# ASSESSMENT OF LOSSES DUE TO INCIDENCE OF PESTS AND DISEASES ON RICE CROP

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## 1. INTRODUCTION

It is believed that an appreciable loss of crops results from pest and disease incidence. However, reliable and objective estimates of such incidence and consequent crop losses are generally not available. This information will be very useful for planning effective and economic control measures. The complicated nature of measurement and sampling techniques for estimation of pest and disease incidence and the difficulty to establish yield loss relationship with such incidence might have been the main reason for inadequate work in this field. The object of this paper is to present the results obtained in a pilot investigation carried out in cultivators' fields to estimate pest and disease incidence on rice crop, and consequent crop losses. Although the techniques employed need further testing and the results achieved have to be corroborated by data from more areas, it was thought that the results are of sufficient interest to be presented, so that this may be utilised for further work in this field.

## 2. SURVEY DESIGN

The survey was carried out in Cuttack District of Orissa State on the main crop paddy. For the purpose of the survey, the district was stratified into 10 strata by grouping together adjoining *thanas* (a police circle consisting of about 200 villages on an average). Generally each stratum thus formed consisted of about 3 or 4 *thanas*. Care was taken to make the stratum agriculturally as homogeneous as possible. In each stratum six villages were selected at random and in each selected village, a simple random sample of 4 rice growing fields were taken, using the list of serial numbers of fields in the village. In each such selected rice field, sampling observations were taken on the incidence of pests and diseases periodically.

## 3. Sampling and Measurement Techniques Adopted for Observation in the Field

In each field, 4 units of size about $0 \cdot 91m \times 0 \cdot 91m$ each were located at random and the sampling observations were confined to these units except for those pests such as Jassids, Hispa for which observations were taken by sweeps. Periodical observations at the interval of about 4 weeks were taken starting from 3-4 weeks after planting upto and including harvest. Two of the sampling units in each field were kept fixed for the entire period of the survey, while the other two were changed at each sampling occasion. At the time of harvest, record of yield was also taken for each sampling unit in addition to observations on pest and disease incidence. The methods adopted for measurement of the various pests and diseases in the sampling unit are as given below :

Stem borer (*Tryporyza incertulas*).

The total number of tillers and the number of affected tillers were counted in each sampling unit and the ratio of the two was taken as an index of the incidence in pre-harvest counts. At harvest, the percentage of white earheads to the total number of earheads was taken as the measure of borer incidence.

Gall fly (*Pachydiplosis oryzae*).

The percentage of affected tillers (silver shoots) to the total number of tillers was the measure adopted.

Helminthosporium (*Helminthosporium oryzae*) and

Blast diseases (*Piricularia oryzae*).

The four corner plants and the central plant were taken from each sampling unit. With the help of standard score charts, prepared by the Central Rice Research Institute, Cuttack, the maximum infected leaf of each of the five plants selected was assigned a score corresponding to the grade of infection indicated by these charts. The number of grades varied from 0 to 8 for Blast and 0 to 9 for Helminthosporium.

These were the main pests and diseases observed in the survey, although measurements were made of some other minor pests and diseases also.

## 4. Estimates of Pest and Disease Incidence

Let $y_{ijk}$, be the measure of the incidence in the $k$th sampling unit of $j$th field in the $i$th village of a strata. The additive model for the incidence $y_{ijk}$ is given as

$$y_{ijk} = \mu + v_i + f_{ij} + e_{ijk} \qquad \ldots(1)$$

where $\mu$ is general mean, $v_i$ the effect of the $i$th village, $f_{ij}$ the effect of the $j$th field in the $i$th village and $e_{ijk}$ the effect of the $k$th sampling unit in the $j$th field of the $i$th village. Assuming that $v_i$, $f_{ij}$ and $e_{ijk}$ are uncorrelated and distributed with means 0 and variance $\sigma_v^2$, $\sigma_f^2$ and $\sigma^2$ respectively, the analysis of variance is given in table-1 below:

