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Assessment of crop loss and economic injury level of maize stem borer, *Chilo partellus* (Swinhoe)

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Abstract
Investigations on assessment of crop loss and economic injury level of maize stem borer, *Chilo partellus* (Swinhoe) was carried out at Main Agricultural Research Station, Dharwad during *kharif* and *rabi-summer* 2010-11 and 2011-12. The percent yield loss increased with increase in larval density. The maximum yield loss of 85.30 and 84.72 percent occurred when 9 larvae/pl were released compared to minimum of 3.47 and 1.27 percent in 1 larva/pl treatment during *kharif* and *rabi* season, respectively. In the present investigation, the economic injury level worked out to be was 2.42 and 2.09 larvae per plant during *kharif* and *rabi*, respectively.

Keywords: Maize, stem borer, yield loss, *Chilo partellus,* EIL

1. Introduction
Maize (*Zea mays* Linn.) is the most important crop in the world after wheat and rice [8]. It is as much a significant crop in the American countries like rice and wheat in Asia. Maize is grown in more than 70 countries of the world including USA, China, Brazil, Mexico, France, Argentina, Romania, India, Italy, Indonesia and South Africa [9]. The area under maize cultivation is maximum in the countries of United States, China, Brazil, Mexico and India. These countries contribute about 4/5th of the world's total maize production. The production of maize is constantly increasing because of the rising demand from the industries since maize is used as raw material [8].

Presently, maize cultivation is gaining importance in Karnataka particularly in rainfed tracts of northern and southern transitional zones due to its increasing demand as animal feed and raw material for industry [8]. Therefore, there is a need to explore the possibilities of increasing the productivity through better understanding of constraints in it's production.

The insect is considered as a pest only based on the damage or loss it causes to the crop. Depending upon this the plant protection measures have to be tailored for getting higher economic returns. So assessment of crop loss due to insect pest becomes essential for any planned crop protection against a particular pest in a particular crop. Yield loss assessment data are the primary tool to design a module for insect pest management. These data are very important and considered for determining the status of the pest. Even then very few attempts have been made in the major maize growing areas.

The maize stem borer, *Chilo partellus* is a major predominant production constraint in both *kharif* and *rabi* tracts of Karnataka by causing direct economic damage to the crop. To study these and to determine the thresh hold limits for decision making the present work was carried out to estimate the loss caused by stem borer, *C. partellus* in maize ecosystem in caged condition with graded level of infestation.

2. Material and Methods
The present investigation on assessment of crop loss and economic injury level of maize stem borer, *C. partellus* (Swinhoe) were carried out at Main Agricultural Research Station, Dharwad during *kharif* and *rabi-summer* 2010-11 and 2011-12. Dharwad is situated in the transitional tract of Karnataka state at 15°-26' North latitude and 75°-07' East longitude at an altitude of 761.8 meters above mean sea level. The experiment was laid out in a randomized block design with three replications comprising of two rows of 3 m length at spacing of 60 X 30 cm. A total of 20 plants were caged together using nylon mesh supported on bamboo sticks and this was considered as a unit for each treatment.

Caging was done at seven days after germination and maintained till the harvest of the crop. Known number of *C. partellus* neonates was released close to the leaf whorl on 20 days old plants. Infestation was done during morning hours between 0800 and 1100 in order to avoid larval mortality due to high temperature. The whorl was gently tapped before infestation to avoid the drowning of larvae in the water accumulated in plant whorl. Observations were made at 15 days interval. The treatment details for the assessment of crop loss due to maize stem borer, *C. partellus* are mentioned in Table 1.

Table 1: Treatment details of assessment of crop loss due to maize stem borer, *C. partellus*

Treatments	Pest density
T_1	Control (no larva)
T_2	1 larva / plant
T_3	2 larvae / plant
T_4	3 larvae / plant
T5	4 larvae / plant
T_6	5 larvae / plant
T_7	6 larvae / plant
T_8	7 larvae / plant
T_9	8 larvae / plant
T_{10}	9 larvae / plant

Leaf feeding score was recorded 15 days after artificial infestation on 20 plants using 1-9 scale. The details of visual damage rating are mentioned Table 2.

