Measuring and assessing the yield loss and yield loss model of green gram due to Anthracnose of green gram (*Vigna radiata*)

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ABSTRACT

Anthracnose of green gram caused by *Colletotrichum truncatum* (Schwein.) Andrus & W.D. Moore occurs severely in Indo-gangetic plains every year. Experiment was conducted for two consecutive years (2013 and 2014) to assess yield losses to develop yield loss models. The linear regression models were developed by two parameters i.e. percent yield loss and avoidable yield loss as dependant variable and area under disease progress curve (AUDPC) as independent variable. The two years pooled mean revealed that a drop of 0.3 to 0.33 qha\(^{-1}\) in pod yield and a drop of 0.16 to 0.20% in avoidable yield loss of pod yield due to every 1% increase in AUDPC. Three sprays of Propiconazole 25 EC (0.1%) at 10 days interval beginning from 20 days after sowing resulted in lowest anthracnose under moderate disease pressure and four sprays for high disease pressure resulted in highest pod yield of 5.17q/ha and 5.08q/ha respectively. Highest avoidable losses of pod yield and percent yield loss over potential yield due to anthracnose were 48.82% and 3.55% for three sprays and 49.74% and 1.77% for four sprays respectively. The result also showed that three sprays of fungicide (Propiconazole 25 EC @ 0.1%) resulted in minimizing the disease and maximizing the profit by high benefit cost ratio (B:C) ratio.

Key words: Anthracnose, AUDPC, Green gram, Yield loss, Yield loss model.

INTRODUCTION

Green gram (*Vigna radiata* (L.) Wilczek) is an important legume crop in India, occupying about an area of 34.4 lakh hectares with 14.89 lakh tones production and 406.98 kg/hectares productivity (Anonymous, 2012). Production of this crop however is reduced due to number of foliar diseases of which anthracnose caused by *Colletotrichum truncatum* (Schwein.) Andrus & W.D. Moore, is an important disease which causes qualitative as well as quantitative losses (Sharma *et al*., 1971). Anthracnose is the main cause of yield loss induced by pathogens in this crop if left uncontrolled. Losses in yield due to anthracnose have been estimated to be in the range of 24 to 67 per cent (Deeksha and Tripathi, 2002). Even disease may reach upto 18.2 to 86.57% severity which reported from northern Karnataka (Laxman, 2006). Loss can be suggested with proportional to integral of disease severity over the duration of epidemic (Vanderplank, 1963). So the area under disease progress curve (AUDPC) used as predictor of yield losses (Shtienberg, 1990). Altogether the methods of estimating the yield (or yield) due to disease by means of statistical analysis in down scale and their implementation in different locations produced inaccurate loss prediction. But only limitation of this experiment is that, it may be inappropriate if many pathogens active together simultaneously. But for green gram, Anthracnose was only foliar diseases infected both leaves and pods. However, exact information on the extent of losses and benefit of crop protection due to anthracnose disease is not known. The purpose of present study was undertaken to know the relationship between disease severity and seed yield and estimation of the loss in the field due to different AUDPC and number of sprays of fungicide required for economic production with low disease in different levels of inoculums pressure of *Colletotrichum truncatum* responsible for anthracnose on greengram.

MATERIALS AND METHODS

Experimental details: The field experiments were carried out at ‘Instructional Farm’ of Bidhan Chandra Krishi Viswavidyalaya (BCKV) at Jaguli, Nadia, West Bengal, India during 2013 and 2014. The susceptible Sonali variety was sown on 10th August in each year in 5m x 5m plots keeping a spacing of 30-45 x 10 cm row to row and plant to plant in a randomised block design with three replications. All the recommended practices for tillage, irrigation and manuring with 20 N; 50 P; 40 K kg/ha\(^{-1}\) was followed.

