# Management of Brown Spot Disease of Rice and Studies of Growth Rate of Disease on Application of Different Synthetic Fungicides by using Different Statistical Tools

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***Abstract*****—** *The in-vivo test of selected fungicides against brown spot disease of rice and studies on growth rate of disease incidence by using different statistical tools was carried out during the crop seasons, kharif (2014-15) and (2015-16). The pool mean results data of two crop seasons revealed that among the synthetic fungicides evaluated against per cent disease incidence, minimum disease index (PDI) was found in Propiconazole (7.39) with maximum disease reduction of 72.75% over the untreated control followed by Propineb (7.91) and Myclobutanil (8.84) with per cent disease reduction of 70.83 and 67.40 respectively over the control. Among the fungicides treatment maximum disease incidence was observed in Thiophanate (16) followed by Carbendazim (10.96) with per cent disease reduction of 41 and 59.58 over untreated control. The studies on rate of growth of disease severity by using linear and non linear parameters among the synthetic fungicides found that lowest average growth rate during the first crop seasons (2014-15) was observed in Propiconazole (0.124) at 10 days intervals of disease progression analysis studies. Similarly in the following crop season (2015-16) also lowest average growth rate of untransformed and transformed model was observed in Propiconazole (0.069). The analysis thus obviously confirmed that among the different synthetic fungicides tested, Propiconazole was the most effective and most promising fungicides in managing the brown spot disease incidence of rice.*

***Keywords*— Brown spot disease, rice, synthetic fungicides, minimum disease index.**

## I. INTRODUCTION

Rice is a staple food to more than half of the world population around 4 billion people. It is a staple food to two third of Indian (Rout and Tiwari, 2012). It is estimated that 3.4 billion people eat rice everyday (*irri.org/news-and-event/news/scaling-sustainable-rice-farming-practices-achieve-food-security-asia, 2020*).

In terms of global rice production India remained as single second largest country with 118.00 million metric tons and China being world number one with 146.73 million metric tons. (*worldagriculturalproduction.com/crop/rice, aspx, Apr.16, 2020*). Although India held a prominent position in global rice areas and production, the productivity per unit area by world standard is still low with average productivity of about 2.39 t/ha, whereas, in case of China it is 6.71 t/ha. One major factor for low productivity of rice in India is due to pest and disease incidence. Several pathogenic and non pathogenic diseases caused an extensive economic loss to rice crops. The losses due to rice diseases have been estimated to be 10-15% in general (Kandhari, 2005). Among the pathogens, fungi alone account for nearly 30 diseases of rice in the country (Rangaswami *et al.* 2002). The brown spot disease of rice incited by *Helminthosporium oryzae* is one major fungal diseases that caused yield loss of upto 45% when no coverage of plant protection were given.

(*http://www.knowledgebank.irri.org/training/factsheets/pestmanagement/diseases/item/brown-spot*). Brown spot disease of rice has been reported to occur in all rice growing countries including Japan, China, Burma, Sri Lanka, Bangladesh, Iran, Africa, South America, Russia, North America, Philipines, Saudi Arabia, Australia, Malaysia and Thailand, (Ou, 1985; Khalili, *et al*. 2012). In India it was known to occur in all rice growing states but was found more severe in dry and direct seeded rice in the state of Bihar, Chhatisgarh, Madhya Pradesh, Orissa, Assam, Jharkhand and West Bengal (Gangopadhyay, 1983; Sunder, *et al*., 2014).

At present era of agriculture, predominant means of crop protection is the use of chemicals. However, the efficacy of existing pesticides available in the open market always need to be thoroughly evaluated so as to deal effectively with the target pest without loss of time, energy and capital, since most chemicals are costly and its indiscriminate use has also resulted a serious ecological and adverse effect on the human and animal health which has become a major global issue. A judicious application of pesticides needs to be advocate at the highest level through researched an extension activity for monitoring economic losses as well as copping with the environmental issue. Hence, the present work was undertaken to resolve issue of menace of brown spot disease of rice and indiscriminate use of chemical through proper evaluation of selected chemicals by using statistical tools such as, Logistic growth model and Gompertz model.