TABLE-1

*Analysis of Variance of Incidence*

| *Source of variation* | *Degrees of freedom* | *M.S.* | *Expected M.S.* |
|---|---|---|---|
| Bet. villages | $l-1$ | $sv^2$ | $\sigma^2+\lambda_2\sigma_f^2+\lambda_3\sigma_v^2$ |
| Bet fields (within villages) | $\sum_{i=1}^{l}(m_i-1)$ | $s_f^2$ | $\sigma^2+\lambda_1\sigma_f^2$ |
| Bet. Sampling Units (within fields) | $\sum_{i=1}^{l}\sum_{j=1}^{mi}(n_{ij}-1)$ | $s^2$ | $\sigma^2$ |

Where $l$ is number of villages in strata, $m_i$ is number of fields in $i$th village, and $n_{ij}$ is number of sampling units in $j$th field of $i$th village,

$$\lambda_1=\frac{1}{\sum_{i=1}^{l}(m_i-1)}\left\{n..-\sum_{i=1}^{l}\left[\frac{\sum_{j=1}^{mi}n_{ij}^2}{n_i.}\right]\right\} \quad ...(2)$$

$$\lambda_2=\frac{1}{l-1}\left\{\sum_{i=1}^{l}\left[\frac{\sum_{j=1}^{mi}n_{ij}^2}{n_i.}\right]-\frac{\sum_{i=1}^{l}\sum_{j=1}^{mi}n_{ij}^2}{n..}\right\} \quad ...(3)$$

$$\lambda_3=\frac{1}{l-1}\left\{n..-\frac{\sum_{i=1}^{l}n_i.^2}{n..}\right\} \quad ...(4)$$

where $n_i.$ is number of sampling units in the $i$th village and $n..=\sum_{i=1} n_i.$

The mean value worked out for a strata is given as

$$\hat{\bar{y}}=\frac{\sum_{i=1}^{l}\sum_{j=1}^{m_i}\sum_{k=1}^{n_{ij}}y_{ijk}}{\sum_{i=1}^{l}\sum_{j=1}^{mi}n_{ij}} \quad ...(5)$$

Other formulae for estimating the means could be used. The relative efficiencies of those estimates will be discussed in another paper.

For calculating the variance of mean incidence, the analysis of variance was carried out, as per table-1 above, to separate the variation between villages, fields and sampling units in fields. Since the number of selected units at different stages did not vary much, instead of the exact formula for the variance of an estimated mean, the approximate formula given below was used :

$$\hat{V}(\bar{y})=\frac{\sigma_v^2}{l}+\frac{\sigma_f^2}{l\bar{m}}+\frac{\sigma^2}{l\bar{m}\,\bar{n}} \qquad \ldots(6)$$

where $\bar{m}$ is the average number of fields in a village, $\bar{n}$ the average number of sampling units in a field and other notations are same as mentioned earlier. As the sampling fraction was small at all stages the finite correction factors have been ignored. The average incidence over all the stratum was calculated by taking a weighted average of the stratum estimates, the weights being proportional to the estimated area und.r rice crop in the different stratum.

The estimates of the mean incidence of pests and diseases and their standard errors for different years and over all the years are given in table-2 below :

TABLE-2

*Mean Incidence of Pests and Diseases on Rice Crop in Cuttack District During 1959-62*