Table 2: Visual damage rating scale for leaf feeding

Score	No. of leaves showing feeding symptoms
1	1-2
2	1-2
3	2-3
4	2-3
5	3-4
6	3-4
7	4-5
8	4-5
9	5-6

Observations on dead heart, cob borer infestation, tunnel length and yield were also recorded. Infestation on stem tunneling was recorded at the time of harvest on the plants selected for recording leaf injury scores. Percent yield loss and Economic Injury Level (EIL) were also calculated.

2.1 Calculation of Economic Injury Level (EIL) for *C. partellus*

Economic Threshold Level indicates the population density at which control measures should be initiated in order to prevent the population reaching EIL. The methodology proposed by [24] was followed to work out economic injury level.

The management cost was calculated using the cost of insecticide and its application which accounted to Rs. 2300/ha. The market value of the produce was considered at Rs. 940/q based on four seasons market price prevailed at APMC, Dharwad. The gain threshold was 2.45 used under study.

The regression coefficient between the pest density and reduction in grain yield was worked out using the formula,

$$\text{(i) Gain threshold (GT)} = \frac{\text{Cost of plant protection measures (Rs/ha)}}{\text{Market price of the produce (Rs/q)}}$$

Economic Threshold Level was calculated by following a linear regression model of Y = a+bx for yield versus *C. partellus* infestation relationships.

$$\text{(ii) Regression co-efficient (b)} = \frac{\sum XY - \sum X . \sum Y}{\sum X^2 - \frac{(\sum X)^2}{N}}$$

Where,
X = Number of *C. partellus*
Y = Yield
N = Number of observations

$$\text{(iii) Intercept on Y (a)} = \frac{\sum Y}{N} - b\frac{\sum X}{N}$$

Y= a + bx
Where,
a & b are constants
X = Number of *C. partellus*
Y = Yield

Economic Injury Level (EIL) was worked out from gain threshold and regression co-efficient using the following formula:

$$\text{Economic Injury Level (EIL)} = \frac{\text{Gain Threshold (GT)}}{\text{Regression Co-efficient (b)}}$$

Crop loss estimation was calculated by using the following formulae:

Yield loss in respective treatment = (Yield in control) - (Yield in respective treatment)

$$\text{Percent yield loss} = \frac{\text{Yield loss in respective treatment}}{\text{Yield in control}} \times 100$$

3. Results and Discussion

3.1 Leaf feeding score

Generally the leaf damage was low, but was more in the higher densities *i.e.* 3 to 9 larvae per plant. As the number of larvae per plant increased from 0 to 9, the leaf feeding score was also increased. The leaf feeding score varied from 0.49 to 7.91 and 0.58 to 8.09 during *kharif* and *rabi* season, respectively (Table 3 & 5).

3.2 Dead heart

The percent dead heart varied from 0.00 (1 larva/pl) to 66.25 (9 larvae/pl) and 0.00 (1 larva/pl) to 86.53 (9 larvae/pl) during *kharif* and *rabi* season, respectively (Table 3 & 5).

3.3 Stem tunneling

Stem tunneling is an important parameter for assessing the intensity of damage caused by *C. partellus* to maize and subsequent reduction in yield. The percent stem tunneling ranged from 1.39 (1 larva/pl) to 33.19 (9 larvae/pl) and 0.32 (1 larva/pl) to 27.16 (9 larvae/pl) during *kharif* and *rabi* season, respectively (Table 3 & 5).

