent disease incidence was taken at 45, 60 & 75 DAS, plant height, number of capsule/plant, number of seeds/capsule, yield, benefit cost ratio, test weight and per cent oil content for each treatments.

2.3.3 Calculation and Statistical Analysis:

Percent disease incidence (PDI) and disease control *in vivo*experiments were calculated as follows:
Percent Disease incidence (%) = (Number of diseased plants/Total number of plants observed)× 100
Percent disease over the control (%) = (Disease incidence Disease incidence in inoculated control (%)- Disease incidence in treatment) / Disease incidence in inoculated control (%) x 100

Management data was analyzed statistically using OPSTAT Software.

Table 3- Experiment details of chemical management under *in vivo* condition

Treatment	Treatment Details		Dose	
	Seed Treatment	**Foliar application (45 & 60 DAS)**	**Seed Treatment**	**Foliar application (45 & 60 DAS)**
T1	Carbendazim 12% WP+ Mancozeb 63 % WP	Mancozeb 75% WP	2.5 gm/l	2.5 gm/l
T2	Carbendazim 12% WP+ Mancozeb 63 % WP	Tebuconazole 50% WG + Trifloxystrobin 25% WG	2.5 gm/l	1.5 gm/l
T3	Carbendazim 12% WP+ Mancozeb 63 % WP	Fluxapyroxad 167 g/L+ Pyraclostrobin 333 g/L SC	2.5 gm/l	1 ml/l
T4	Carbendazim 12% WP+ Mancozeb 63 % WP	Carbendazim 12% WP+ Mancozeb 63 % WP	2.5 gm/l	1.5 gm/l
T5	Carbendazim 12% WP+ Mancozeb 63 % WP	Hexaconazole 5% SC	2.5 gm/l	3 ml/l
T6	Carbendazim 12% WP+ Mancozeb 63 % WP	Pyraclostrobin 13.3 % SE+ Epoxiconazole 5 % SE	2.5 gm/l	1.5 ml/l
T7	Carbendazim 12% WP+ Mancozeb 63 % WP	Mancozeb 50% WG + Thiophenate methyl 25% WG	2.5 gm/l	1 gm/l
T8	Carbendazim 12% WP+ Mancozeb 63 % WP	Chlorothalonil 75% WP	2.5 gm/l	2 gm/l
T9	Carbendazim 12% WP+ Mancozeb 63 % WP	Difenoconazole 25% EC	2.5 gm/l	1 ml/l
T10	Control			

3. RESULTS AND DISCUSSION

3.1 Correlation between PDI and weather parameters

The progress of root & stem rot disease incidence with different weather parameter variables was studied in two crop season *i.e*. *kharif* 2023 & 2024 under field conditions. Sesame cultivar RT-351 (susceptible) was used in both seasons. In *kharif* 2023, the first observation on percent disease incidence was recorded from standard week at the time of flowering *i.e.* 10^{th} September, 2023 (36^{th} standard meteorological week) till the day of harvesting *i.e.* 12 November, 2023 (45^{th} standard meteorological week. The root & stem rot disease incidence progressively increased and varies from 7.32 to 48.86 percent.The maximum progression of disease was from 44^{th} (37.21%) to 45^{th} (48.86) week. During this progression of disease, temperature maximum & minimum was 30.5 to 31.6 & 14 to 14.1ºC respectively. Relative humidity morning & evening varies from 79 to 85.9% & 42 to 36 percent respectively. Soil temperature and moisture varies from 28.33 to 30ºC & 31.2 to 33.5 % respectively. Rainfall intensity during this period varies from 13.2 to 12.3 mm and there were number of rainy days. (Table.1). In*kharif* 2024, the first observation on percent disease incidence was recorded from 36^{th} standard meteorological week (8^{th}September, 2024) till the day of harvesting *i.e.*45^{th}standard meteorological week (6^{th} November, 2024). The maximum progression of disease was from 37^{th} week (15.28%) to 38^{th} week (25.51%). During this period temperature maximum & minimum varies 30.0 to 30.6ºC & 24.2ºC. Relative humidity morning & evening varies 91.7 to 93.6percent& 76.0 to 67.7percent. Soil temperature & moisture varies 25 to 25.33ºC to 52.6 to 48.4% respectively. Rainfall intensity varies 184.8 to 93.8 mm and number of rainy days varies 3 to 2 days during this period.

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Table 4. Correlation matrix between PDI and all the weather parameters (*Kharif* 2023).

	PDI	***X1***	***X2***	***X3***	***X4***	***X5***	***X6***	***X7***	***X8***
PDI	1								
X1	0.008^{NS}	1							
X2	-0.915**	0.300^{NS}	1						
X3	-0.612^{NS}	0.075^{NS}	0.748*	1					
X4	-0.963**	-0.113^{NS}	0.895**	0.767*	1				
X5	0.718*	0.564^{NS}	-0.518^{NS}	-0.357^{NS}	-0.732*	1			
X6	-0.853**	-0.108^{NS}	0.738*	0.572^{NS}	0.852**	-0.673^{NS}	1		
X7	-0.946**	0.123^{NS}	0.978**	0.783*	0.953**	-0.635^{NS}	0.777*	1	
X8	-0.787*	-0.315^{NS}	0.648^{NS}	0.667^{NS}	0.852**	-0.610^{NS}	0.831*	0.712*	1

Correlation is significant at the 0.05 level, ** Correlation is highly significant at the 0.01 level, ^{NS} Non-Significant, **X1 = Temperature (max),**X2** = Temperature (min), **X3** =Relative humidity (morning), **X4** = Relative humidity (minimum), **X5**= Soil temperature, **X6** = Soil moisture, **X7** = Rainfall, **X8**= number of rainy days*

Table 5. Correlation matrix between PDI and all the weather parameters (*Kharif* 2024).