Disease progress curves over time have been referred to be as the "*signature*" of the epidemic and represent an integration of an all host, pathogen and environmental effects occurring during the epidemic (Campbell and Madden, 1990). A disease progress curve shows the epidemic dynamics over time (Agrios, 2005). This mathematical tool can be used to obtain information about the appearance and amount of inoculums, changes in host susceptibility during growing period, weather events and the effectiveness of cultural and control measures. Growth models provide a range of curves that are often similar to disease progress curves (Van Maanen and Xu, 2003) and represent one of the most common mathematical tools to describe temporal disease epidemics (Xu, 2006). The growth models commonly used are: Monomolecular, Exponential, Logistic and Gompertz (Zadok and Schein, 1979; Nutter, 1997; Nutter and Parker, 1997; Xu, 2006). A brief description of each growth model is presented as follows: Equations with linear parameters from each of four models of Richard's family of growth curves, i.e. monomolecular $(ln[1(1-y)]=ln[1/(1-y_0)]+r_M t$, $logistic(ln[/(1-y)]= ln[y_0/(1-y_0)]+r_L t$,*log-logistic(ln[y/(*log-logistic $logistic(ln[/(1-y)]= ln[y_0/(1-y_0)]+r_L t$ and Gompertz (-ln[-ln(y)] = -ln[-ln(yo)]+ rGt were employed as predicted equations to statistically compare linearly transformed data (Campbell and Madden, 1990; Nutter and Parker, 1997). Variables were: y=Mean severity of disease(S) as a proportion from 0 to 1 at time t, yo=the initial disease level and r*=rate of disease increase for each model. After the regression analysis, goodness of fit of the models was determined by examining the coefficient of determination $R^{2,}$ which is the proportion of the variation in the data accounted for by the variation in the data error of estimates (SEE), and the plot of the standardized residuals versus the predicted values. An $R^2 \geq 80\%$ is the desirable: if $R^2 \leq 50\%$, the model fits the data poorly.

To compare models using different transformation of the dependent variables for goodness-of-fit, predicted transformed y was back-transformed and the co-efficient of determination calculated based on these values ($R^{*2}$) (Campbell and Madden, 1990). Having selected the most suitable models, regression analysis was performed between observed and back-transformed dependent variables. Analysis of variance (ANOVA) was used to reveal any significant difference between the regions in rated parameters.

# II. METHODOLOGY

## 2.1 *In-vivo* test

Field trial was carried out in the experimental plot of Department of Plant Pathology, Allahabad School of Agriculture, SHUATS, Allahabad, U.P., in a consecutive two cropping seasons of kharif (2014-15) and (2015-16) by using a susceptible Manipur paddy cultivar *viz.,* Daram-phou. Field layout were made in Randomized Block Design (RBD) with plot size (2x3) sq. m., a 25 days old seedlings were transplanted with spacing 20 cm (row x row) and 15 cm (plant x plant), with 2-3 seedlings/hill. Five fungicides *viz.,* Thiophanate, Carbendazim, Myclobutanil, Propineb, Propiconazole at 1000ppm were sprayed at 10 days intervals from 48, 58 and 68 days after transplantation of the paddy and when prominent disease symptoms start appearing. Periodical monitoring on fixed plot were performed for obtaining real time data for rice brown spot disease incidence and severity in experimental plots. Observation was made one day ahead of each time of the treatment application and final observation was taken at 10 days after the final or third spray. For measuring disease progress 5 plants per plot were tagged inside of the field borders and one in the centre and top three leaves were taken into consideration in each time of disease rating during observation and data were systematically recorded and maintained as per the standard procedure.

The rating of the disease severity was done by using disease scoring scale of 0-4, based on percentage number of leaves showing symptoms according to Kalloo and Banerjee (2000) [where, 0=No symptoms observed, 1=1-25 % leaf area affected, 2=26-50 % leaf area affected, 3=51-75% leaf area affected and 4=75% and above leaf area affected]. Disease rating was recorded and the percent disease severity was worked out subsequently at every 10 days interval of the growth stage of the crop by following formula (Mc Kinny, 1923):

$$\text{PDI (\%)} = \frac{\text{Summation of numerical ratings}}{\text{Total number of leaves observed} \times \text{Maximum rating grade}} \times 100$$

## III. STUDIES ON GROWTH RATE OF DISEASE ON APPLICATION OF DIFFERENT SYNTHETIC FUNGICIDES

### 3.1 Logistic growth model:

It was proposed firstly by Veshulst in 1838 to represent human population growth. A second type of logistic model was proposed by Van der Plank (1963), being more appropriate for most polycyclic diseases, meaning that there is a secondary spread within a growing season (Forrest, 2007). This growth model is the most widely used for describing epidemics of plant disease (Segarra *et al.*, 2001; Jeger, 2004).

Logistic compound interest: (rate of function)= Ry( l-y),

According to Vander Plank's (1963) equation: dx/dt = QR,

Where, X = the proportion of tissue disease,

R = apparent infection rate,

(l-x) = the proportion of tissue available for infection.