| Year | | % white earheads at harvest ($x_1$) | % tillers attacked by Borers (pre-flowering stage) ($x_2$) | % tillers attacked by Gallfly (pre-flowering stage) ($x_3$) | % neck-infected earheads at harvest ($x_4$) | Helminthosporium infection at flowering stage (score) ($x_5$) |
|---|---|---|---|---|---|---|
| 1959-60 | Av. | 1·09 | 1·32 | 1 69 | 0·68 | 1·73 |
| | S.E. | 0·19 | 0·13 | 0·28 | 0·10 | 0·11 |
| 1960-61 | Av. | 0·61 | 3·90 | 1·45 | 0·41 | 1·49 |
| | S.E. | 0·06 | 0 39 | 0·33 | 0·07 | 0·09 |
| 1961-62 | Av. | 0·80 | 2·68 | 1·34 | 0·70 | 1·05 |
| | S.E. | 0·06 | 0·12 | 0·12 | 0·08 | 0·04 |
| Pooled | Av. | 0·83 | 2·63 | 1·49 | 0·60 | 1·42 |
| | S.E. | 0·07 | 0·14 | 0·15 | 0·05 | 0·05 |

## 5. Relationship of the Incidences with the Yield of the Crop

### 5·1. Correlation between pest and disease incidences

Since several pests and diseases simultaneously attack the crop, the correlation of the incidence of the same pest in different stages as well as between different pests and diseases is of some interest, both for the selection of variables in regression analysis and for the interpretation of the overall loss in crop yield. The correlation matrix obtained in the case of selected pest and disease incidence after pooling sum of squares and sum of products between sampling units (within fields) over all the years 1959-60 to 1961-62 is given below in Table-3.

TABLE-3

*Correlation Matrix of Major Pests and Dise. ses Incidences*

| | *White earheads at harvest* ($x_1$) | *Tillers attacked by Borers (pre-flowering stage)* ($x_2$) | *Tillers attacked by Gall-fly (pre-flowering stage)* ($x_3$) | *Neck-infected earheads at harvest* ($x_4$) | *Helminthosporium at flowering* ($x_5$) |
|---|---|---|---|---|---|
| $x_1$ | | 0·06 | 0·05 | 0·19 | —0·07 |
| $x_2$ | | | 0·02 | 0·11 | 0·01 |
| $x_3$ | | | | 0·05 | 0·11 |
| $x_4$ | | | | | 0·01 |

The low correlation coefficients show that there is no appreciable association of incidence of a particular pest or disease with another in the same field. However, it may be worth noting that all except one of the correlation coefficients are positive, indicating some tendency for infestation of pests and diseases simultaneously in the field.

### 5·2. Relationship of yield with incidence

The general approach was to calculate multiple regression equation of yield of sampling units on the measures of incidence observed at different stages on these units. This was done after removing strata, village and field variation. Only the fixed sampling units were taken as the observations on incidence at all the stages and yield were available only for these units. The other alternative would have been to fit the regression of estimated yield of the field on the estimated incidence in the field, which in view of the sampling of the field would have lowered the regressions and correlations. Since there were a large number of independent variables, *viz.*, periodical observations in respect of each of the pests and diseases recorded during the growth period and at harvest stage were involved, in the first instance, some of the variables which had extremely low values were rejected. The correlations, as given above, and multiple regression equation of yield on the five variables was pooled over all the years. The pooled figures were obtained by simply adding sum of squares and sum of products between sampling units (within fields) over all the years. The multiple regression equation estimated by least square method can be written as :

$$y=\bar{y}_o+\sum_i b_i x_i \quad \text{.. (7)}$$

where $\bar{y}_o=\bar{y}-\Sigma b_i \bar{x}_i$

$\bar{y}$ is general mean and $b_i s'$ are the partial regression coefficients of yield on the $i$th character estimated as

$$b_i=\sum_j c_{ij}\Sigma x_j y \quad \text{.. (8)}$$

$c_{ij}$ is the $i, j$th element of the inverse of $SS-SP$ matrix of the variables.

Since the values of incidence ($x_s$) were observed from the same ultimate sampling unit for which yield ($y$) was collected, the usual regression theory treating the independent variables as measured without error is applicable in the present case.