	PDI	***X1***	***X2***	***X3***	***X4***	***X5***	***X6***	***X7***	***X8***
PDI	1								
X1	0.144^{NS}	1							
X2	-0.845**	0.104^{NS}	1						
X3	-0.671^{NS}	-0.664^{NS}	0.545^{NS}	1					
X4	-0.899**	-0.272^{NS}	0.901**	0.711*	1				
X5	0.709*	0.868**	-0.338^{NS}	-0.862**	-0.612^{NS}	1			
X6	-0.735*	-0.590^{NS}	0.599^{NS}	0.792*	0.784*	-0.798*	1		
X7	-0.712*	-0.680^{NS}	0.379^{NS}	0.619^{NS}	0.682^{NS}	-0.769*	0.899**	1	
X8	-0.850**	-0.519^{NS}	0.669^{NS}	0.812*	0.899**	-0.708*	0.826*	0.777*	1

Correlation is significant at the 0.05 level, ** Correlation is highly significant at the 0.01 level, ^{NS} Non-Significant, **X1 = Temperature (max),**X2** = Temperature (min), **X3** =Relative humidity (morning), **X4** = Relative humidity (minimum), **X5**= Soil temperature, **X6** = Soil moisture, **X7** = Rainfall, **X8**= number of rainy days*

During *kharif* 2023, correlation coefficient between per cent disease incidence and weather parameters *viz*., soil temperature (r = 0.754*), soil moisture (r = -0.745*), maximum temperature (r =0.008^{NS}), minimum temperature (r = -0.915**), rainfall (r = -.946**), morning relative humidity (r = -0.612^{NS}), evening relative humidity (r =-0.963**) and number of rainy days (r = -0.787*) shows that high soil temperature, low soil moisture, low minimum temperature, low rainfall, less evening relative humidity and less number of rainy days plays significant role for maximum per cent disease incidence of root & stem rot of sesame. Among all the weather parameters, maximum temperature and relative humidity morning shows non-significant correlation with per cent disease incidence (table-4).During *Kharif* 2024, correlation coefficient between per cent disease incidence and weather parameters *viz*., soil moisture (r = -0.735*),soil temperature (r = -0.712*), minimum temperature (r = -

0.844**), morning relative humidity (r = -0.671*), evening relative humidity (r = -0.899**), rainfall (r = -0.712*) and number of rainy days (r = -0.850**)shows that low soil moisture, high soil temperature, less minimum temperature, less morning relative humidity, low evening relative humidity, less rainfall intensity and less number of rainy days plays significant role which is favourable for per cent disease incidence of root & stem rot of sesame. Remaining meteorological parameters *viz*., maximum temperature (r = 0.144^{NS}) and relative humidity morning (r = -0.671^{NS})are non-significantly correlated with per cent disease incidence (table-5, figure-1 & 2). The present data investigated by previous workers, Gupta *(*2016) who reported that weather parameter plays crucial role for disease progression of root & stem rot disease of sesame under field condition.Wokocha (2000) observed that under the humid tropical conditions of south-western Nigeria, high soil moisture levels were unfavorable for the growth and pathogenicity of *M. phaseolina*, while low soil moisture levels favored these fungal traits. Mihail (1989) also observed a marked increase in mortality of plants due to *M. phaseolina* when soil temperature at 5-cm depth reached 28–30°C. Other researchers (Satpathi and Gohel., 2018, Rathore *et al.*, 2021, Khamari*et al.,* 2022) also observed the influence of weather parameters on disease incidence.

3.2Regression analysis between PDI and weather parameters

Regression analysis revealed that are eight regression lines which were obtained for independent variables *viz.*, soil temperature, soil moisture, temperature (max), temperature (min),rainfall, relative humidity (morning),relative humidity (evening) and number of rainy days on the dependent variable as per cent disease incidence (figure 3 & 4). Analysis shows that all the weather parameters contributed 99.96% and 99.06% towards disease development during year *Kharif* 2023 & 2024 respectively.

Multiple linear regression analysis predicts equation during *Kharif* 2023 as $Y= 94.854 + 0.101\ x_1+0.237\ x_2+ 0.113x_3 -1.148x_4 -0.065x_5 + 0.898x_6-0.716\ x_7-0.518\ x_8$ ($R= 0.999$, $R^2= 0.999$). During *Kharif* 2024 multiple linear regression analysis represented as$Y= 102.068 + 6.220\ x_1 + 0.927\ x_2 - 9.707\ x_3 -4.815\ x_4 - 0.124\ x_5 + 1.273\ x_6 + 2.377\ x_7 -18.011\ x_8$ ($R= 0.9953$, $R^2= 0.9604$ (table-7). During both the years, relative humidity (evening) contributed maximum toward per cent disease incidence of 92.9 percent and 80.8 percent respectively. Least influence of weather parameter on disease incidence during both the years was observed in temperature (maximum). The present data investigated by previous workers, Gupta *et al*. (2016) observed that multiple regression equation between disease index and weather variables exhibited strong relationship among the different component of the epiphytotic during both the years (R^2 =0.989 and 0.985). Rathore *et al*. (2021) reported that per cent disease incidence and weather parameters exhibited strong relationship during all the date of sowing studied and combine effect of different weather variation favoured disease development causing up to 99 per cent variation in disease index, the R^2 value of function ranged from 0.94 to 0.99. Mohan *et al*. (2005) reported that multiple regression coefficients between disease incidence and weather variables exhibited strong relationship among the different components of epidemic during both the years of study and found that minimum temperature contribute maximum for disease incidence *i.e*., 95.3% and 95.4% during both the year.Sharma and Pande (2013) reported that a combination of high temperature (35°C) and soil moisture content (60%) predisposes chickpea to dry root rot caused by *M. phaseolina*.Satpathi and Gohel (2018) conducted a study on the impact of various meteorological factors on the development of stem and root rot in sesame and found that maximum soil temperature, maximum soil moisture, low relative humidity and less rainfall favouring the disease development during 37th and 39thmeterological week**.**