3.4 Yield and yield loss

The grain yield ranged from 7.03 q/ha (9 larvae/pl) to 47.66 q/ha (0 larva/pl) and 6.20 (9 larvae/pl) q/ha to 40.31 q/ha (0

larva/pl) during *kharif* and *rabi* season, respectively (Table 4 & 6).
The percent yield loss increased with increase in larval density. [28] observed that damage by maize stalk borer, *Busseola fusca* Full. had a positive correlation with the number of larvae per plant. Similarly, [17] found that higher the egg density of *C. partellus,* higher was the yield loss. Others who found a similar pest population or damage or yield loss relationship in maize were [31] on *B. fusca* and [7] on *Ostrinia nubilalis* Hubner.
In the present study, maximum yield loss of 85.30 and 84.72 percent occurred in the plots with 9 larvae/plant and minimum of 3.47 and 1.27 percent in 1 larva/pl treatment during *kharif* and *rabi* season, respectively.
Similar trends of increased yield loss by maize stem borer, *C. partellus* in response to increase in larval densities were also reported by [17, 22, 18] They recorded maximum reduction in yield to be 50.03 percent, 95 percent and 79.52 percent, respectively. Such variations in infestation-loss relationship may be due to a number of biotic and abiotic factors which influence the life cycle of the pest. Also the variations could be as a result of the differences in the cultivars used and the agro ecological zones.
[10] from Pakistan reported that major loss in grain weight was because of dead hearts and stunting of the growth rather than tunneling by *C. partellus* larvae. Yield losses in different agro climatic regions of India due to *C. partellus* were in the range of 26.7 to 80.4 percent [3], 24.3 to 36.3 percent [16] and 25-80 percent [14].Yield loss of up to 87.8 percent was observed when plants were infested with 10 first instar larvae at 10 DAE, while only 13 percent occurred at 60 DAE infestation [19]. At 15 DAE infestation, yield loss on sorghum at ICRISAT [26] was about 88 percent compared to 20 percent at 40 DAE. Infestation with larvae at 21 DAE reduced yield by one fifth to one fourth over the uninfested control, compared to much less at 56 DAE of maize [2]. When different larval densities were used, maximum yield reduction was caused by four to five larvae at 15-20DAE [26]. In Kenya the damage caused by stem borers lead to 13.5 percent yield loss estimated to be 400,000 MT of maize annually [27] and 26.7 to 80.4 percent in India [12]. Yield losses caused by stem borers in Africa could be as high as 80 percent for maize [29] and as much as 88 percent in sorghum [20].

3.5 Economic injury level (EIL)

Economic injury level was calculated based on significant linear regression model of y= a+bx for yield loss, infestation relationship, cost of protection and market price of the crop. Increasing awareness of environmental safety from pesticides is critical consideration here to restrict or to minimize insecticide use in maize to maximum possible extent. The experiment conducted has many considerations from the earlier works on EIL or ETL [30, 6, 5].
The concept of EIL serves as the economic foundation in decision making. The importance of the EIL in formulating any pest management programme has been highlighted by many workers [23, 25, 13, 24, 1]. Despite its great significance, it is often the weakest component of pest management programme. Very few research based on EIL have been established, especially on stem borers.
In the present investigation, the economic injury level for *C. partellus* was worked out to be 2.42 and 2.09 larvae per plant during *kharif* and *rabi*, respectively (Table 7). A low EIL may be due to high damage potential of the pest or low cost of control [4]. In the present study, it may be due to the former, since stem borer damage at times may be severe leading to formation of dead hearts in young plants and also the cost of Rs. 2300/ha for chemical control is not at all cheap. However, EIL is flexible [15] and varies with protection costs, market value of the crop to withstand damage.
These results are in conformity with findings of [18] from Kenya who determined economic injury level of the stem borer, *C. partellus* at 3.2 and 3.9 larvae per plant for 20 and 40 days old maize, respectively. [22] from Pantnagar reported that economic injury level was found to increase as the crop stage increased. In case of Basi local, EIL was 1.24, 1.38, 2.56 and 3.36 larvae/plant for 12, 17, 22 and 27 days old crop. On the other hand, CM-500 required 1.16, 1.17, 8.86 and 14.13 larvae/plant for 12, 17, 22 and 27 day old crop. A significant difference in yield loss in Basi local and CM-500 was found when 20 larvae per plant were released on 22 day old crop.