Treatment details: Five numbers of sprayings of fungicide Propiconazole (0.1% a.i.) was used as five treatments with a no fungicide spraying as treated control. The sprayings were started from 20 days after sowing irrespective of disease appearance due to the assumed severe incidence of the disease in every year. The details of the treatment were: \(T_{0}\)= one spray (at 20days after sowing); \(T_{1}\)= two sprays (at 20 and 30 DAS); \(T_{2}\)= Three sprays at 20, 30 and 40 DAS; \(T_{4}\)=...
Four sprays at 20, 30, 40 and 50 DAS; \( T_5 \); Five sprays at 20, 30, 40, 50, and 60 DAS; and \( T_e \), no fungicide spray (Water spraying).

**Disease scoring:** The disease was recorded at different crop growth stages viz. 25, 32, 39, 46, 53 and 60 days after sowing (DAS). The intensity of the disease was recorded by scoring all the individual plants selected (10 plants/replication) at random in each treatment using 0-9 scale (Mayee and Dattar, 1986). Further the PDI was calculated by using the following formula (Wheeler, 1969).

\[
\text{Percent Disease Index (PDI)} = \frac{\text{Sum of all numerical ratings}}{\text{Total number of leaf observed} \times \text{maximum rating}} \times 100
\]

**AUDPC calculation:** The disease severity records were averaged over the three replications and disease progress curves were plotted. For each replication, the areas under disease progress curves (AUDPC) were calculated by using the following formula (Wilcoxon et al. 1975).

\[
\text{AUDPC} = \sum_{i=1}^{N} \frac{X_{i+1} + X_i}{2(X_{i+1} - X_i)}
\]

where \( Y_i = \) severity at \( i \)-th observation, \( X_i = \) Time (days) at first observation, \( N = \) Total number of observation

The correlation between AUDPC vs. avoidable loss in seed yield were calculated using linear regression models as per Mahapatra and Das (2016).

**Yield loss and avoidable yield loss assessment:** Crop was harvested after maturity at 75 days after sowing. The seed yield of net plots (kg ha\(^{-1}\)) was recorded during harvest. Overall efficiency and economics of these treatments in managing this disease were worked out by comparing their mean disease severity as AUDPC, seed yield, additional net income and cost-benefit (C:B) ratio. The avoidable yield loss (ALY) due to this disease was calculated using seed yield from the fungicidal spraying trials by using following formula: (Walker 1983)

\[
\text{ALY} = \frac{\text{YP}-\text{YU}}{\text{YP}} \times 100
\]

Where \( \text{YP} = \) yield under protected condition, \( \text{YU} = \) yield under unprotected condition, whereas for yield loss the following formula was used, percent (%) yield loss= \( \frac{[\text{YP} - \text{YU}]}{\text{YU}} \times 100 \), \( \text{YU} = \) potential yield, \( \text{YP} = \) yield when percent disease index is \( x \).

**Calculation of B:C ratio:** Benefit cost (B:C) ratio was calculated using formula and following the work done by Mahapatra and Das 2017.

\[
\text{B:C ratio}= \frac{\text{additional income from protection}}{\text{cost of protection}}
\]

**Linear regression model:** Avoidable crop loss models of anthracnose of greengram were developed using simple linear regression functions in the form of \( Y = bx \) with \( Y \) as yield in kilograms and grams and \( x \) AUDPC. The square of the correlation co-efficient (\( r \)) known as coefficient of determination (\( R^2 \)) was calculated to know the extent to which the model is capable of explaining the relation between yield and the AUDPC (Mahapatra and Das 2016).

**Statistical analysis:** The experimental results were statistically interpreted through calculating the ‘Analysis of Variance’ by standard method of Error mean square by Fisher and Syndecor’s F test at probability level 0.05. For determination of critical difference (CD at 5% level significant) Fisher’s and Yates’s table were consulted.

**RESULTS AND DISCUSSION**

The relationship between disease severity and grain yield of green gram were achieved with repeated disease severity measurements.

