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Assessment of crop loss caused by *Chilo partellus* in maize

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ABSTRACT

The crop loss assessment in the present study is based on the premise that yield loss caused by maize stem borer, *Chilo partellus* (Swinhoe) depends upon the degree of leaf injury measured in the form of leaf injury rating (LIR) that would help in adopting management measures at appropriate time to prevent the loss. The yield of large number of individual plants in two popular maize hybrids, i.e. HQPM1 and DHM117 was recorded at all leaf injury ratings at ICAR-Indian Institute of Maize Research, Pusa Campus, New Delhi. With increasing LIR, the average yield of plants decreased. A set of formula was developed to calculate yield loss, yield loss percentage and monetary loss. A template to calculate the same was formulated in excel sheet by entering input data on LIR scores, average yield at LIR, frequency of plants under each LIR, yield potential of test cultivars and market price of maize grain. The template gives output on yield loss percentage due to *C. partellus* damage and the corresponding economic loss by entering frequency of plants under each LIR, yield potential of cultivar and the current market price of grain. By comparing economic loss with the management cost, the economic threshold level can be determined which is an essential prerequisite for robust integrated pest management. After the harvest, by deducting actual yield from the expected yield (*C. partellus* yield loss), the loss caused by other factors is also calculated by the template.

Keywords: *Chilo partellus*, Crop loss assessment, Economic threshold, Maize

Crop losses due to pests and diseases are a major threat to the food security of nations worldwide and have been estimated between 20–40% at country and regional levels in major food and cash crops (Oerke 2006). Attacks of pests and diseases during the production cycle (pre-harvest) and/or during the storage (post-harvest) reduce the crop yield as well as its quality (Savary *et al*. 2006). Maize stem borer, *Chilo partellus* (Swinhoe) and *Sesamia inferens* (Walker) are the most important pests of this crop, causing major crop losses in the field. The quantification of yield losses and a better understanding of their drivers are essential to evaluate the efficacy of crop protection practices, making better decisions for integrated pest management and assessing the sustainability of agricultural production systems (Allinne *et al*. 2016). Crop loss assessment is also useful to reduce pest and disease incidence (Avelino *et al*. 2015).

Most attempts to measure yield losses were based on relationships between yields and an indicator of a given pest or disease. Seshu Reddy and Sum (1991) found a linear relationship between infestation and yield loss, and an increasing loss with earlier infestation. Likewise, yield of naturally infested field was compared with that of those protected chemically (Berg and Rensburg 1991, Sharma and Gautam 2010) or through other means. However, these methods cannot be used over large area. Also, insecticides treatment may change the physiology of the crop with phytotonic or phytotoxic effects. The plants under encloser may become pale and weak due to the change of micro-environment (Atwal and Singh 1990). The scarcity of quantifications of crop losses and analyses of their causes is related mainly to the difficulty of their assessment. So far, no systematic study of assessment of stem borer damage has been undertaken in India. In the light of these limitations, a very simple method was conceptualized, experimented and validated to give a robust accounting of yield losses caused by stem borer in maize.

MATERIALS AND METHODS

The injury caused by *C. partellus* is reflected in direct yield reduction. Visual scoring of plant damage in 1-9 leaf

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injury rating (LIR) scale was developed by Sarup (1977) and Rao (1983). The leaf injury rating from 1–9 gives complete profile of susceptibility of germplasm; 1 being a healthy plant in which insect could not inflict injury at all hence resistant, whereas rating 9 is dead heart. Based on this premise, an experiment was set up to quantify the yield reduction corresponding to each LIR, caused by *C. partellus*.

Maize cultivars, HQPM1 and DHM117 were sown in 1000 m^2 plot at experimental fields of ICAR-Indian Institute of Maize Research, Pusa Campus, New Delhi (28.6139^0 N, 77.2090 E^0). Crop was raised at 70 cm × 20 cm row to row and plant to plant placing with good agricultural practices. After 12 days of germination, the plants were artificially infested with black-headed stage eggs of laboratory reared *C. partellus.* In both the plots, the plants were infested by placing the eggs in whorl. One third rows were infested by placing 5 eggs, another set of one third rows with 10 eggs and the remaining one third rows with 15 eggs. The plants were observed for the leaf injury rating (LIR) 30 days after germination (DAG).

Determination of yield loss at each Leaf Injury Rating: Plants were observed for the level of infestation based on the leaf injury rating caused by *C. partellus.* Seventy plants of each LIR (from LIR 1-9) were tagged in each cultivar and maintained and protected from birds till harvest. Ears of the tagged plants were harvested separately and sun-dried to 14% moisture level. Sixty ears from group of each LIR were shelled and weighed. The moisture content of grains was recorded and the weight was adjusted at 14% moisture content. Average weight of grains obtained from each LIR was calculated for each cultivar. For each LIR, a combined average of both cultivars was also calculated, where each LIR represented mean weight of grains from 120 cobs, contributed equally by HQPM1 and DHM117. The experiment was repeated in *kharif* 2012 in the same field. After second year's data, a two-year combined average was calculated from 240 ears apiece for each LIR, contributed equally by HQPM1 and DHM117.