The standard errors of the fitted regression coefficients are obtained as :

$$V(b_i)=\sigma^2 c_{ii} \quad \text{...(9)}$$

$$V(\bar{y}_o)=\sigma^2\left\{\frac{1}{n}+\Sigma c_{ii}\bar{x}_i^2+2\Sigma c_{ij}\bar{x}_i\bar{x}_j\right\} \qquad i<j \quad \text{...(10)}$$

and

$$R=\sqrt{\frac{\Sigma\hat{y}^2}{\Sigma y^2}} \quad \text{...(11)}$$

The estimated regression equation and the corresponding analysis of variance tables are given below :

$$\hat{Y}=3596-42{\cdot}1x_1+8{\cdot}6x_2+21{\cdot}5x_3-34\ 9x_4-314\ 9x_5 \quad \text{...(12)}$$

(161) (21·1) (12·3) (16·4) (21 7) (72 7)

(kg./hectare)

Multiple correlation coefficient ($R$)=0 28 ...(13)

(Figures in the brackets are the S.Es. and $x$s have the same meaning as in table-2.)

TABLE-4

*Analysis of Variance*

| *Source of variation* | *Degrees of freedom* | *S.S.* | *M.S.* | *V.R.* |
|---|---|---|---|---|
| Due to regression | 5 | $\Sigma\hat{y}^2=$ 5735293 | 1147059 | 5·26** |
| Deviation from regression | 320 | $\Sigma d^2=$69770721 | $\sigma^2=$218034 | |
| Total | 325 | $\Sigma y^2=$75506014 | | |

**Indicates significance at 1% level.

The regression coefficients except for Helminthosporium and white earheads were not significant. The incidence of stemborer and Gallfly in the pre-flowering stage did not even show a negative trend in yield. Leaving these two variables, the revised regression equation comes out to be

$$\hat{\bar{Y}} = \underset{(139)}{3655} - \underset{(21\cdot1)}{40\cdot3x_1} - \underset{(21\cdot7)}{32\cdot2x_4} - \underset{(72\cdot3)}{303\cdot8x_5} \qquad ...(14)$$

with a multiple correlation coefficient ($R$)=0·26.

The corresponding analysis of variance is given in Table-5. It is often convenient to express the loss in terms of percentage of the expected yield without loss, from pests and diseases. For this purpose the regression equation was converted to percentage yield as given below :

$$\hat{\bar{Y}} = \underset{(3\cdot80)}{100} - \underset{(0\cdot57)}{1\cdot10x_1} - \underset{(0\ 59)}{0\cdot88x_4} - \underset{(1\cdot67)}{8\cdot31x_5} \qquad ...(15)$$

TABLE-5

*Analysis of Variance*

| *Source of variation* | *d. f.* | *S.S.* | *M.S.* | *V. R.* |
|---|---|---|---|---|
| Due to regression | 3 | $\Sigma\hat{y}^2=$ 5249810 | 1749937 | 8 02** |
| Deviation from regression | 322 | $\Sigma d^2=$70256204 | $\sigma^2=$218187 | |
| Total | 325 | $\Sigma y^2=$75506014 | | |

The regressions and their S.Es. in percentage form in equation (15) have been worked out from equation (14) as

$$\frac{b_i}{\bar{y}-\Sigma b_j \bar{x}_j}\times 100 \qquad \ldots(16)$$

and its variance

$$V\left(\frac{b_i\times 100}{\bar{y}-\Sigma b_j\bar{x}_j}\right)=\left(\frac{b_i\times 100}{\bar{y}-\Sigma b_j\bar{x}_j}\right)^2\left\{\frac{\sigma^2 c_{ii}}{b_i^2}+\frac{V(\bar{y}-\Sigma b_j\bar{x}_j)}{(\bar{y}-\Sigma b_j\bar{x}_j)^2}-\frac{2\text{cov}\,(b_i,\bar{y}-\Sigma b_j\bar{x}_j)}{b_i\,(\bar{y}-\Sigma b_j\bar{x}_j)}\right\} \qquad \ldots(17)$$

where $\text{cov}(b_i,\ \bar{y}-\sum_j b_j\bar{x}_j)=-\sigma^2\sum_j \bar{x}_j c_{ij}$