Table 3: Influence of different levels of *Chilo partellus* infestation on leaf feeding, dead heart and stem tunneling in maize during *kharif* season (pooled)

Pest density	Leaf feeding score (1-9)			Dead hearts (%)			Stem tunneling (%)		
	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled
Control	0.00	0.00	0.00	0.00 (0.00)h	0.00 (0.00)g	0.00 (0.00)g	0.00 (0.00)h	0.00 (0.00)g	0.00 (0.00)i
1 larva/plant	0.40	0.58	0.49	0.00 (0.00)h	0.00 (0.00) g	0.00 (0.00)g	1.30 (6.37)g	1.48 (6.47)f	1.39 (6.46)h
2 larvae/plant	1.75	1.98	1.86	0.00 (0.00)h	0.00 (0.00) g	0.00 (0.00)g	9.65 (18.08)f	10.88 (19.24)e	10.27 (18.67)g
3 larvae/plant	3.64	3.70	3.67	4.44 (12.00)g	3.33 (10.52) g	3.89 (11.32)f	12.92 (21.05)e	14.56 (22.42)d	13.74 (21.74)f
4 larvae/plant	4.69	4.60	4.65	10.00 (18.43)f	13.61 (21.65) g	11.81 (20.09)e	24.51 (29.67)d	22.20 (28.10)c	23.35 (28.89)e
5 larvae/plant	5.92	5.97	5.95	18.89 (25.75)e	19.17 (25.96) g	19.03 (25.86)d	28.43 (32.21)c	26.49 (30.97)b	27.46 (31.60) d
6 larvae/plant	6.11	6.15	6.13	48.33 (44.04)d	49.17 (44.52) g	48.75 (44.28)c	29.89 (33.14)bc	27.13 (31.38)ab	28.51 (32.27)cd
7 larvae/plant	6.97	7.26	7.12	48.33 (44.04)c	49.72 (44.84) g	50.69 (45.39)c	31.80 (34.32)b	28.25 (32.09)ab	30.03 (33.22)bc
8 larvae/plant	7.62	7.83	7.73	59.72 (50.60)b	60.00 (50.77) g	59.86 (50.69)b	34.35 (35.87)a	28.92 (32.52)ab	31.63 (34.21)a
9 larvae/plant	7.65	8.17	7.91	66.11 (54.39)a	66.39 (54.56) g	66.25 (54.48)a	36.65 (37.24)a	29.73 (33.03)a	33.19 (35.16)a
S.Em. ±	-	-	-	0.59	0.37	0.41	0.48	0.53	0.44
C.D. (0.05)	-	-	-	1.76	1.11	1.21	1.42	1.58	1.30

Figures in parentheses are arcsine transformed values, means followed by same alphabet do not differ significantly (0.05) by DMRT

Table 4: Effect of varying levels of *Chilo partellus* infestation on yield and yield loss during *kharif* season (pooled)