RESULTS AND DISCUSSION

The mean weight of single cob yield obtained from each LIR plant was recorded. The average yield of both the cultivars for the two years was dependent on variable LIR (Table 1). The relationship between yield and LIR was found be;

$$Y= -18.136x + 175.03\ (R^2 = 0.9789);$$ where Y and x represent yield and LIR

The correlation coefficient between LIR and yield of both the cultivars for both the years and the combination of these two were negative and very high (-0.9532 to -0.9927). To compare the correlation coefficient of all these combinations, they were converted in to Z score and put into the matrix (Table 2). The consistency in correlation coefficient worked out between two cultivars for two years was tested by Z score which did not find significant difference ($P< 0.05$).

Table 1 Mean yield of plants at different Leaf Injury Rating levels in two cultivars for two years

LIR	2011		2012		Mean of both the cultivars for both the yrs. (n=240)
	HQPM1 (n=60)	DMH117 (n=60)	HQPM1 (n=60)	DMH117 (n=60)	
1	132.18	162.54	142.34	158.9	148.99
2	118.21	144.82	137.22	147.3	136.89
3	107.98	135.07	139.76	99.1	120.47
4	89.24	112.44	98.82	119.7	105.06
5	85.76	96.34	94.66	94.4	92.79
6	62.44	70.28	61.43	90.1	71.05
7	54.66	59.01	47.55	71.4	58.16
8	30.21	24.90	23.49	24.2	25.70
9	0.00	0.00	0.00	0.0	0

Development of template for determining crop loss parameters: The LIR 1-9 and the corresponding mean yield was entered in the excel sheet. The grain weight loss at each LIR was calculated by subtracting the yield of each LIR from the maximum obtained yield, i.e. yield of LIR 1. The 'FREQ.' column was filled in with the frequency of each LIR (number of the sampled plants belonging to each LIR) observed in the field, which was under assessment of crop loss. The 'T. LOSS' column gave output of total loss of the sampled plants under each LIR by using the formula in the sheet:

Total loss from the sample plants:

$$\Sigma\ (\textit{Frequency of plants of each LIR} \times \textit{Yield loss of corresponding LIR})$$

Percentage yield loss in the field was calculated by using the formula:

$$\text{Percentage yield loss in the field} = \frac{\text{Total loss from the sampled plants}}{\text{Yield of LIR 1 plants} \times \text{No. of plants sampled}} \times 100$$

The yield potential of the cultivar grown in the field is known, hence expected yield is calculated

$$\text{Expected yield} = \frac{100 - \text{Yield loss due to } \textit{C. partellus}\ (\%)}{100} \times \text{Potential yield of the cultivar}$$

Yield Loss per hectare was calculated as:

$$\text{Yield loss per hectare} = \frac{\text{Loss }(\%)}{100} \times \text{Potential yield of the cultivar}$$

The market rate of the grain is put in the template and the economic loss caused due to *C. partellus* can be calculated. Taking into considerations of the economic loss and the cost of control measures, economic threshold level (ETL) was worked out.

After the crop harvest, the yield is recorded and. the crop losses caused by factors other than *C. partellus* are calculated as;

Table 2 Calculated Z Value

	2011-12 both cultivars	2011 both cultivars	2012 both cultivars	2011 HQPM1	2012 HQPM1	2011 DHM117
2011-12 both cultivars						
2011 both cultivars	0.02966518					
2012 both cultivars	-0.0915055	-0.12117				
2011 HQPM1	-0.1364363	-0.1661	-0.04493			
2012 HQPM1	-0.2270328	-0.2567	-0.13553	-0.0906		
2011 DHM117	0.14090477	0.11124	0.23241	0.277341	0.367938	
2012 DHM117	-0.5654413	-0.59511	-0.47394	-0.429	-0.33841	-0.70635

Yield loss cause by factors other *C. partellus* = (Potential yield – Actual yield) – Loss due to *C. partellus* (Table 3)

Sample size: A sample of randomly selected 140–245 maize plants taken from a crop of one-hectare if the expected infestation level ranges from 10–20% for estimating the loss percentage with 95% confidence level. The sample range is suggestive, in practice it is rule of thumb that works.

Validation of formula: The formula was validated by conducting the experiment at Institute of Pesticide Formulation Technology (IPFT), Gurgaon. HQPM1 was grown in 15 plots of 0.1 ha each in the experimental field of the institute during July 2014. The crop was maintained under good agriculture practices. After 35 days of germination, the frequencies of plants of different LIRs were recorded. The frequencies of each LIR were put in template and percent yield loss was calculated.