From the regression equations (14 and 15) we get the estimates of absolute decrease and % decrease in yield per unit increase in the various pests and diseases as given in table-6 below :

TABLE-6

*Estimates of Decrease in Yield Per Unit Increase in Incidence of Pests and Diseases*

| *Due to* | *Absolute decrease in Yield kg./hectare* | *% decrease in yield* |
|---|---|---|
| 1. 1% increase in attack of earheads by stemborer at harvest | 40·3 (21·1) | 1·10 (0·57) |
| 2. 1% increase in neck-infected earheads at harvest | 32·2 (21·7) | 0·88 (0·59) |
| 3. An increase of unit of score due to Helminthosporium at flowering stage | 303·8 (72 3) | 8·31 (1·67) |

(Figures in the brackets are the S.Es.)

It is seen that 1 per cent increase in white earheads leads to about 1 10 per cent decrease in yield, while in the case of Neck-infection, this ratio is 0·88. For an increase of one score in the incidence of Helminthosporium at flowering stage, the yield decreases by as much as about 8·31 per cent. The multiple correlation coefficient however is only about 0·26, which means only about 7 per cent of the yield variation is explained by the incidence of pests and diseases.

The regression equations were also worked out after applying angular transformation to the values of percentages and logarithmic transformation to the values of scores. Variation in yield accounted for by the regression fitted after transforming the data was not more than that accounted without transformation.

## 6. Estimation of Loss in Yield

The estimation of the crop loss in any particular season involves estimation of the degree and prevalence of pests and disease incidence and the knowledge of expected loss per unit of incidence. In the preceding sections these two aspects have been studied. The estimates of crop loss for each season are considered in this section. The average regression relationship between yield and incidence obtained in 3 years has been used for evaluating loss in yield in any particular year. Thus for example the incidences due to $x_1$, $x_4$ and $x_5$ during 1959-60, as seen from table-2, are 1.09%, 0·68% and 1·73 score respectively and the partial regression coefficients of yield on $x_1$, $x_4$ and $x_5$, as seen from equation (14) are $-40{\cdot}3$, $-32{\cdot}2$ and $-303{\cdot}8$ respectively, so the absolute loss in yield in kg./hectare will be $-b_i \bar{x}_i$ in general and in particular

$$-b_1\bar{x}_1 = 1{\cdot}09(-40{\cdot}3) = -43{\cdot}93 \qquad \ldots(18)$$

$$-b_4\bar{x}_4 = 0{\cdot}68(-32{\cdot}2) = -21\ 90 \qquad \ldots(19)$$

$$-b_5\bar{x}_5 = 1{\cdot}73(-303{\cdot}8) = -525{\cdot}57 \qquad \ldots(20)$$

The estimated variances of estimated losses have been worked out as follows

$$V(-b_i\,\bar{x}_i) = \bar{x}_i^2\ V(b_i) + b_i^2\ V(\bar{x}_i) - V(b_i)\ V(\bar{x}_i) \qquad \ldots(21)$$

Here $b_i$ and $\bar{x}_i$ have been taken as independent and the variance of the product has been estimated as shown by Goodman [2]. Similarly the values of losses and their variances due to these pests and diseases for other years have been worked out. The values have also been converted into percentages. The % loss in yield due to $x_1$ incidence will be

$$\frac{-b_1\bar{x}_1 \times 100}{\bar{y} - \Sigma b_i\bar{x}_i} \qquad \ldots(22)$$

where $\bar{y}$ is the mean of yield in kg/hectare for a particular year. For example percentage loss in yield due to white earheads ($x_1$) during 1959-60 will be

$$\frac{-43{\cdot}93 \times 100}{2942{\cdot}95 + 591{\cdot}40} = -1{\cdot}24 \qquad \ldots(23)$$