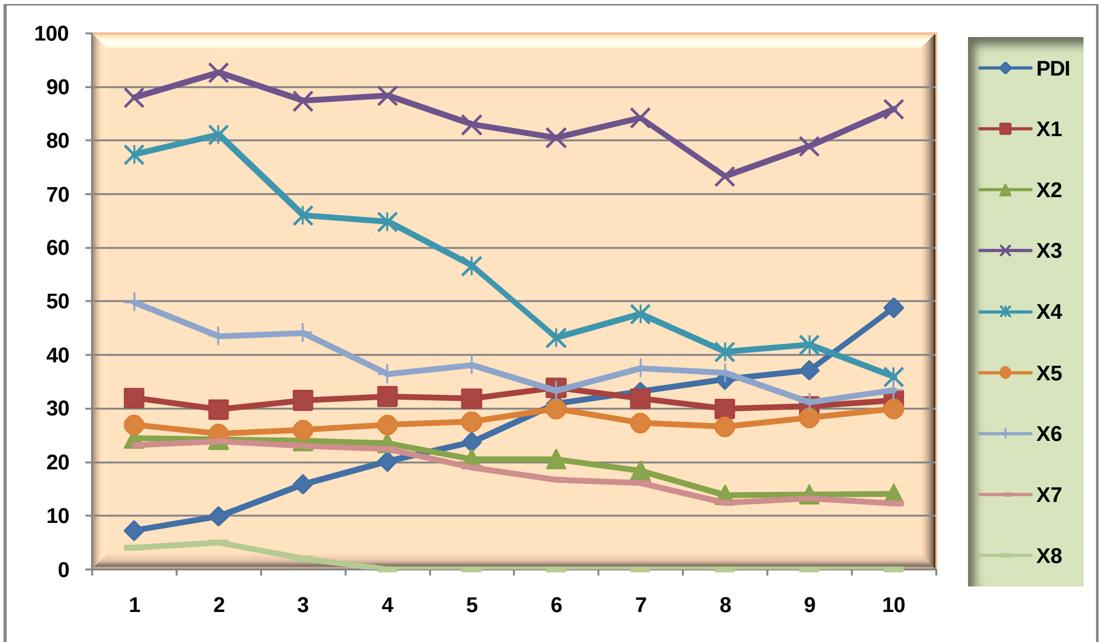

***Figure 1.(Kharif 2023) PDI**- Per cent disease incidence,**X axis**- Ten meteorological week (36th SMW to 45th SMW), **Y axis**- Meteorological values; **X1** = Temperature (max),**X2** = Temperature (min), **X3** =Relative humidity (morning), **X4** = Relative humidity (minimum), **X5**= Soil temperature, **X6** = Soil moisture, **X7** = Rainfall, **X8**= number of rainy days*

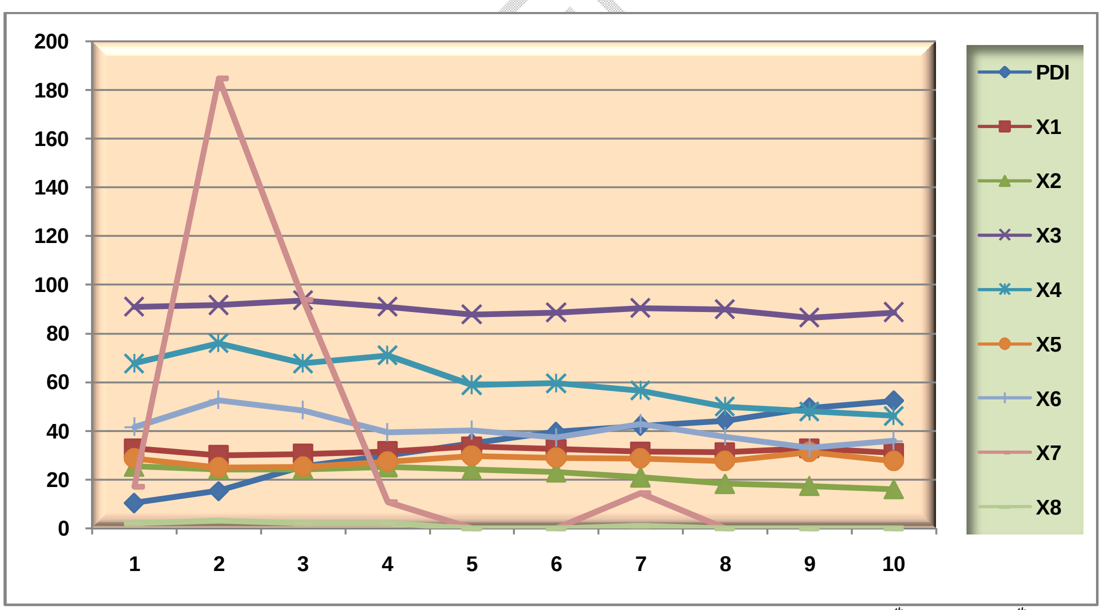

***Figure 2. (Kharif 2024)PDI**- Per cent disease incidence, **X axis**- Ten meteorological week (36th SMW to 45th SMW), **Y axis**- Meteorological values; **X1** = Temperature (max),**X2** = Temperature (min), **X3** =Relative humidity (morning), **X4** = Relative humidity (minimum), **X5**= Soil temperature, **X6** = Soil moisture, **X7** = Rainfall, **X8**= number of rainy days*