If the total amount of "X" of capital interest varies with time 't', then dt means a very small interval of time, and dx is the very small bit that X increase in that interval. a, k, c, b and 0.05 = constant.

### 3.2 Gompertz model

This growth model is appropriate for polycyclic diseases as an alternative to logistic models. Gompertz model has an absolute rate curve that reaches a maximum more quickly and declines more gradually than the logistic models (Forrest, 2007) shows examples of disease progress curves represented by growth models, where it can be seen that Gompertz and logistic models have a characteristic sigmoid form and an inflection point meaning secondary inoculation or plant-to-plant spread within the crop in contrast to monomolecular model, which does not have inflection point. The exponential model presents a very small value at the beginning comparing with the other models and latter it increases exponentially. In general, growth models that incorporate few variables to describe temporal disease dynamics have a good performance; however, this kind of models sometimes do not satisfy the acquiring process of key characteristics because they frequently ignore relevant variables that affect the epidemic development (Xu, 2006), *e.g.* host growth, fluctuating environmental condition, length of latent and infectious period, etc. Nevertheless, advances in statistical and computing technologies have allowed incorporating several of these kinds of characteristics in order to obtain a more reliable model. It is important to mention that the researchers should be aware of some violations presented in these models by checking if some assumptions about the epidemic are not met and if there are some inevitable violations; they must try to find means to reduce such violations in order to diminish the bias and to correctly interpret results (Xu, 2006). Van der Plank (1960) used exponential, monomolecular and logistic models to describe the development of epidemics. Xu (1999) used a logistic model to forecast and model the apple powdery mildew provoked by *Podosphaera leucotricha*. The work presented by Mersha and Hau (2008) uses logistic and Gompertz models to study the effects of rust bean on host dynamics of common bean in controlled greenhouse experiments with and without fungicide sprays. A deep description of these growth models can be found in the book written by Campbell and Madden (1990).

Gompertz model: X(t)=c exp(-b exp(-at))+e, Where X(t), the disease severity at time t; a, b, c, d the parameters, and e, the error term.

**Software packages used (for growth model):** Curve expert professional

## IV. RESULTS AND DISCUSSION

The results obtained during the course of investigation are presented in the following tables and figures and inferences were made there on:

### 4.1 Efficacy of selected fungicides on per cent disease incidences of brown spot of rice

TABLE 1
SELECTED FUNGICIDES AND PER CENT DISEASE INCIDENCE OF BROWN SPOT OF RICE DURING FIRST CROPPING SEASON (2014-15)

| S. No. | Treatment | PDI crop season (2014-15) | | | | | |
|---|---|---|---|---|---|---|---|
| | | **BS*<br>a** | **AFS*<br>b** | **ASS*<br>c** | **ATS*<br>d** | **Mean (abcd)** | **% Control** |
| 1. | **$T_0$**<br>(Control) | 8.2 | 22.43 | 29.15 | 32.76 | **28.11** | **-** |
| 2. | **$T_1$**<br>(Thiophanate) | 7.8 | 12.01 | 18.17 | 20.91 | **17.03** | **39.41** |
| 3. | **$T_2$**<br>(Myclobutanil) | 9.16 | 6.96 | 11.83 | 11.69 | **10.16** | **63.52** |
| 4. | **$T_3$**<br>(Carbendazim) | 8.6 | 6.91 | 15.01 | 13.33 | **11.75** | **58.19** |
| 5. | **$T_5$**<br>(Propineb) | 8.2 | 4.69 | 10.72 | 10.39 | **8.6** | **69.40** |
| 6. | **$T_6$**<br>(Propiconazole) | 7.8 | 4.44 | 9.92 | 8.94 | **7.76** | **72.39** |
| | **Mean (abcd)** | **8.29** | **9.57** | **15.80** | **16.33** | **12.50**** | - |
| | **S.Ed (±)** | **1.7** | **0.43** | **0.21** | **0.22** | **0.71** | **1.9** |
| | **CD (0.05%)** | **2.03<br>(NS)** | **0.61** | **0.29** | **0.32** | **0.40** | **5.60** |

***Mean value of four replication***
***BS-before spray, AFS-after first spray, ASS-after second spray, ATS-after third spray,***
***bcd-mean PDI value three observation after the spray***
***abcd-mean PDI value of four observation*****
***NS-non significant***

The data presented on Table 2, is the per cent disease incidence of brown spot disease of rice and the selected fungicides at three consecutive schedule of spray at 48, 58 and 68 days and subsequent observation taken at 10 days interval *i.e.* 47, 57, 67 and 77 days after transplanting of the first cropping season (2014-15).