**Assessment of effect of Anthracnose disease on yield of greengram:** The results revealed that AUDPC was maximum in control plots (no spray) in comparison to treated plots sprayed with fungicide in both the years and their pooled mean (Table 1). The differences in AUDPC in different plots

| Table 1: Area under disease progress curve of Anthracnose of greengram in different spraying schedule during kharif: 2013, 2014 and pooled mean. |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| No. of Propiconazole sprays | AUDPC (A) | Percent reduction of (A) value over control |
| 2013 | 2014 | Pooled | 2013 | 2014 | Pooled |
| \( T_1 \) | 536.56 | 537.76 | 537.16 | 24.26 | 24.87 | 24.56 |
| \( T_2 \) | 497.77 | 498.30 | 498.03 | 29.73 | 30.38 | 30.06 |
| \( T_1 \) | 484.10 | 484.46 | 484.28 | 31.66 | 32.32 | 31.99 |
| \( T_e \) | 476.58 | 477.18 | 476.88 | 32.72 | 33.33 | 33.03 |
| \( T_e \) (control no spray) | 398.80 | 398.15 | 398.48 | 43.70 | 44.37 | 44.04 |
| S.Em ± | 1.25 | 1.04 | 0.81 | - | - | - |
| C.D. at 5% | 3.83 | 3.18 | 2.37 | - | - | - |

\( T_1 \), one spray (at 20days after sowing); \( T_2 \), two sprays (at 20 and 30 DAS); \( T_e \), Three sprays at 20, 30 and 40 DAS; \( T_{ve} \), Four sprays at 20, 30, 40 and 50 DAS; \( T_{ve} \), Five sprays at 20, 30, 40, 50, and 60 DAS; and \( T_e \), no fungicide spray (Water spraying).
within number of applications of fungicide were statistically significant. The reduction in the disease severity was to the extent of 43.70 % for the year 2013 and 44.37% for 2014 and 44.04% in pooled mean when sprayed with five number of sprays followed by four sprays 32.72%, 33.33% and 33.03%, respectively. While it was less in plots receiving one and two sprays. It was indicated that minimum AUDPC was recorded in the plots receiving five number of spraying (398.48) followed by four spraying (476.88) and maximum was noticed in one spray (537.16) followed by two sprays (498.03) and their differences were statistically significant (Table 1). Similarly maximum reduction in disease in plots receiving five sprays followed by four and decreased as the reduction of number of sprays as in one spray and two sprays and so on (Table 1).

The result of the experiment clearly indicates that five numbers of fungicial sprays on the susceptible variety like Sonali, reduce the disease levels significantly. These findings are in agreement with those of Mahapatra and Das (2017), who reported the reduction in AUDPC values of Alternaria leaf blight in mustard with increased number of Iprodione sprays. Shukla et al. (2014) suggested that two sprays of Carbenzazim (0.1%) were sufficient to manage the disease severity. Similar views were also confirmed by Mahapatra and Das (2013) in Alternaria leaf blight of mustard, Deeksh and Tripathi (2002) in urdbean and Laxman (2006) in greengram and Lal et al. (2014) in late blight of potato.

**Relationship between AUDPC and yield by linear regression:** The correlation between seed yield vs. disease severity (Area under disease progress curve AUDPC) and disease severity vs. avoidable loss in seed yield were calculated using linear regression analysis and the model was developed.

Disease severity (AUDPC) and seed yield relationship was negatively correlated and the correlation coefficient (r) for the two consecutive years (2013-2014) and pooled means were r = -0.95; -0.91 and -0.94 respectively. The coefficient of determination (R$^2$) for the two different years and pooled mean were R$^2$ =0.90; 0.83 and 0.87, respectively showed a high goodness of fit for linear regression. The equations were: Y=11.22 - 0.30x (2013); Y=10.73 - 0.33x (2014) and Y=11.03 - 0.32x (pooled mean). It indicated that attainable seed yield were 11.22 q ha$^{-1}$ 10.73 q ha$^{-1}$ and 11.03 q ha$^{-1}$, respectively and a drop of 0.30 to 0.33 q ha$^{-1}$ due to every 1 % unit increase in AUDPC (Fig 1).