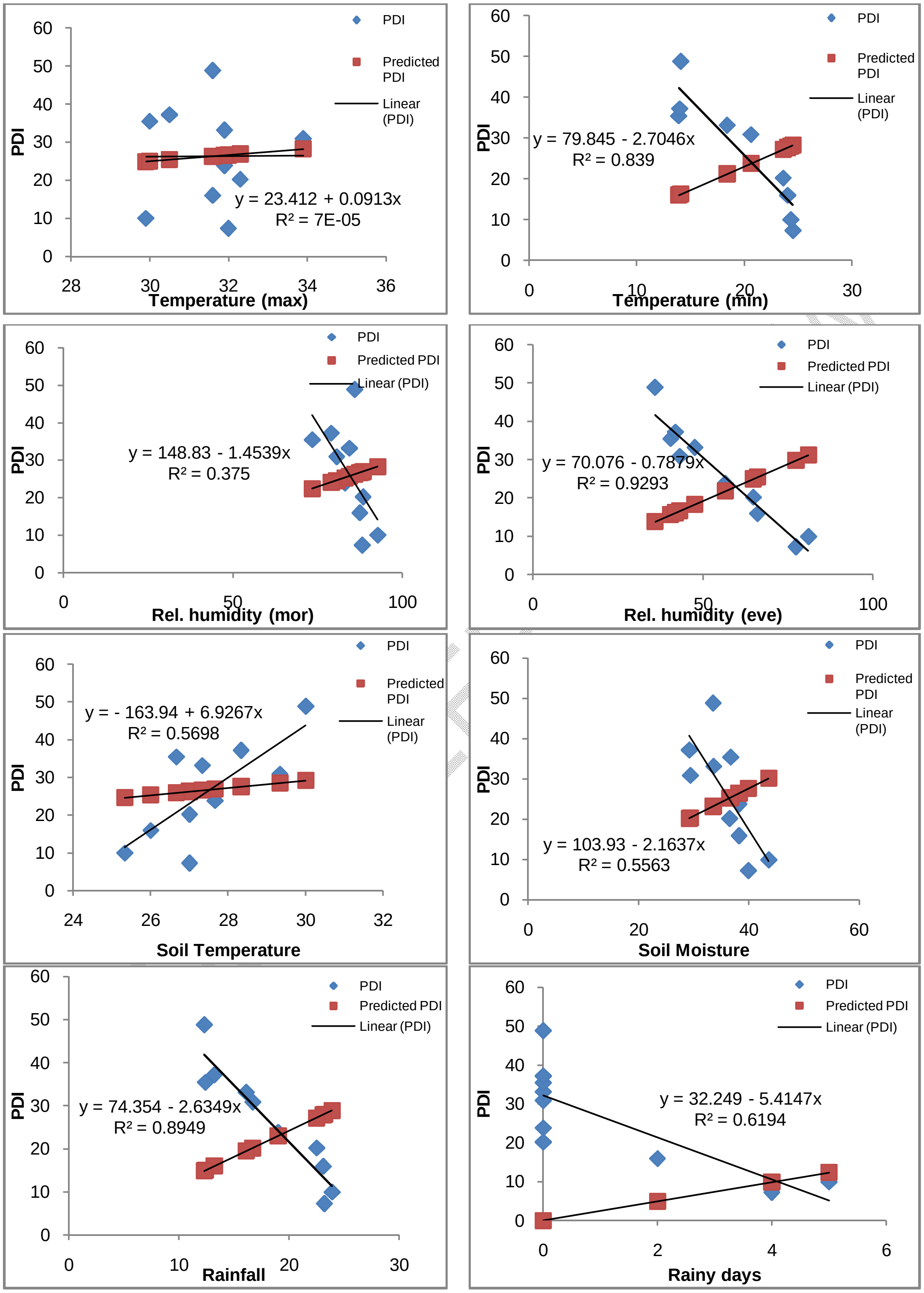

Figure 3- *Kharif*-2023; *Regression analysis with their equation between Per cent disease incidence (PDI), and weather parameters*