The results data revealed that before the treatment was applied there was no significance different among the treatment and between non treatment control plots concerning disease incidences. However, observation taken at 9 days after the first treatment found per cent disease incidence was lowest in Propiconazole (4.44) followed by Propineb (4.69), Myclobutanil (6.96) and highest incidence was observed in Thiophanate and Carbendzim treatment with per cent disease incidence of (12.01) and (11.01) respectively over the untreated control (22.43). However, all treatment fungicides were found significantly different among themselves and the untreated control. Similarly in the following second and third treatment on each time of observation taken at 9 days after the treatment application it was observed that per cent disease incidence (PDI) was always found lowest in treatment with Propiconazole followed by Propineb and Myclobutanil and maximum disease incidence was observed in Thiophanate and Carbendazim. It is also evident from the mean PDI value of treatment (bcd) that lowest per cent disease index was found in Propiconazole (7.76) with per cent disease control (72.39) followed by Propineb (8.6) and Myclobutanil (10.16) with per cent control (69.40) and (63.52) respectively over control, whereas, maximum per cent disease index was found in Thiophanate (17.03) and Carbendazim (11.75) with per cent disease control of (39.41) and (58.19) respectively over the untreated control. However, in all cases all treatment fungicides were found significantly different among themselves and the untreated control.

### TABLE 2
### SELECTED FUNGICIDES AND PER CENT DISEASE INCIDENCE OF BROWN SPOT OF RICE DURING SECOND CROPPING SEASON (2015-16)

| S. No. | Treatment | PDI crop season (2015-16) | | | | | |
|---|---|---|---|---|---|---|---|
| | | **BS*<br>a** | **AFS*<br>b** | **ASS*<br>c** | **ATS*<br>d** | **Mean<br>(bcd)** | **%<br>control** |
| 1. | $T_0$<br>Control | 9.16 | 20.68 | 26.42 | 31.29 | **26.13** | **-** |
| 2. | $T_1$<br>Thiophanate | 8.32 | 9.21 | 16.36 | 19.37 | **14.98** | **42.67** |
| 3. | $T_2$<br>Myclobutanil | 8.36 | 5.94 | 7.59 | 9.04 | **7.52** | **71.22** |
| 4. | $T_3$<br>Carbendazim | 7.64 | 6.91 | 12.55 | 11.1 | **10.18** | **61.04** |
| 5. | $T_4$<br>Propineb | 7.65 | 4.70 | 8.31 | 8.70 | **7.23** | **73.09** |
| 6. | $T_5$<br>Propiconazole | 8.12 | 4.23 | 8.76 | 8.12 | **7.03** | **73.09** |
| | **Mean (abcd)** | **8.20** | **8.61** | **13.33** | **14.60** | **11.18**** | - |
| | **S.Ed (±)** | **1.32** | **0.17** | **0.22** | **0.19** | **0.19** | **0.75** |
| | **CD (0.05%)** | **3.04<br>(NS)** | **0.51** | **0.68** | **0.57** | **0.58** | **2.32** |

***Mean value of four replication***
***BS-before spray, AFS-after first spray, ASS-after second spray, ATS- after third spray,***
***bcd- Mean PDI value three observation after spray***
***abcd- mean PDI value of four observation*****
***NS - Non significance***

The data presented on Table 2, are selected fungicides on brown spot disease incidence observation taken at 10 days interval *i.e.* 47, 57, 67 and 77 days after transplanting of the second cropping season (2015-16).

The results data revealed that before the treatment was applied there was no significance among the treatment and untreated control plots concerning per cent disease incidence. However, observation taken at 9 days after the first sprayed it was observed that per cent disease incidence was lowest in Propiconazole (4.23) followed by Propineb (4.70), Myclobutanil (5.94) and highest incidence was observed in Thiophanate and Carbendzim treatment with per cent disease incidence of (9.21) and (6.91) respectively over the untreated control (20.68). However, all treatment fungicides were found significantly different among themselves and the untreated control. Similarly in the following second and third treatment and on each time of observation taken at 9 days after the treatment application it was observed that per cent disease incidence (PDI) was always found lowest in treatment with Propiconazole followed by Propineb and Myclobutanil and maximum disease incidence was observed in Thiophanate and Carbendazim. It is also evident from the mean PDI value of treatment (bcd) that lowest per cent disease index was found in Propiconazole (7.03) with per cent disease control (73.09) followed by Propineb (7.23) and Myclobutanil (7.52) with per cent control (73.09) and (71.22) respectively over control, whereas, maximum mean per cent disease index value bcd was found in Thiophanate (14.98) and Carbendazim (10.18) with per cent disease control of (42.67) and (61.04) respectively over the untreated control. However, in all cases all treatment fungicides were found significantly different among themselves and with the untreated control.