The variance of (22) has been worked out as

$$V\left(\frac{-b_1\bar{x}_1\times 100}{\bar{y}-\Sigma\, b_i\bar{x}_i}\right)=\left(\frac{-b_1\bar{x}_1\times 100}{\bar{y}-\Sigma\, b_i\bar{x}_i}\right)^2\left\{\frac{V(-b_1\bar{x}_1)}{(-b_1\bar{x}_1)^2}+\frac{V(\bar{y}-\Sigma b_i\bar{x}_i)}{(\bar{y}-\Sigma\, b_i\bar{x}_i)^2}-\frac{2\,\text{cov}(-b_1\bar{x}_1\,,\,\bar{y}-\Sigma\, b_i\bar{x}_i)}{(-b_1\bar{x}_1)(\bar{y}-\Sigma\, b_i\bar{x}_i)}\right\} \quad ...(24)$$

Since the constants of the regression equation have been estimated from the data of all the years, we may ignore their correlations with $\bar{x}_i$'s in any particular year. Under this assumption the terms in the above expression (24) are given as

$$V(\bar{y}-\Sigma b_i\bar{x}_i)=V(\bar{y})+\Sigma\bar{x}_i^2\, V(b_i)+\Sigma b^2_i\, V(\bar{x}_i)-\Sigma\, V(b_i)V(\bar{x}_i)$$
$$+2\sum_{i,j}\bar{x}_i\,\bar{x}_j\,\text{cov}\,(b_i,\, b_j)+2\sum_{i,j} b_ib_j\,\text{cov}\,(\bar{x}_i,\ \bar{x}_j)$$
$$-2\sum_{i,j}\text{cov}\,(b_i,\, b_j)\,\text{cov}\,(\bar{x}_i\,,\,\bar{x}_j)-2\,\Sigma\, b_i\,\text{cov}\,(\bar{x}_i\,,\,\bar{y})\quad i<j \quad ...(25)$$

and

$$\text{cov}\,(-b_1\bar{x}_1\,,\,\bar{y}-\Sigma\, b_i\bar{x}_i)=\bar{x}^2_1\, V(b_1)+b^2_1\, V(\bar{x}_1)+\Sigma\,\bar{x}_1\,\bar{x}_j\,\text{cov}\,(b_1,\, b_j)$$
$$+\Sigma\, b_1b_j\,\text{cov}\,(\bar{x}_1\,,\,\bar{x}_j)-V(b_1)V(\bar{x}_1)$$
$$-\Sigma\,\text{cov}\,(b_1,\, b_j)\,\text{cov}\,(\bar{x}_1\,,\,\bar{x}_j)$$
$$-b_1\,\text{cov}\,(\bar{x}_1,\,\bar{y})\qquad j>1 \quad ...(26)$$

Similarly variances of other values have been worked out. The absolute loss in yield pooled over all the pests and diseases incidence for a particular year is given by

$$-\Sigma\, b_i\bar{x}_i \quad ...(27)$$

and its variance given as

$$V-(\Sigma b_i\bar{x}_i)=\Sigma\,\bar{x}_i^2\, V(b_i)+\Sigma\, b_i^2V\,(\bar{x}_i)-\Sigma\, V(b_i)\, V(\bar{x}_i)$$
$$+2\sum_{i,j}\bar{x}_i\,\bar{x}_j\,\text{cov}\,(b_i,\, b_j)+2\sum_{i,j} b_ib_j\,\text{cov}\,(\bar{x}_i,\,\bar{x}_j)$$
$$-2\sum_{i,j}\text{cov}\,(b_i,\, b_j)\,\text{cov}\,(\bar{x}_i\,,\,\bar{x}_j)\qquad i<j \quad ...(28)$$