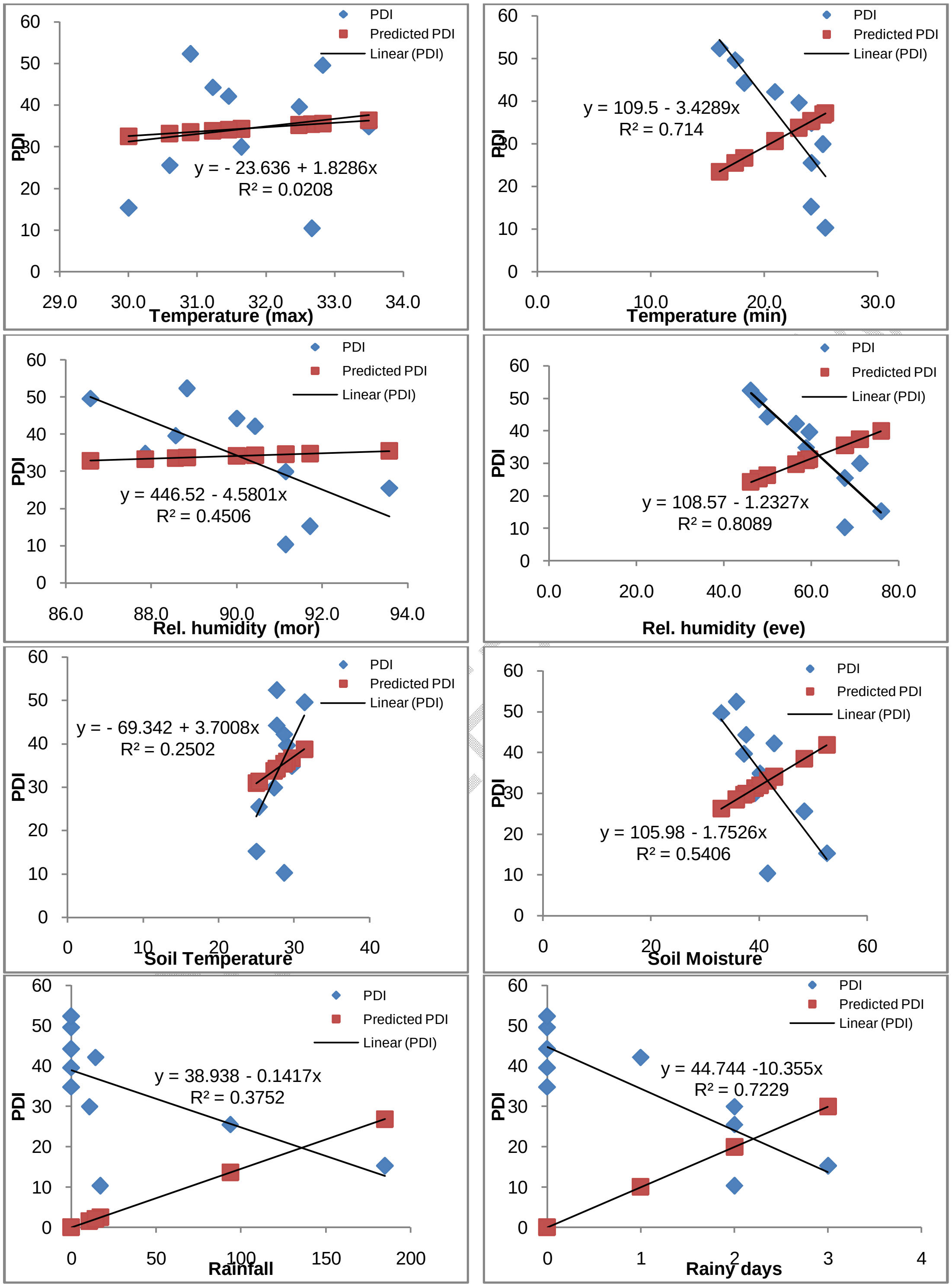

Figure 4- *Kharif*-2024; *Regression analysis with their equation between Per cent disease incidence (PDI), and weather parameters*

Table 6.Correlation coefficient and regression equation between weather parameters with percent disease incidence (PDI)

Description	*PDI Correlation coefficient (r)*	*Multiple regression coefficient(R^2)*	*Regression Equation*
		Kharif 2023-24	
Temperature maximum (ºC)	0.008^{NS}	7e-5	$y = 23.412 + 0.0913x_1$
Temperature minimum (ºC)	-0.915**	0.839	$y = 79.845 - 2.7046x_2$
Relative humidity morning (%)	-0.612^{NS}	0.375	$y = 148.83 - 1.4539x_3$
Relative humidity evening (%)	-0.963**	0.9293	$y = 70.076 - 0.7879x_4$
Soil temperature (ºC)	0.754*	0.5698	$y = - 163.94 + 6.9267x_5$
Soil moisture (%)	-0.745*	0.5563	$y = 103.93 - 2.1637x_6$
Rainfall (mm)	-0.946**	0.8949	$y = 74.354 - 2.6349x_7$
Number of rainy days	-0.787*	0.6194	$y = 32.249 - 5.4147x_8$
		Kharif 2024-25	
Temperature maximum (ºC)	0.144^{NS}	0.0208	$y = - 23.636 + 1.8286x_1$
Temperature minimum (ºC)	-0.844**	0.714	$y = 109.5 - 3.4289x_2$
Relative humidity morning (%)	-0.671*	0.4506	$y = 446.52 - 4.5801x_3$
Relative humidity evening (%)	-0.899**	0.8089	$y = 108.57 - 1.2327x_4$
Soil temperature (ºC)	0.709^{NS}	0.2502	$y = - 69.342 + 3.7008x_5$
Soil moisture (%)	-0.735*	0.5406	$y = 105.98 - 1.7526x_6$
Rainfall (mm)	-0.712^{NS}	0.3752	$y = 38.938 - 0.1417x_7$
Number of rainy days	-0.850**	0.7229	$y = 44.744 -10.355x_8$

***Significant at 5% level of significance;** Significant at 1% level of significance; ^{NS}Non- Significant; Y= Percent disease incidence (PDI); R^2= multiple regression coefficient, X1 = Temperature (max),X2 = Temperature (min), X3 =Relative humidity (morning), X4 = Relative humidity (minimum), X5= Soil temperature, X6 = Soil moisture, X7 = Rainfall, X8= number of rainy days*

Table 7.Multiple regression equation for root & stem rot in sesame

Year	**R^2**	**Multiple regression equation**	**p value**
Kharif 2023-24	0.9996	$Y= 94.854 + 0.113X_1 - 1.148X_2 + 0.898X_3 - 0.716X_4 + 0.101X_5 + 0.237X_6 - 0.065X_7 - 0.518 X_8$	0.028
Kharif 2024-25	0.9604	$Y= 102.068 - 9.707X_1 - 4.815X_2 + 1.273X_3 + 2.377X_4 + 6.220X_5 + 0.927X_6 - 0.124X_7 -18.011X_8$	0.149

R^2= multiple regression coefficient, X1 = Temperature (max),X2 = Temperature (min), X3 =Relative humidity (morning), X4 = Relative humidity (minimum), X5= Soil temperature, X6 = Soil moisture, X7 = Rainfall, X8= number of rainy days

3.3*In vitro* evaluation of fungicides against *M. phaseolina*

For the management of root & stem disease in sesame, *in vitro* evaluation of fungicides (single & combinations) was done and all the fungicides *viz*., Mancozeb, Tebuconazole + Trifloxystrobin, Fluxapyroxad + Pyraclostrobin, Carbendazim + Mancozeb, Hexaconazole, Pyraclostrobin + Epoxiconazole, Mancozeb + Thiophenate methyl, Chlorothalonil and Difenoconazole were evaluated at three different concentrations*viz*., 100, 250 & 500 ppm.