Pest density	Yield (q/ha)			Reduction in yield over control (q/ha)			Reduction in yield over control (%)		
	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled
Control	46.88^{h}	48.44^{i}	47.66^{h}	-	-	-	-	-	-
1 larva/plant	45.31^{gh}	46.77^{hi}	46.04^{gh}	1.56^{g}	1.67^{hi}	1.61^{gh}	3.24 (8.45)^{f}	3.70 (10.23)^{h}	3.47 (10.54)^{g}
2 larvae/plant	40.00^{fg}	41.25^{gh}	40.63^{fg}	6.88^{f}	7.19^{gh}	7.03^{fg}	14.02 (20.81)^{e}	14.94 (22.69)^{g}	14.48 (22.14)^{f}
3 larvae/plant	36.25^{ef}	36.77^{fg}	36.51^{ef}	10.63^{ef}	11.67^{fg}	11.15^{ef}	22.07 (27.84)^{de}	24.27 (29.31)^{fg}	23.17 (28.73)^{ef}
4 larvae/plant	32.81^{de}	33.33^{ef}	33.07^{ed}	14.06^{de}	15.10^{ef}	14.58^{de}	28.79 (32.00)^{d}	30.35 (32.96)^{ef}	29.57 (32.50)^{de}
5 larvae/plant	30.31^{d}	29.48^{de}	29.90^{d}	16.56^{d}	18.96^{de}	17.76^{d}	34.53 (35.86)^{d}	38.75 (38.41)^{de}	36.64 (37.15)^{d}
6 larvae/plant	23.54^{c}	23.54^{cd}	23.54^{c}	23.33^{c}	24.90^{cd}	24.11^{c}	49.02 (44.43)^{c}	51.05 (45.60)^{cd}	50.03 (45.02)^{c}
7 larvae/plant	18.96^{bc}	19.17^{bc}	19.06^{bc}	27.92^{bc}	29.27^{bc}	28.59^{bc}	58.93 (50.17)^{bc}	60.24 (50.91)^{bc}	59.58 (50.54)^{bc}
8 larvae/plant	15.10^{b}	14.90^{b}	15.00^{b}	31.77^{b}	33.54^{b}	32.66^{b}	67.57 (55.29)^{b}	69.28 (56.34)^{b}	68.43 (55.81)^{b}
9 larvae/plant	6.88^{a}	7.19^{a}	7.03^{a}	40.00^{a}	41.25^{a}	40.63^{a}	85.41 (67.55)^{a}	85.20 (67.37)^{a}	85.30 (67.46)^{a}
S.Em. ±	1.91	2.21	1.95	1.72	2.27	1.91	2.75	2.83	2.25
C.D. (0.05)	5.66	6.57	5.81	5.16	6.79	5.73	8.25	8.48	6.74

Figures in parentheses are arcsine transformed values, means followed by same alphabet do not differ significantly (0.05) by DMRT

Table 5: Influence of different levels of *Chilo partellus* infestation on leaf feeding, dead heart and stem tunneling in maize during *rabi* season (pooled)

Pest density	Leaf feeding score (1-9)			Dead hearts (%)			Stem tunneling (%)		
	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled
Control	0.00	0.00	0.00	0.00 (0.00)^{h}	0.00 (0.00)^{g}	0.00 (0.00)^{i}	0.00 (0.00)^{h}	0.00 (0.00)^{i}	0.00 (0.00)^{i}
1 larva/plant	0.64	0.53	0.58	0.00 (0.00)^{h}	0.00 (0.00)^{g}	0.00 (0.00)^{i}	0.04 (1.05)^{h}	0.60 (3.59)^{h}	0.32 (2.75)^{h}
2 larvae/plant	2.78	2.61	2.69	0.00 (0.00)^{h}	3.33 (10.52)^{f}	1.67 (7.42)^{h}	3.85 (11.31)^{g}	3.89 (11.34)^{g}	3.87 (11.34)^{g}
3 larvae/plant	4.87	4.80	4.83	11.67 (19.83)^{g}	14.44 (22.25)^{e}	13.06 (21.07)^{g}	10.37 (18.78)^{f}	9.78 (18.20)^{f}	10.08 (18.51)^{f}
4 larvae/plant	6.26	6.19	6.22	18.33 (25.32)^{f}	20.28 (26.69)^{e}	19.31 (26.02)^{f}	16.25 (23.76)^{e}	15.48 (23.16)^{e}	15.87 (23.47)^{e}
5 larvae/plant	6.44	6.31	6.38	28.61 (32.33)^{e}	35.56 (36.58)^{d}	32.08 (34.49)^{e}	19.19 (25.97)^{d}	16.71 (24.12)^{de}	17.95 (25.06)^{d}
6 larvae/plant	6.61	6.49	6.55	55.83 (48.35)^{d}	58.33 (49.81)^{c}	57.08 (49.07)^{d}	22.22 (28.11)^{c}	19.65 (26.29)^{cd}	20.94 (27.21)^{c}
7 larvae/plant	7.56	7.10	7.33	70.28 (56.96)^{c}	76.67 (61.14)^{b}	73.47 (59.00)^{c}	24.69 (29.79)^{b}	21.96 (27.93)^{bc}	23.33 (28.87)^{b}
8 larvae/plant	7.56	7.58	7.57	78.61 (62.45)^{b}	76.94 (61.46)^{b}	77.78 (61.91)^{b}	25.86 (30.56)^{b}	25.50 (30.33)^{ab}	25.68 (30.44)^{ab}
9 larvae/plant	7.56	8.63	8.09	83.89 (66.33)^{a}	89.17 (70.95)^{a}	86.53 (68.48)^{a}	28.03 (31.96)^{a}	26.28 (30.83)^{a}	27.16 (31.40)^{a}
S.Em. ±	-	-	-	0.71	1.52	0.92	0.41	0.83	0.53
C.D. (0.05)	-	-	-	2.11	4.51	2.72	1.21	2.46	1.58