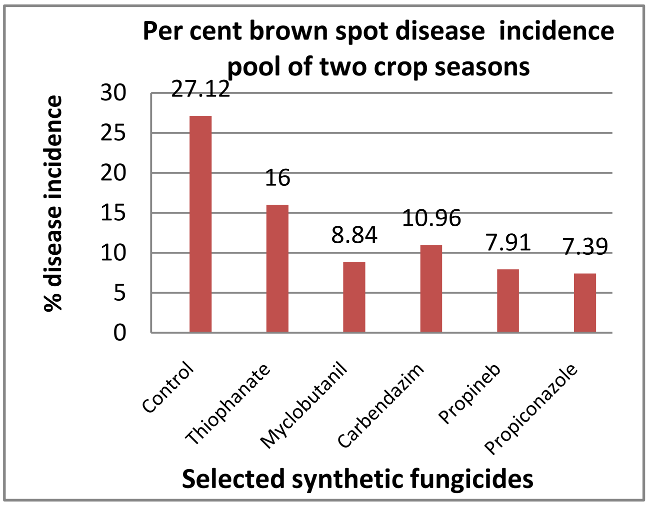

**FIGURE 1: Fungicides and per cent disease incidence pool data of two crop seasons**

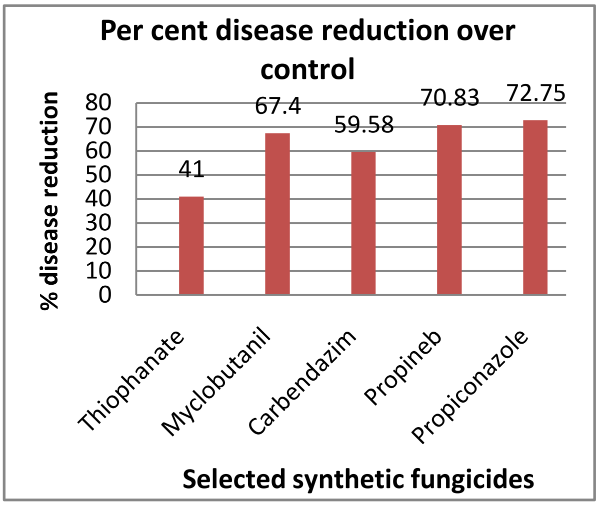

**FIGURE 2: Fungicides and per cent disease reduction over control**

**TABLE 3**
**SELECTED FUNGICIDES AGAINST PER CENT DISEASE INCIDENCE OF BROWN SPOT OF RICE (POOL DATA OF TWO CROPPING SEASONS)**

| S. No. | Treatment | PDI | | Pooled mean | % disease reduction |
|---|---|---|---|---|---|
| | | 2014- 15 | 2015-16 | | |
| 1. | $T_0$<br>Control | 28.11 | 26.13 | 27.12 | - |
| 2. | $T_1$<br>Thiophanate | 17.03 | 14.98 | 16.00 | 41.00 |
| 3. | $T_2$<br>Myclobutanil | 10.16 | 7.52 | 8.84 | 67.40 |
| 4. | $T_3$<br>Carbendazim | 11.75 | 10.18 | 10.96 | 59.58 |
| 5. | $T_4$<br>Propineb | 8.6 | 7.23 | 7.91 | 70.83 |
| 6. | $T_5$<br>Propiconazole | 7.76 | 7.03 | 7.39 | 72.75 |
| | **S.Ed (±)** | **0.28** | **0.19** | **0.23** | **0.21** |
| | **CD** | **0.40** | **0.58** | **0.49** | **0.53** |

The data presented in the above Table 3, and fig. 1&2, is the results data, pooled of two consecutive cropping seasons, kharif (2014-15) and (2015-16) of the selected fungicides treatment against per cent disease incidence and the per cent disease reduction index over untreated control. Among the treatments minimum brown spot incidence was recorded in Propiconazole (7.39) with per cent disease reduction (72.75), followed by Propineb (7.91), Myclobutanil (8.84) with per cent disease reduction (70.83) and (67.40) respectively over the control. Among the treatment fungicides least significant disease incidence was recorded in Thiophanate (16) with per cent disease reduction of (41%) followed by Carbendazim (10.96) with per cent disease reduction (59.58%) over the untreated control with percent disease incidence of (27.12).