In case of avoidable loss in yield the correlation coefficient values (r) was r = - 0.95, for the two years and in pooled mean and the coefficient of determination (R$^2$) was also R$^2$ = 0.91. The equations were Y= 117.0- 0.161x; Y= 148.9-0.204x and Y= 131.7-0.181x for the two years and pooled mean respectively. It indicated the avoidable loss in seed yield were 117 to 148.9% for the two years and 131.7% in pooled mean and a drop of 0.161 to 0.204% avoidable loss in grain yield can be reduced due to every 1 % decrease in AUDPC (Fig 2).

The loss model will play a vital role in the prediction and forecasting of loss due to the disease which is prerequisite for determining decision in threshold and deployment of cost effective management practices. Similar types of results were reported by Saha and Das (2013) in tomato and Mahapatra and Das (2016) in mustard.

**Assessment of yield loss:** Spraying of fungicides resulted in significant increase in the seed yield of mungbean for both the years (2013 and 2014) and in pooled mean. In the year 2013 and 2014, significantly higher yields were recorded from plots sprayed with five and four times, which were attributed to the lower disease index in these treatments. Maximum yield were obtained on five sprays 5.70, 4.84 and 5.27 qha$^{-1}$ for the year 2013, 2014 and followed by four 5.59, 4.76 and 5.17 qha$^{-1}$ for the two years mean and in pooled mean respectively and three sprays for both the years and in pooled mean and their differences were statistically significant. Minimum seed yield was observed in one spray plots 3.98, 2.57 and 3.28, respectively followed by two sprays of 5.48, 4.48 and 4.98 qha$^{-1}$ and their differences were statistically significant (Table 2).

### Table 2: Loss assessment due to anthracnose of greengram in grain yield (q/ha) for the year 2013 and 2014.

<table>
<thead>
<tr>
<th>No. of Propiconazole sprays</th>
<th>Grain yield (q/ha)</th>
<th>Avoidable yield loss (%)</th>
<th>Percent yield loss over potential yield (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2013</td>
<td>2014</td>
<td>Pooled</td>
</tr>
<tr>
<td></td>
<td>2013</td>
<td>2014</td>
<td>Pooled</td>
</tr>
<tr>
<td></td>
<td>2013</td>
<td>2014</td>
<td>Pooled</td>
</tr>
<tr>
<td>T$_1$ (control no spray)</td>
<td>3.15</td>
<td>2.05</td>
<td>2.60</td>
</tr>
<tr>
<td>S.Em ±</td>
<td>0.05</td>
<td>0.03</td>
<td>0.02</td>
</tr>
<tr>
<td>C.D. at 5%</td>
<td>0.16</td>
<td>0.09</td>
<td>0.06</td>
</tr>
<tr>
<td>T$_2$ one spray (at 20days after sowing)</td>
<td>4.48</td>
<td>4.98</td>
<td>42.47</td>
</tr>
<tr>
<td>T$_3$ two sprays (20 and 30 DAS)</td>
<td>5.52</td>
<td>4.64</td>
<td>42.97</td>
</tr>
<tr>
<td>T$_4$ three sprays at 20, 30 and 40 DAS</td>
<td>5.59</td>
<td>4.76</td>
<td>43.65</td>
</tr>
<tr>
<td>T$_5$ four sprays at 20, 30, 40, 50 and 60 DAS</td>
<td>5.70</td>
<td>4.84</td>
<td>44.70</td>
</tr>
<tr>
<td>T$_6$ five sprays at 20, 30, 40, 50, 60 DAS; T$_7$ no fungicide spray (Water spraying)</td>
<td>5.70</td>
<td>4.84</td>
<td>44.70</td>
</tr>
</tbody>
</table>
The two years pooled mean showed that with increase in number of sprays, there was an increase in avoidable loss in yield over untreated control. Maximum avoidable yield loss was recorded in the five sprayed plots (50.63%) followed by four sprays (49.74%) and three sprays (48.82%). Minimum avoidable loss in yield was recorded in single spray (20.73%) followed by two sprays (47.75%).

The losses in yield over maximum number of sprays (five sprays) were different in two different years and also in pooled mean. In both years, the loss was maximum in untreated control and minimum in the plots receiving five numbers of sprays.