At 100 ppm, after 7 days minimum mycelia growth of test pathogen was found in treatment T2 (Tebuconazole + Trifloxystrobin) having 100% fungal growth inhibition over control, and least effective among all the tested fungicides was T1 (Mancozeb) with having 24.26% fungal growth inhibition when compared with control.At 250 ppm, best treatment with minimum mycelia growth of *M. phaseolina* was found in treatment T2 (Tebuconazole + Trifloxystrobin) having 100% fungal growth inhibition over control, and least effective among all the tested fungicides is T1 (Mancozeb) with having 38.15% fungal growth inhibition when compared with control.At 500 ppm, three fungicide treatments *viz*., T2 (Tebuconazole + Trifloxystrobin), T3 (Fluxapyroxad + Pyraclostrobin) and T6 (Pyraclostrobin + Epoxiconazole) found to be most effective among all the treatments with having 100% fungal mycelia growth inhibition, and least effective among all the tested fungicides is T1 (Mancozeb) with having 65.93% fungal growth inhibition when compared with control (figure-5, table-8). Similar observation was confirmed by Parmar *et al.* (2017) who worked on systemic and non-systemic fungicides at different concentrations (2000, 2500 and 3000 ppm) against castor root rot pathogen *M. phaseolina*. Nagamma*et al.* (2012) also reported that thiophanate methyl, hexaconazole, carbendazim, difenoconazole, propiconazole and mancozeb showed 100 per cent inhibition at 500 ppm.Rahman *et al.* (2021) evaluated fungicidal trials and found that Provax 200WP (Carboxin 37.5% + Thiram 37.5% WP) was the most effective seed-treating fungicide at moderate concentration (150 ppm), while Conza 5% EC (Hexaconazole) and Bavistin 50WP (Carbendazim 50% WP) at the highest concentration were most effective for inhibiting the radial growth of *M. phaseolina* isolate MSP-4**.**

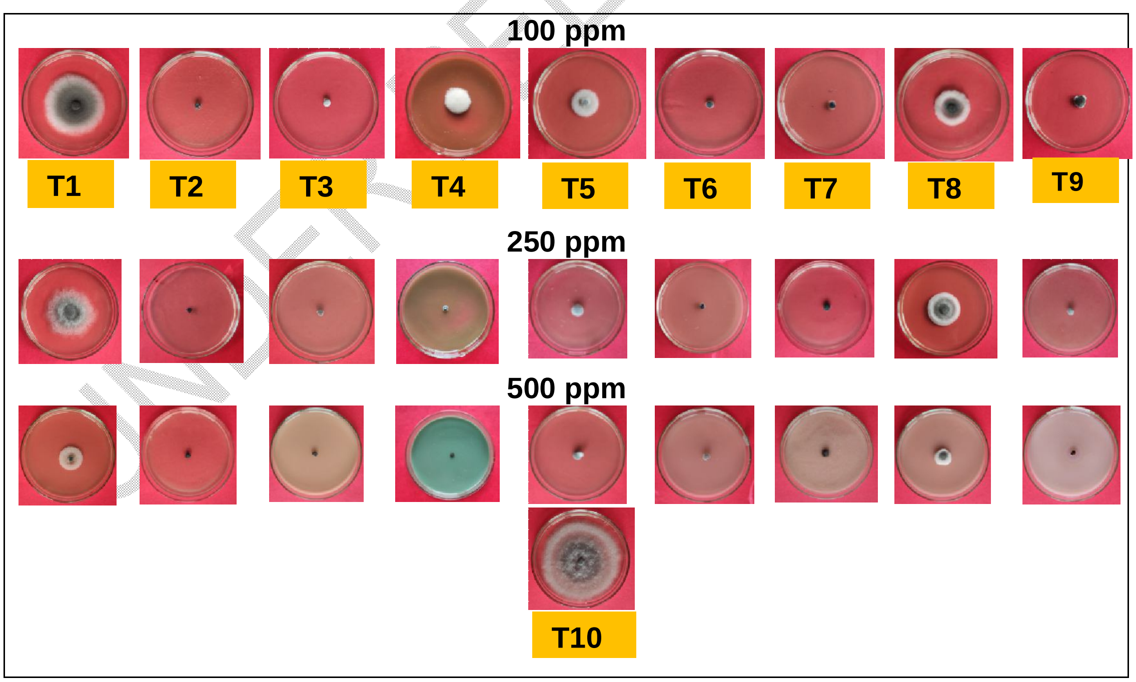

Figure 5- *In vitro* evaluation of fungicides against *M. phaseolina* at 100, 250 and 500 ppm concentration

Table 8- Evaluation of different fungicides against *Macrophominaphaseolina*under *in vitro* condition

Treatment	Treatment Details	100 ppm			250 ppm			500 ppm		
		*Colony diameter (mm)	% inhibition over control	Sclerotia density	*Colony diameter (mm)	% inhibition over control	Sclerotia density	*Colony diameter (mm)	% inhibition over control	Sclerotia density
T1	Mancozeb 75% WP	68.16 (55.97)	24.26	++++	55.66 (48.23)	38.15	+++	30.66 (33.61)	65.93	++
T2	Tebuconazole 50% WG + Trifloxystrobin 25% WG	0.00 (0.00)	100	-	0.00 (0.00)	100	-	0.00 (0.00)	100	-
T3	Fluxapyroxad 167 g/L+ Pyraclostrobin 333 g/L SC	8.00 (15.14)	91.11	+	6.00 (14.16)	93.33	+	0.00 (0.00)	100	-
T4	Carbendazim 12% WP+ Mancozeb 63 % WP	33.33 (35.51)	62.96	+++	29.16 (32.67)	67.60	++	13.33 (21.39)	85.18	++
T5	Hexaconazole 5% SC	28.16 (31.96)	68.71	++	19.16 (25.95)	78.71	++	12.33 (20.53)	86.30	++
T6	Pyraclostrobin 13.3 % SE+ Epoxiconazole 5 % SE	7.33 (15.60)	91.85	+	6.16 (14.36)	93.15	+	0.000 (0.00)	100	-
T7	Mancozeb 50% WG + Thiophenate methyl 25% WG	11.66 (19.71)	87.04	++	9.00 (17.44)	90.00	+	5.33 (13.34)	94.07	+
T8	Chlorothalonil 75% WP	38.50 (38.33)	57.22	+++	37.33 (37.64)	58.52	++	20.66 (27.02)	77.04	++
T9	Difenoconazole 25% EC	15.33 (22.99)	82.96	++	12.50 (20.69)	86.11	++	6.33 (14.55)	92.96	+
T10	Control	90.00 (71.53)	-	++++	90.00 (71.53)	-	++++	90.00 (71.53)	-	++++
CD (p=0.05)		1.086			0.980			1.035		
SE (m) ±		0.366			0.330			0.349		