The analysis of the above results data of the *in-vivo* test during the crop seasons (2014-15) and (2015-16) revealed that all selected fungicides significantly inhibit the disease incidence in all the three schedule of spray. However, among the treatments highest significant per cent reduction of brown spot disease incidence was recorded in Propiconazole followed by Propineb, Myclobutanil and minimum significant reduction was found in Thiophanate followed by Carbendazim. However, all fungicides were found significantly different in reducing the per cent disease incidence over the untreated control. Our present finding are in corroborate with that of Percich (1989) who reported that foliar application with Propiconazole was found to have better results in management of brown spot disease of rice. Pannu *et al.* (2003) also reported that application of Propiconazole was found most effective against brown spot disease. Moletti *et al.* (1996) reported that application of Iprodione and Propiconazole was most effective against brown spot disease, whereas Celmer *et al.* (2007) reported that

Trifloxystrobin + Propiconazole can effectively control the brown spot diseases of rice. Kumar and Rai (2008) also reported that application of Antracol or Propineb and RIL-FA 200SC can effectively reduced the brown spot incidence of rice. Sunder *et al*. (2010) reported that spraying of Hexaconazole and Propiconazole at early booting stage considerably reduced both leaf spot and stalk rot phase of brown spot disease of rice. The results data also found disease severity was more during the first cropping season 2014-15 as revealed by higher mean PDI value of four observation abcd (12.50**) whereas, in the second cropping seasons (2015-16) with lower mean PDI value of four observation abcd (11.18**).

### 4.2 Analysis on growth rate of brown spot disease incidences of rice in relation to application of different synthetic fungicides

TABLE 4
STUDIES OF DISEASE GROWTH RATE USING DIFFERENT LINEAR AND NON-LINEAR PARAMETERS DURING (2014-15)

| Disease Growth Rate (2015-16) | | | | | | |
|---|---|---|---|---|---|---|
| **Fungicides** | **DS** | **% Disease** | **Arcsine** | **Logit** | **Gompit** | **Average** |
| Thiophanate | 0.684 | 0.006 | 0.567 | 0.052 | 0.061 | 0.274 |
| Myclobutanil | 0.327 | 0.003 | 0.006 | 0.05 | 0.018 | 0.081 |
| Carbendazim | 0.282 | 0.002 | 0.319 | 0.015 | 0.041 | 0.132 |
| Propineb | 0.233 | 0.002 | 0.028 | 0.043 | 0.043 | 0.070 |
| Propiconazole | 0.260 | 0.002 | 0.029 | 0.041 | 0.014 | 0.069 |
| Control | 0.960 | 0.009 | 0.073 | 0.794 | 0.799 | 0.527 |

TABLE 5
STUDIES OF DISEASE GROWTH RATE BY USING DIFFERENT LINEAR AND NON-LINEAR PARAMETERS DURING (2014-15)

| Disease Growth Rate (2014-15) | | | | | | |
|---|---|---|---|---|---|---|
| **Fungicides** | **DS** | **% Disease** | **Arcsine** | **Logit** | **Gompit** | **Average** |
| Thiophanate | 0.596 | 0.006 | 0.561 | 0.067 | 0.026 | 0.251 |
| Myclobutanil | 0.327 | 0.003 | 0.372 | 0.054 | 0.018 | 0.155 |
| Carbendazim | 0.799 | 0.002 | 0.293 | 0.044 | 0.014 | 0.230 |
| Propineb | 0.282 | 0.002 | 0.319 | 0.015 | 0.015 | 0.127 |
| Propiconazole | 0.260 | 0.002 | 0.303 | 0.043 | 0.014 | 0.124 |
| Control | 0.960 | 0.009 | 0.805 | 0.089 | 0.037 | 0.380 |

## V. CONCLUSION

In this present investigation, disease severity data were transformed to determine the disease progression. Disease data were subjected to untransformed disease data and transformed to obtained disease percent, and arcsine, logit and gompit transformation. The growth rate was calculated based on untransformed and transformed of the disease data in order to detect the changes taking place for formulating effective management strategies. It is indicated that Propiconazole (0.124) showed the most effective fungicide among treated chemicals, as indicated by the lowest growth rate was observed among the treated chemicals at ten days intervals of disease progression. Here, it was observed that gompit transformation showed lowest among transformed, and it was confirmed that the disease severity growth rate of the target pathogens can be predicted. Considering all the models, the most effective fungicide in minimizing the spread of disease and its severity were observed in Propiconazole treatment. Similarly, in the following year (2015-16) the most promising fungicide showing lowest growth rate was propiconazole as was in the previous year (2014-15), obviously as indicated by the average growth rate values from untransformed and transformed models being observed lowest in propiconazole treatment (0.069) as depicted in Table-3 and Table-4 respectively. Disease progress curves exploiting growth model, described the disease progress in a good way with few weathers factors (Xu, 2006). The disease data subjected on transformed to investigate disease progression was also reported by Gompertz (Kranz, 1974; Berger, 1981) and the logistic transformation (Vander plank, 1963). Plant disease progress was described for Comparison of the Gompertz and logistic equations (Berger, 1981). Similarly, Logistic and

Gompertz models with and without fungicide sprays was also reported to study the effects of rust of bean on host dynamics of common bean in controlled Greenhouse experiment (Hau, 2008). Similar observations have been reported earlier for other patho systems such as wheat leaf rust (Hau and Kranz, (1977), apple scab (Analytis, 1979) and groundnut rust (Das and Raj, 2000).

