Assessment of Yield Loss of Sorghum and Pearl Millet due to Stem Borer Damage

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Abstract

The stem borer species that infest sorghum and pearl millet are listed At ICRISAT Center in India, loss in grain yield due to Chilo partellus *damage in sorghum was estimated by two methods These experiments involving the phased use of carbofuran, or artificial infestation using laboratory-reared first instar larvae showed that maximum grain yield loss occurred when infestation took place 15 30 days after crop emergence The maximum number of deadhearts was formed when infestation took place during this period Stem tunneling caused by later infestations did not cause a reduction in grain yield*

In two studies at the ICRISAT Sahelian Center in Niger, results showed that under low levels of borer infestation (caused by Coniesta ignefusalis*), a nonprotected pearl millet crop gave slightly higher yields than one that was protected by insecticide In a date of sowing trial, losses were heavier on late-sown millet with an increase in proportion of nonproductive tillers Yield loss caused by other borer species are also discussed*

Résumé

Estimation de la baisse de rendement du sorgho et du mil due aux dégâts causés par les foreurs des tiges : *Les différentes espèces de foreurs des tiges infestant le sorgho et le mil sont répertoriées Au Centre ICRISAT en Inde, la baisse de rendement en grain de sorgho due à* Chilo partellus *est déterminée de deux manières, soit par l'application échelonnée de carbofuran, soit par une infestation artificielle en utilisant des larves de premier stade élevées au laboratoire Les pertes sont maximales lorsque l'infestation a lieu entre 15 et 30 jours après la levée C'est pendant cette période que le nombre de coeurs morts est le plus élevé Les galeries creusées lors d'infestations plus tardives n'entraînent pas de réduction du rendement en grain*

*Deux études menées au Centre sahélien de l'ICRISAT au Niger ont montré que, pour de faibles niveaux d'infestation d'*Acigona ignefusalis*, une culture de mil non protégée par des insecticides a donné un rendement légèrement supérieur à celui d'une culture traitée Dans un essai de date de semis, les pertes étaient plus importantes sur une culture de mil semée tardivement, avec une augmentation du pourcentage de talles non productives La baisse de rendement due à d'autres espèces de foreurs est également étudiée*

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Introduction

Out of 27 species of stem borers that attack sorghum crops *Chilo partellus* Swinhoe is the predominant species in Asia and East Africa Prominent in other regions are *Busseola fusca* Fuller *Sesamia calamistis* Hampson and *Eldana saccharina* Walker in Africa *Sesamia cretica* Laderer in Mediterrarean Europe and the Middle East and *Diatraea* spp in the southern U S Mexico and New World Tropics (Young 1970 FAO 1980) In pearl millet the predominant species of stem borer is *Coniesta (Acigona) ignefusalis* Hampson which is a major pest in West Africa

Assessment of crop losses due to insect attack is essential in determining pest status economic threshold levels and suppression strategy options for pest control It is also a tool in decision making in agricultural planning and forecasting Although severe stem borer infestations in sorghum and pearl millet have been reported from a number of locations there are no reliable qualitative estimates of resultant crop losses Several methods have been used in an attempt to estimate crop losses due to insect attack These include visual damage scores comparing yield from fields having different levels of natural infestation comparing yield of individual plants with and without infestation and comparing yield of chemically protected and nonprotected plots Another method involves releasing insects in varying number per plant or plot and correlating damage yield with insect density This method has also been used in comparing yield of resistant and susceptible varieties under insect infestations (Walker 1983) Two studies on yield loss estimation are reported in this paper The first involves the spotted stem borer *C partellus* in sorghum at ICRISAT Center in India and the second is on the millet stem borer *C ignefusalis* in pearl millet at the ICRISAT Sahelian Center in Niger

Materials and Methods

Sorghum

Yield loss in sorghum due to stem borer (*C partellus*) attack was estimated by two methods protecting the crop from stem borer infestation at different growth stages by insecticide application (Carbofuran 3G) in the leaf whorl and infesting the crop with eggs and larvae at different growth stages The first experiment was conducted under natural borer infestation at Hisar India from 1982 to 1985 The second experiment was conducted at ICRISAT Center in 1985 and 1986 Eggs and larvae were obtained from ICRISAT s insect rearing laboratory where the insect is reared on artificial diet

Natural infestation Natural infestation of stem borer at Hisar is usually severe on sorghum planted during the first half of July (Taneja and Leuschner 1985) Sorghum was sown for these trials during this period in each of the study years During 1982 83 only genotype CSH 1 was used In 1984 three genotypes CSH 1 ICSV 1 and IS 2205 were used and in 1985 two genotypes ICSV 1 and PS 28157 1 were included Planting was done in 8 row plots of 4 m length In 1982 and 1983 a randomized block design was used while in 1984 and 1985 a split plot design was used with genotypes as main plots

Carbofuran granules (2 g meter row) were applied at 15 30 and 45 days after emergence (DAE) in various combinations to obtain the protection [illegible] is indicated in Tables 1 3 Total number of plants and those showing deadhearts in the central four rows of each plot were counted 45 DAE At harvest the number of harvestable panicles were recorded sun dried and threshed and grain mass was recorded From each plot 50 100 stems were split open and stem tunneling was recorded