Figures in parentheses are arcsine transformed values, means followed by same alphabet do not differ significantly (0.05) by DMRT

Table 6: Effect of varying levels of *Chilo partellus* infestation on yield and yield loss in maize during *rabi* season (pooled)

Pest density	Grain yield (q/ha)			Reduction in yield over control (q/ha)			Reduction in yield over control (%)		
	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled
Control	41.46f	39.17i	40.31f	-	-	-	-	-	-
1 larva/plant	41.35f	38.23h	39.79f	0.10f	0.94de	0.52f	0.26 (1.70)g	2.27 (6.46)g	1.27 (4.76)g
2 larvae/plant	39.38f	37.92g	38.65f	2.08f	1.25de	1.67f	5.17 (12.27)f	2.95 (9.83)fg	4.06 (11.42)g
3 larvae/plant	35.73ef	35.31f	35.52ef	5.73ef	3.85de	4.79ef	13.72 (21.13)ef	9.43 (17.87)ef	11.58 (19.70)f
4 larvae/plant	32.60e	31.15e	31.88e	8.85e	8.02d	8.44e	21.36 (27.52)e	20.62 (26.01)e	20.99 (27.06)e
5 larvae/plant	23.02d	22.81de	22.92d	18.44d	16.35c	17.40d	44.27 (41.68)d	41.64 (40.14)d	42.95 (40.91)d
6 larvae/plant	18.13cd	16.56cd	17.34c	23.33cd	22.60bc	22.97c	55.71 (48.47)cd	57.63 (49.40)c	56.67 (48.88)c
7 larvae/plant	13.23bc	12.40bc	12.81bc	28.23bc	26.77ab	27.50bc	67.59 (55.64)bc	68.40 (55.90)bc	68.00 (55.75)bc
8 larvae/plant	10.94ab	9.79ab	10.36ab	30.52ab	29.38ab	29.95ab	73.44 (59.05)ab	74.97 (60.09)ab	74.21 (59.57)b
9 larvae/plant	6.67a	5.73a	6.20a	34.79a	33.44 a	34.11a	84.14 (66.76)a	85.29 (67.63)a	84.72 (67.17)a
S.Em. ±	2.20	1.43	1.77	2.02	2.25	1.81 g	3.01	3.01	2.43
C.D. (0.05)	6.54	4.25	5.25	6.06	6.73	5.44	9.03	9.03	7.29

Figures in parentheses are arcsine transformed values, means followed by same alphabet do not differ significantly (0.05) by DMRT

Table 7: Economic Injury Level (EIL) of *Chilo partellus* infestation

Season	Gain threshold (GT)	Regression coefficient (b)	EIL = GT/b	ETL
Kharif				
2010-11	2.45	1.10	2.22	1.00
2011-12	2.45	0.91	2.66	1.00
Mean	2.45	1.01	2.42	1.00
Rabi				
2010-11	2.45	1.09	2.22	1.0
2011-12	2.45	1.25	2.00	1.0
Mean	2.45	1.17	2.09	1.0

Kharif: Y=32.37-1.01x; *Rabi:*Y=30.03-1.17x

4. Conclusion

Yield loss assessment data are the primary tool to design a module for insect pest management. These data are very important and considered for determining the status of the pest. The percent yield loss increased with increase in larval density. The maximum yield loss was occurred in the treatment with 9 larvae/pl. The economic injury level was worked out to be 2.42 and 2.09 larvae per plant during *kharif* and *rabi*, respectively.

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