Therefore, the result of two years of field studies proved that in a susceptible variety (Sonali) four sprayings of propiconazole (0.1%) are sufficient to manage the anthracnose of mungbean and realize economic yields. The disease incidence was higher in control plots than fungicide applied plots, thus indicating relationship between the diseases and also yield (Kulkarni, 2009). These findings are in accordance with the reports of Bharadwaj and Thakur.

### Table 3: Benefit: Cost ratio in loss estimation study due to Anthracnose as influenced by the number of fungicial sprays.

<table>
<thead>
<tr>
<th>Spray No.</th>
<th>Cost of fungicides (Rs.)</th>
<th>Labour cost/ha (Rs/ha)</th>
<th>Total cost/ha (Rs/ha)</th>
<th>Additional increase in yield over control (q/ha)</th>
<th>Additional benefits (Rs.)</th>
<th>Benefit: Cost ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>250</td>
<td>386</td>
<td>636</td>
<td>0.67</td>
<td>3000.00</td>
<td>4.72</td>
</tr>
<tr>
<td>2</td>
<td>500</td>
<td>772</td>
<td>1272</td>
<td>2.33</td>
<td>10485.00</td>
<td>8.24</td>
</tr>
<tr>
<td>3</td>
<td>750</td>
<td>1158</td>
<td>1908</td>
<td>2.37</td>
<td>10665.00</td>
<td>5.59</td>
</tr>
<tr>
<td>4</td>
<td>1000</td>
<td>1544</td>
<td>2544</td>
<td>2.44</td>
<td>10980.00</td>
<td>4.32</td>
</tr>
<tr>
<td>5</td>
<td>1750</td>
<td>2702</td>
<td>4452</td>
<td>2.55</td>
<td>11475.00</td>
<td>2.58</td>
</tr>
</tbody>
</table>

**Cost of protection:**

- Efficacy of sprayer, 5000 m²/day; rent of sprayer, Rs. 50.00/day, Labour charges Rs. 100/day.
- Cost of fungicide: Rs. 50/100ml
- Per hectare: Rs. 250
- Labour cost/spray/ha: Rs. 193
- No. of labours: 2 (male)
- Grain value: Rs. 4500/q

The two years pooled mean showed that with increase in number of sprays, there was an increase in avoidable loss in yield over untreated control. Maximum avoidable yield loss was recorded in the five sprayed plots (50.63%) followed by four sprays (49.74%) and three sprays (48.82%). Minimum avoidable loss in yield was recorded in single spray (20.73%) followed by two sprays (47.75%).

The losses in yield over maximum number of sprays (five sprays) were different in two different years and also in pooled mean. In both years, the loss was maximum in untreated control and minimum in the plots receiving five numbers of sprays.

Therefore, the result of two years of field studies proved that in a susceptible variety (Sonali) four sprayings of propiconazole (0.1%) are sufficient to manage the anthracnose of mungbean and realize economic yields. The disease incidence was higher in control plots than fungicide applied plots, thus indicating relationship between the diseases and also yield (Kulkarni, 2009). These findings are in accordance with the reports of Bharadwaj and Thakur.
It was also reported that the grain yields varied from 7.75 to 10.9 q/ha in protected plots and the disease intensity was also low in plots receiving two sprays of fungicides (Shukla et al., 2014). The present study also emphasizes that the treatment cost involved in the use of fungicides must be taken into consideration while selecting the fungicides for the effective and economical control.

**Benefit cost ratio:** Higher benefits (B:C) were recorded in treatments getting two number of Propiconazole (0.1%) spraying (8.42) followed by three sprays (5.85) and four sprays (4.55). The cost-benefit ratio of different fungicidal sprayings were 4.20, 8.42, 5.85, 4.55, 2.70, respectively (Table 3).

Thus, it may be inferred that two sprays of Propiconazole (0.1%) in green gram crop are essential to obtain maximum yield when disease pressure is moderate or less. Whereas, when disease pressure is very high four sprays of Propiconazole (0.1%) are necessary in pulse growing areas of West Bengal. This is in agreement with the earlier report of Deeksha and Tripathi (2002a) and Shukla et al. (2014).

**REFERENCES**