The pooled loss in yield per year in percentage is

$$\frac{-\Sigma\, b_i\bar{x}_i\times 100}{\bar{y}-\Sigma\, b_i\bar{x}_i} \quad ...(29)$$

and its variance is

$$V\left(\frac{-\Sigma\, b_i\bar{x}_i\times 100}{\bar{y}-\Sigma\, b_i\bar{x}_i}\right)=\left(\frac{-\Sigma\, b_i\bar{x}_i\times 100}{\bar{y}-\Sigma\, b_i\bar{x}_i}\right)^2\left\{\frac{V(-\Sigma\, b_i\bar{x}_i)}{(-\Sigma\, b_i\bar{x}_i)^2}+\frac{V(\bar{y}-\Sigma b_i\bar{x}_i)}{(\bar{y}-\Sigma b_i\bar{x}_i)^2}-\frac{2\,\text{cov}\,(-\Sigma b_i\bar{x}_i\,,\,\bar{y}-\Sigma\, b_i\bar{x}_i)}{(-\Sigma\, b_i\bar{x}_i)(\bar{y}-\Sigma\, b_i\bar{x}_i)}\right\} \quad ...(30)$$

where $\text{cov}\,(-\Sigma\, b_i\bar{x}_i\,,\ \bar{y}-\Sigma\, b_i\bar{x}_i) = \Sigma\, \bar{x}^2_i\, V(b_i) + \Sigma\, b^2_i\, V(\bar{x}_i) - \Sigma\, V(b_i)V(\bar{x}_i)$

$$+2 \sum_{i,j} \bar{x}_i\, \bar{x}_j \text{ cov } (b_i, b_j) + 2 \sum_{i,j} b_i b_j \text{ cov } (\bar{x}_i, \bar{x}_j)$$

$$-2 \sum_{i,j} \text{cov } (b_i, b_j) \text{ cov } (\bar{x}_i\,, \bar{x}_j)$$

$$-\Sigma\, b_i \text{ cov } (\bar{x}_i\,, \bar{y}) \qquad i < j \qquad \ldots(31)$$

The values regarding absolute as well as percentage loss in yield due to different pests and diseases for different years are given below in table 7.

TABLE-7

*Estimates of Loss in Yield Due to Different Pests and Diseases Incidences*

| *Pest/Disease Incidence* | *Year* | | | | | |
|---|---|---|---|---|---|---|
| | *1959-60* | | *1960-61* | | *1961-62* | |
| | *Absolute loss in yield kg/hectare* | *% loss in yield* | *Absolute loss in yield kg/hectare* | *% loss in yield* | *Absolute loss in yield kg/hectare* | *% loss in yield* |
| White earheads at harvest ($x_1$) | 43·93 (23·91) | 1·24 (0·69) | 24·58 (13 03) | 0·78 (0·42) | 32 24 (17·01) | 0·91 (0·49) |
| Neck-infected earheads at harvest ($x_4$) | 21 90 (14·95) | 0·62 (0·43) | 13·20 (9·10) | 0 42 (0·29) | 22·54 (15·31) | 0·64 (0 44) |
| Helminthosporium infection at flowering stage ($x_5$) | 525·57 (129·22) | 14·83 (4·22) | 452·66 (110·95) | 14·37 (4·04) | 318·99 (76·83) | 9·04 (2·38) |
| Pooled | 591·40 (129·92) | 16·69 (3 06) | 490·44 (209·84) | 15·57 (3·00) | 373·77 (80·16) | 10·59 (2·03) |

(Figures in the brackets are the S.Es.)

As seen from table-7, the loss in yield due to white earheads at harvest ($x_1$) ranges from 0·78 per cent to 1·24 per cent during three years and due to Neck-infected earheads at harvest ($x_4$) ranges from 0·42% to 0·64% and due to Helminthosporium infection, infection at flowering stage ($x_5$) ranges from 9·04% to 14·87%.

The maximum loss is thus consistently due to Helminthosporium incidence. The importance of controlling this disease so that about 10 to 15% of the yield can be saved is clearly brought out.