## REFERENCES

[1] Agrios, G. N. (2005). Plant Pathology. Fifth Edition, Elsevier Academic Press, London,UK.

[2] Analytis, S., (1979). Die transformation Van Befallswerten in der quantitative phytopathology. IF Das Liverisie ren von Befallskurven. *Phytopath Z.* **96**: 156-171.

[3] Berger, R. D., (1981). Comparison of the Gompertz and logistic equations to describe plant disease progress. *Phytopathology*, ***71*,** 716–719. doi:10.1094/Phyto-71-716

[4] Campbell, C. L. and Madden, L. V. (1990). Introduction to plant disease epidemiology. John Wiley & Sons, New York, pp 532.

[5] Celmer, A., Madalosso, M.G., Debortoli, M.P.,Navarini,L. and Balardin,R.S., (2007). Chemical control of irrigated rice diseases. *Pesquisa Agropecuaria Brasilleira*. 42: 901-9046.

[6] Chakrabarty, S., Tiedemann, A.V. and Teng, P. S., (2000). Climate change: potential impact on plant diseases. *Environmental Pollution,* 108**:** 317-326.

[7] Chattopadhyay, C., Meena, P.D., Godika, S., Yadav, M.S., Meena, R.L. and Bhunia, C.K. (2005). Garlic bulb extracts a better choice, than chemical fungicides in managing oilseed crop diseases. *J. Mycol. Pl. Pathol*. 35: 574-575.

[8] Dasgupta, M.K. and Chattopadhyay, S.B., (1977). Effect of different doses of N and P on the susceptibility of rice to brown spot caused by *Helminthosporium oryzae*. *Z. Pftanzenkrankh. Pftlanzensch*. 84**:** 276-285

[9] Das, S. and Raj, S.K. (2000). Comparison between Logistic and Gompertz equation for predicting groundnut rust epidemics. *Indian Phytopath*. **53**: 71-75.

[10] Forrest, B.M., (2007). Managing risks from invasive marine species: is post-border management feasible? PhD Thesis, Victoria University of Wellington, Wellington, New Zealand

[11] Gangopadhyay, S., (1982). Current concepts on Fungal Diseases of Rice. Today and Tomorrow's Printers & Publishers, New Delhi, 349pp.

[12] Ghose, R.L.M., Ghatge, M.B. and Subramanian, V., (1960). Rice in India (revised edn.), New Delhi, ICAR, 474pp.

[13] Hau, B. and Kranz, J., (1977). Ein vergleich Vershiedener transformation en von Befallskurven. *Phytopath Z.* **88:** 53- 68.

[14] Khalili, E., Sadravi, M., Naeimi, S. and Khosravi,V.,(2012). Biological control of rice brown spot with native isolates of three trichoderma species. *Braz. J. Microbiol*. 43**:** 297-305

[15] Kranz, J., (1974). The role and scope of mathematical analyse and Modelling in epidemiology. In Epidemics and Plant Diseases, Mathematical analysis and Modelling (Ed. J. Kranz), pp. 7-54 Sringer, New York. 170pp.

[16] Kranz, J. and Royle, D.J., (1978). Perspectives in mathematical modelling of plant disease epidemics,in plant disease epidemiology . Scott PR and Bainbridge A(eds). Blackwell Scientific Publications. Oxford, London, Edingburgh, Melbourne. pp111-120

[17] Kumar, S. and Rai, B., (2008). Evaluation of new fungicides and biopesticides against brown spot of rice. *Indian Agriculturist* 52:117-119

[18] Mc kinney, H.H., (1923). A new system of grading plant diseases. *J. Agric. Res.,* 26: 195-218

[19] Mersha, Z. and Hau, B., (2008). Effect of bean rust (*Uromyces appendiculatus*) epidemics of host dynamics of common beans (*Phaseolus bulgaris*). *Plant Pathol.,* **57:** 674-686.