Table 3 Pradyumn Kumar *et al*. 2019 CLA Template

LIR	Yield	Loss	Freq.	T. loss
1	148.99	0.00	142	0.00
2	136.89	12.10	7	12.10
3	120.47	28.51	11	313.64
4	105.06	43.92	9	395.30
5	92.79	56.19	9	505.73
6	71.05	77.94	7	545.57
7	58.16	90.83	8	726.62
8	25.70	123.29	3	369.87
9	0.00	148.99	4	595.94
		Sample size	200	3464.78

Percentage yield loss due to *C. partellus*	11.99
Yield potential of the cultivar	6200.00
Expected yield (kg)	5456.77
Loss per ha due to *C. partellus (kg)*	743.23
Rate of maize (₹/kg)	16.00
Economic loss due to *C. partellus* (₹)	11892
Realized yield (kg)	4989
Yield loss due to other factors (kg)	467.77
Percent yield loss due to other factors	7.54

The actual yield obtained from each plot was recorded after harvesting the crop. The percentage of total loss minus the percentage of loss caused by *C. partellus* was calculated by the template as the percentage of loss caused due to other factors. The correlation coefficient between crop loss due to *C. partellus* and loss due to other factors was calculated to be -0.44. In validation of method, the negative correlation between crop loss due to *C. partellus* and the loss due to other factors suggested that the niche where it remained unoccupied by *C. partellus* was infested by other pests. The plants with LIR1 displayed no damage symptom which suggested that they were not infested by *C. partellus,* therefore, the mean yield of such plants was taken as the potential yield of the cultivar under given conditions by farmer. With the increasing LIR, the yield obtained decreased consistently in both the cultivars during both the years. The plants with dead heart, i.e. LIR 9 yielded off shoots and did not bear cob hence did not contribute to yield.

Since mean yield used was of two cultivars, HQPM1 which has moderate yield potential of 6200 kg/ha and DHM117 which is a high yielding cultivar with a yield potential 8900 kg/ha; the ratio of mean yield of both the cultivars for both the years at different LIRs is likely to be close to the ratio of yield at corresponding LIRs of any other cultivar. The consistency in the correlation coefficients of LIR and yield and the regression results, further support the hypothesis that a similar trend of yield reduction will be obtained with any other cultivar. In any ecosystem the different niches are occupied by different species. While considering the sample size of plants to be observed for loss estimation, the sample size did not increase significantly when the population exceeds 50000. In the current studies there was no cob formation on plant with LIR 9. Similar results have been reported by Pal *et al.* (2009) from Pakistan. Mohyuddin and Attique (1978) also reported that the dead heart incidence in different treatments was the major cause of reduction of maize grain yield. They further reported that on an average 1% of infested plants resulted in 85.30 kg/ha reduction in maize grain yields. Panwar *et al*. (2005) also reported that dead heart formation resulted in complete loss of the plant that ultimately affected the targeted yield.

The effect of plant damage parameters with yield losses has been worked out by earlier workers also. Correlation analysis revealed that plant height, number of leaves per plant, weight of cobs per plant, weight of grains per cob and weight of grains per plant decreased with infestation of maize by *B. fusca*. Plants infested with 1 or 2 larvae of *B. fusca* reduced the plant yield by 25% (Usua 1968). Every one percent plant damaged by O. *nubilalis* was estimated to reduce yield by 0.28% whereas, one larva per plant was estimated to reduce yield by 6.05% (Bohn *et al.* 1999). Stem tunneling due to *Eldana saccharina* showed negative correlation with the 100-grain weight (Bosque-Perez and Mareck 1991). The yield reduction showed positive correlation with foliage lesions, dead hearts and stem tunneling due to *Chilo partellus*. Among the damage parameters, stem tunneling contributed the most in yield reduction (Ajala and Saxena 1994).

The present method of crop loss assessment is non-destructive hence, no plant was needed to be dissected or damaged in any manner. By this method loss is assessed early in the crop growth stages, thus there is still time to control the pest and prevent loss to much extent. The information on economic loss at this stage can be used to work out the economic injury level (EIL) and economic threshold level (ETL), important prerequisites for integrated pest management. If the management measures used are chemical insecticides, then in addition to economic loss there is a need to take into consideration the ecological and social losses of insecticides before determining the meaningful ETL. There is no need for setting of experiment, waiting for incidence or artificial infestation in the crop. Unlike other methods, this method can be used for assessing the crop losses over large area. This method is inexpensive as the crop loss is assessed under natural incidence. There is no need for chemical or mechanical exclusion of insect or rearing of insect for artificial infestation. However, this method does not account for recovery made by plants in the cultivars having good tolerance though the loss caused by other pests can be estimated after the crop harvest.

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