*Average of *three replications*; *Parenthesis are angular transformed value; No sclerotia (-), poor sclerotia (+), fair sclerotia (++), good sclerotia (+++), excellent sclerotia (++++)*

3.3*In vivo* evaluation of fungicides against *M. phaseolina*

It is evident from the Table-9 that all treatments were found to be superior over untreated control (T10) in reducing the disease incidence and increasing grain yield, B:C ratio and other qualitative parameters during *kharif* 2023 & 2024. Of which, T2 including the seed treatment with Carbendazim 12% WP + Mancozeb 63% WP @ 2 g/kg + foliar application of tebuconazole + trifloxystrobin @ 1.5 g/l was found to be significantly effective by recording the minimum incidence of stem and root rot (20.42%), higher yield (477.28 kg/ha), and highest B:C ratio (1.55) during *kharif* 2023. During year 2024, treatment T2 (tebuconazole + trifloxystrobin) was found best with least disease incidence (21.22%), highest yield (467.99kg/ha), and highest B:C ratio (1.50). Pooled data revealed T2 was best with least disease incidence (20.49%), highest yield (472.53 kg/ha), and highest B:C ratio (1.52) (Figure-6 & Table-9). This result is confirmed by the finding of Thombre and Kohire (2018) who observed good control of *M. Phaseolina* by seed treatment with carbendazim + mancozeb. A similar observation also made by Prasad *et al.* (2022) who conducted field experiments for three years to manage *Macrophomina* root & stem rot disease of sesame by foliar application of fungicides. The experiment was conducted in different seasons for the management of Macrophomina root rot and found that foliar spray with Difenconazole @ 0.05% on 30 and 45 DAS reduced the root rot from 19.03 to 5.73%. Gea*et al.* (2023 also evaluated treatments for disease severity and crop loss and found that of these modules, two sprays of combi-product (Tebuconazole 50% + Trifloxystrobin 25%) @ 0.5 g L-1 first between 30 to 35 days after sowing (DAS) and second between 50 to 60 DAS substantially decreased both *Macrophomina* stem and root rot. Muhammad *et al*. (2017) also conducted management of sesame charcoal rot caused by *M. phaseolina* under field conditions. Nativo exhibited minimum mean disease incidence (12.55%) whereas the interaction between treatments and days showed minimum of 14.95%, 12.82% and 9.90% disease incidences by Nativo as compared to all other treatments including control (66.86%, 77.57% and 87.22%) after ten, twenty and thirty day, respectively under field conditions.

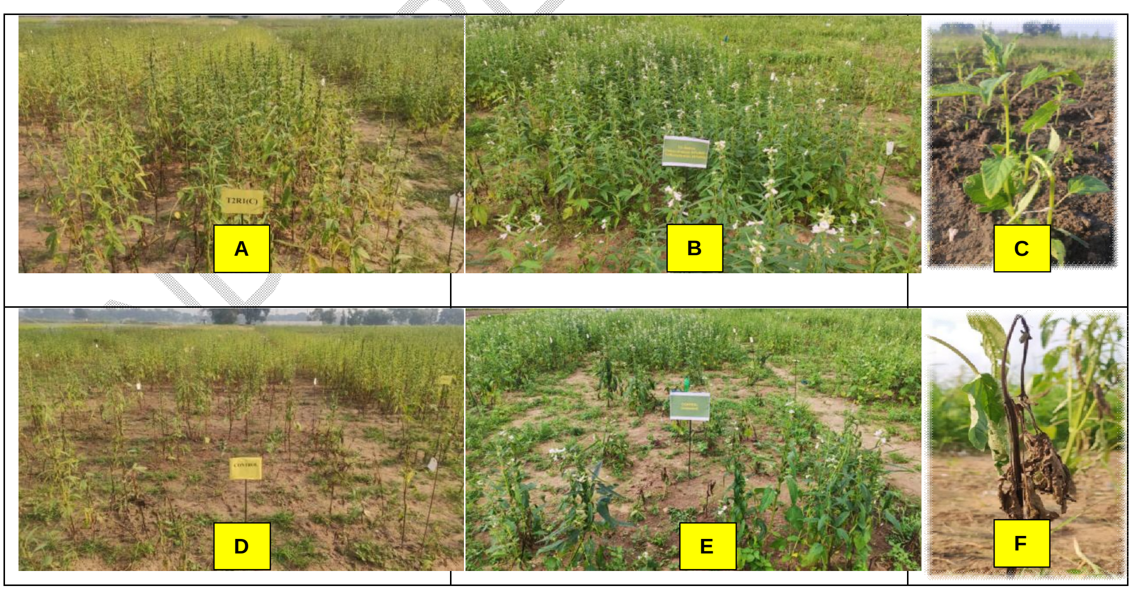

Figure 6- Best treatment plot (A)*Kharif* 2023; (B)*Kharif* 2024), (C) Healthy plant; Control plot (D) *Kharif* 2023; (E)*Kharif* 2024; (F) Diseased plant

Table 9- Evaluation of different fungicides against root & stem rot diseaseunder *in vivo* condition (Disease and Yield parameters)