[20] Molletti, M., Giudici, M.L. and Villa, B., (1996). Rice Akiochi brown spot disease in Italy: agronomic and chemical control. *Informators Fitopathologico.* 46**:** 41-46

[21] Nutter FW, and Parker, SK., (1997). Fitting disease progressive curved EPIMODEL. In exercise in plant disease epemiology . fraci. IJ and Neher DA (eds). APS press, St. Paul, MN, USA, pp.24-28

[22] Ou, S.H. (1985). Rice diseases 2nd edn. CMI, Kew, England, 370pp

[23] Pannu,P.P.S., Mandeep Kaur and Chahal, S.S. (2003).Evaluation of different fungicides against *Helminthosporium oryzae* in vitro and in-vivo conditions. *J.Mycol.Pl.Pathol*. 33: 473 (abstr.)

[24] Percich, J.A., (1989). Comparison of Propiconazole rates for control of fungal brown spot of wild rice by Bipolaris oryzae in the growth chamber. *Plant Dis.* 73**:** 588-589

[25] Pico, A.M. and Rodofil , M., (2002). Pyricularia grisea and Bipolaris oryzae: a preminary study on the occurrence or airborne spores in a field. Aerobiology, 18(2):163-167.[doi: 10.1023/A:102654319130]

[26] Rangawami, G. and Mahadevan, A, (2002): Diseases of crop plants in India, fourth edition IEEE, pp160.

[27] Segarra, J., Jerger, M.J., Van den Bosch, F., (2001). Epidemic dynamics and patterns of plant diseases. *Phytopathology*, 91:1001-1010.

[28] Sangeetha, C.G. and Siddaramaiah, A.L., (2007). Epidemiological studies of white rust downy mildew and Alternaria blight of Indian mustard *(Brassicae juncea* (Linn). (Zern. and loss).*AfricanJ.Agril.Res*.2**:** 305-308.

[29] Sasaki, T. and Burr, B. (2000). International rice genome sequence project: The effort to complete the sequence of rice genome. Current opinion in plant Biology; 3:2, pp138-141

[30] Scherm, H. and Yang, X. B., (1995). Interannual variations in wheat rust development in China and the United States in relation to the El Nino/Southern Oscillation. *Phytopathology,* 85: 970-976

[31] Schoeny,A. Jumel,S. Rouault, F., May, Le C. and Tivoli, B., (2007). Assessment of airborne primary inoculums availability and modelling of disease onset of Ascochyta blight in field peas. *Eur. J. Plant Pathol*. 119**:** 87-97.

[32] Singh Chhidda, Singh Prem., and Singh Rajbir, (2008). Modern Techniques of Raising Field Crops, Second Edn. Pp.68-73

[33] Singh, R. K., Singh, C. V., & Shukla, V. D., (2005). Phosphorus nutrition reduces brown spot incidence in rainfed upland rice. *International Rice Research Notes,* 30(2): 31–32.

[34] Sunder, S., Singh, R. and Dodan,D.S., (2010). Evaluation of fungicides, botanicals and non conventional chemicals against brown spot of rice. *Indian Phytopath.* **63:**192-194

[35] Sunder. S, Ram Singh and Rashmi Agarwal, (2014). Brown spot of rice: an over view. *Indian Phytopath.* 67(3): 201-215

[36] Sutherst, R.W., (1993). Role of modelling in sustainable pest management. In: Pest control and sustainable agriculture. Corey S, Dall D and Mine W (eds.) CSIRO, Australia, pp.66-71

[37] Taylor MC, Hardwick NV, Bradshaw NJ, Hall AM. Relative performance of five forecasting schemes for potato late blight (*Phytophthora infestans*) I. Accuracy of infection warnings and reduction of unnecessary, theoretical, fungicide applications. *Crop Protection*. 2003;22:275283.doi:10.1016/S0261-2194 (02) 00148-5[Cross Ref.]

[38] Van der plank, J.E., (1963). Plant disease epidemics and control. Academic Press. New York. 349pp.

[39] Van der plank, J.E., (1960). Analysis of epidemics. In: Plant pathology. Horsefall J G and Cowling EB (eds). Academic Press, New York, USA.pp.230-287

[40] Van Maanen, A., and Xu, X.M., (2003). Modelling plant disease epidemics, European J.Plant Pathol. **109:** 669-682.

[41] Xu, (2006). Modelling and interpreting disease progress in time. In: The epidemiology of plant disease. Cooke BM, Gareth Jones D and Kaye B (eds) Springer, Dordrecht, The Netherlands, pp. 215-238.

[42] Zadoks,J.C., and Shein,R.D., (1979). Epidemiology and plant disease management. Oxford, New York. 427pp.