**Direct method of estimating loss due to incidence at harvest**

In case of damage by some of the pests such as stemborer at harvest stage, when the whole attacked panicle becomes chaffy, the assessment of loss is given usually as the percentage of such attacked earheads to the total number of earheads. However, this estimate cannot be considered entirely satisfactory for the following reasons.

The attacked earhead may not be a random sample of all the earheads for, instance, if the attack is mainly on the panicle on the main shoot the loss is more than that indicated by the percentage incidence and in case the attack is mainly on the later formed side tillers, the loss as estimated by the percentage of attacked earheads is likely to be an overestimate. In addition, the possibility of healthy earheads gaining in yield on account of death of some of the earheads of the plant due to the attack cannot also be ruled out. The approach of directly estimating the loss on the above lines is illustrated on the basis of the data from one zone during 1960-61. In order to find out the extent to which the yield of healthy earheads is influenced by the level of attack on the remaining earheads, the regression of the weight of healthy earheads on the percentage of attacked earheads was calculated. If $W_h$ is the mean weight of healthy earheads and $p$ is the percentage of attacked earheads in the fields, $b$ the regression of mean yield per healthy earhead on the percentage of attacked earheads, the estimate of the percentage loss in yield is given by

$$\left(1-\frac{N_h}{N}\frac{W_h}{W_h'}\right)\times 100 \qquad .. (32)$$

where $N_h$ is number of healthy earheads, $N$ is total number of earheads and

$$W_h' = W_h - b_p$$

In the present case

$$W_h = 1\cdot9153 \text{ (gm)}$$
$$p = 3\cdot02$$
$$b = 0\cdot0104$$
$$W_h' = 1\cdot9153 - 0\cdot0104 \times 3\ 02 = 1\cdot8839$$

giving the percentage loss as 1·71. Since the incidence was 3·02% the loss is estimated as about 0·6 per cent for every 1 per cent attack of earheads.

## Compensatory Effect

In directly estimating the loss in yield, sometimes the percentage of dead hearts in the earlier stage is taken also as contributing proportionately to the loss in yield. However, depending on the stage of attack, the mortality of some tillers gives rise to higher tiller production subrequently. The assumption that the loss is proportionate to the number of attacked tillers will not be then satisfactory. A study was made of the correlation between the number of tillers attacked a month after planting and the additional production of tillers in the subsequent month, the correlation averaged over all the zones was 0·12 only and the corresponding regression was 0·35. This indicates that an increase in attack of 1 tiller, an extra 0·35 tiller is produced so that there is some compensation achieved by the plant. Such compensation due to different pests and diseases needs further plantwise study in detail so that this effect may also be taken into account while calculating the net loss in yield.

## SUMMARY

A pilot sample survey to estimate the incidence of major pests and diseases on rice crop and consequent crop losses was carried out in Cuttak District of Orissa State during the three years 1959-60 to 1961-62. A multistage random sampling procedure was adopted for the selection of survey fields. Periodical observations on incidence of pests and diseases were made in each selected field taking suitable sampling units. The mean incidence and standard errors were calculated for the major pests and diseases. It was found that stem-borer and gall-fly were the major pests and among the diseases, helminthosporium was the main disease.

There was practically no correlation between incidence of different pests or diseases. The multiple regression equation of yield on white earheads, neck-infected ears and helminthosporium attack at flowering indicated a multiple correlation of 0·26 thus accounting for only less than 9% of the total yield variation.

The expected loss in yield was worked out using the multiple regression equation. About 11 to 17% crop losses were estimated for each year. The maximum loss was due to helminthosporium consistently in all the years.

Estimation of yield loss obtained at harvest time was also made directly by taking observation on the percentage of white earheads and adjusting for the influence of percentage of earheads attacked

on the yield of healthy earheads. It was found that for every one per cent increase in white earheads, the yield decreased by 0·6 per cent.

## ACKNOWLEDGEMENT

We are grateful to Dr. V.G. Panse, Statistical Adviser, Indian Council of Agricultural Research, for his encouragement.

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