Treatment	*Percent disease incidence	% disease control	*Percent disease incidence	% disease control	*Percent disease incidence	% disease control	Yield (kg/ha)			B:C ratio
	2023		2024		Average Pooled		2023	2024	Average Pooled	Average Pooled
T1	31.62 (34.11)	35.28	35.30 (36.39)	32.58	33.45 (35.31)	33.90	424.90	411.84	419.550	1.46
T2	20.42 (26.83)	58.20	21.22 (27.22)	59.47	20.49 (26.81)	59.51	477.28	467.99	472.533	1.69
T3	21.99 (27.92)	54.99	23.18 (28.68)	55.72	21.76 (27.77)	57.00	462.87	458.37	463.160	1.20
T4	23.45 (28.90)	52.00	25.59 (30.24)	51.12	24.52 (29.60)	51.55	451.34	445.21	450.867	1.75
T5	27.19 (31.34)	44.35	30.14 (33.23)	42.43	28.66 (32.30)	43.37	436.98	426.06	431.173	1.55
T6	23.43 (28.84)	52.04	24.17 (29.31)	53.89	23.80 (29.10)	52.97	458.80	450.54	455.637	1.25
T7	25.37 (30.19)	48.07	26.61 (30.90)	49.17	25.99 (30.55)	48.64	447.65	439.57	443.913	1.24
T8	29.36 (32.72)	39.90	33.09 (35.05)	36.80	31.22 (33.95)	38.31	428.87	420.28	426.173	1.26
T9	26.12 (30.70)	46.54	28.76 (32.29)	45.07	27.43 (31.56)	45.80	440.57	434.27	438.490	1.32
T10	48.86 (44.32)	-	52.36 (46.34)	-	50.61 (45.33)	-	253.98	234.46	243.690	0.61
CD (p=0.05)	5.231		6.298		4.317		6.066	6.646	5.378	
SE (m) ±	1.747		2.103		1.442		2.026	2.220	1.796	

*Average of *three replications*; *Parenthesis are angular transformed value*

Table 10- Evaluation of different fungicides against root & stem rot diseaseunder *in vivo* condition (Qualitative parameters)

Treatment	Plant Height (cm)			Number of capsule / plant			Number of seeds / capsule			Test Weight (1000 seeds) (g)			Oil content (%)		
	2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled
T1	138.54	137.13	137.83	93.93	91.20	92.56	53.86	51.20	52.53	3.13	3.15	3.14	48.20	48.06	48.13
T2	152.31	151.60	151.95	104.20	102.60	103.40	64.53	63.33	63.93	3.95	3.97	3.96	49.93	49.86	49.90
T3	150.92	149.46	150.19	101.76	102.26	102.03	62.73	62.86	62.80	3.89	3.91	3.90	49.86	49.73	49.80
T4	147.35	146.93	147.14	99.06	98.26	98.66	60.06	59.86	59.96	3.74	3.77	3.75	49.13	48.93	49.03
T5	141.08	140.86	140.97	95.13	93.03	94.08	55.06	55.66	55.36	3.38	3.40	3.39	48.20	48.13	48.16
T6	150.12	149.73	149.92	98.73	98.40	98.56	61.93	61.00	61.46	3.81	3.83	3.82	49.20	49.06	49.13
T7	146.13	145.60	145.86	97.53	95.93	96.73	59.26	59.53	59.40	3.52	3.54	3.53	48.66	48.53	48.60
T8	139.92	138.40	139.16	94.00	92.30	93.15	54.20	53.86	54.03	3.27	3.29	3.28	48.13	48.13	48.13
T9	145.43	143.16	144.30	97.80	94.76	96.28	56.53	57.86	57.20	3.39	3.40	3.39	48.46	48.26	48.36
T10	89.77	86.10	87.93	47.06	45.06	46.06	40.73	39.86	40.30	2.85	2.84	2.84	32.93	31.60	32.26
CD (p=0.05)	6.849	5.457	4.273	6.076	9.517	6.107	5.462	3.628	2.418	0.126	0.154	0.099	0.503	0.707	0.580
SE (m) ±	2.288	1.823	1.427	2.002	3.179	2.039	1.824	1.212	0.808	0.042	0.052	0.033	0.168	0.236	0.194

4. CONCLUSION

Weather conditions play a predominant role in determining the course and severity of disease epidemic. It is concluded that root & stem rot disease incidence was higher during both the years of study. Correlation with weather parameters indicate that disease incidence was considerably influenced by the prevailing weather conditions.High soil temperature, low soil moisture, low relative humidity (evening), less frequent rainfall and less number of rainy days are critical weather parameters and were significantly related with disease incidence during both the years. Regression analysis revealed that there are six regression lines which were obtained for independent variables. Analysis shows that all the weather parameters contributed 99.99 percent and 99.19 percent towards disease development during both the years. Multiple linear regression analysis predicts equation during *kharif* 2023 and 2024and revealed that all the influential weather parameters (independent variables) contribute 99.96 percent (R^2= 0.9953)and 96.04 percent (R^2= 0.9604) towards development of disease incidence (dependent variable). The fungus is greatly influenced by environmental factors and produces the pycnidia when the soil temperature and soil moisture ranges between 25°C to 35°C and below 50 percent respectively. Among all the tested fungicides under *in vitro* condition against *M. phaseolina* at 100, 250 and 500 ppm concentration,Tebuconazole + Trifloxystrobin was found to be most effective having 100 percent inhibition of fungus over control.Under *in vivo* condition average pooled data analysis of revealed that, the seed treatment with carbendazim 12% WP + mancozeb 63% WPfollowed byfoliar application of Tebuconazole + Trifloxystrobin at 45 & 60 DAS was most effective in minimizing disease with 59.51 % disease over the control with yield 478.98 kg/ha and B:C ratio 1.69. .

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