Artificial infestation Stem borer infestation on sorghum is very low during the rainy season at ICRISAT Center Uniform infestation is obtained by using eggs or first instar larvae reared on artificial diet (Taneja and Leuschner 1985) For larval infestation a split split plot design was used in both years with genotypes ICSV 1 and PS 28157 1 planted in the main plots Subplots within the main plots were infested at 15 20 30 40 and 50 DAE Within these subplots insect density was varied in subplots Insect density per plant was tested at 0 4 8 12 in 1985 and 0 1 2 4 8 12 in 1986 Each sub subplot consisted of 3 rows of 4 m length All plants in central rows were infested with a specified number of first instar larvae A selected number of larvae (noted above for each year) were gently mixed with a carrier (poppy seeds) and introduced in the leaf whorl to initiate infestation

For egg infestation a split plot design was used in 1985 with genotype ICSV 1 and infestation stages of 15 20 30 40 and 50 DAE were established as main plots Insect density of 0 10 20 33 and 50% plants infested with single egg masses were established as subplots In 1986 a split split plot design was used

Table 1. Effect of protection levels on stem borer infestation, grain yield, and avoidable losses in sorghum, Hisar, rainy seasons 1982-83.

Treatment	1982 Deadhearts (%)	1982 Grain yield (t ha^{-1})	1982 Avoidable loss (%)[1]	1983 Deadhearts (%)	1983 Grain yield (t ha^{-1})	1983 Avoidable loss (%)
Protection between						
15-60 DAE[2]	10.5	3.70	0.0	9.5	2.33	0.0
15-45 DAE	8.2	3.40	8.1	12.4	2.00	14.2
15-30 DAE	20.3	2.93	20.8	21.8	1.74	25.3
Zero protection	62.2	1.08	70.8	60.1	1.01	56.6
SE	±2.98	±0.126		±3.79	±0.147	
CV (%)	17	8		23	17	

1. Avoidable loss (%) = $\frac{\text{Yield in intensive protected plot} - \text{Yield in a particular treatment}}{\text{Yield in intensive protected plot}} \times 100$

2. DAE denote days after crop emergence.

genotypes ICSV 1 and PS 28157-1 as the main plots, infestation stages as subplots and insect density as sub-subplots. Plot size was 8 rows of 4 m length and the central 4 rows were infested with a specified number of egg masses. Each egg mass, containing 50-60 eggs was stapled at the top fourth leaf.

Observations on leaf damage were recorded one week after infestation. Total number of plants and those showing deadhearts were recorded three weeks after infestation. At harvest, harvestable panicles on main stems and tillers were counted in the infested rows. These panicles were dried and threshed, and grain mass was recorded. Stem tunneling was also recorded at harvest by splitting open 50 stems from each plot.

Pearl Millet

Date of sowing trial. The relationship between crop age, date of sowing and extent of crop damage by *C. ignefusalis* in pearl millet was investigated in field trials at the National Agricultural Research Station, Kamboinsé, Burkina Faso, in 1981 and 1982, and at the ICRISAT Sahelian Center, Sadoré, Niger in 1984 and 1985. Three varieties were used in each trial: Nigeria Composite, Ex-Bornu, and a local cultivar at Kamboinsé; and HKBtif, CIVT, and a local cultivar at Sadoré. Four replications of a randomized split-plot design were set up with sowing dates as main plots and cultivars as subplots (5m × 5m). Observations on borer infestation were recorded at 35 days after sowing (DAS), 50 DAS, and at harvest.

Insecticide trial. Quantitative estimates of yield loss in millet were determined in 1985 by using paired comparisons of insecticide-protected and nonprotected plots. Two varieties, Nigeria Composite and a local cultivar, were sown in a randomized split plot design in six replications with varieties as main treatments and insecticide application of Rogor® (dimethoate, 500g a.i. ha^{-1}) as subtreatments. The first insecticide treatment was applied at 15 DAS and subsequently at two-week intervals for a total of four applications. Observations on borer infestation were recorded at 35 and 50 DAS, and at harvest from an effective area of 5m × 5m within subplots of 8m × 8m. Grain yield from harvested panicles was recorded after sun-drying and threshing.

Results and Discussion

Sorghum

Natural infestation. During 1982 and 1983, when only genotype CSH 1 was used, stem borer infestation in control plots (no protection treatment) was 60 and 62% (Table 1). Grain yield in fully protected treatments was 3.7 t ha^{-1} in 1982 and 2.33 t ha^{-1} in 1983. Avoidable loss, calculated on the basis of grain yield obtained through intensive protection and no

Table 2. Effect of protection levels on stem borer infestation, grain yield, and avoidable losses in sorghum, Hisar, rainy season 1984.

	CSH 1			ICSV 1			IS 2205		
Treatment	Dead-heart (%)	Grain yield (t ha^{-1})	Avoidable loss[1] (%)	Dead-heart (%)	Grain yield (t ha^{-1})	Avoidable loss (%)	Dead-heart (%)	Grain yield (t ha^{-1})	Avoidable loss (%)
Protection between									
15-60 DAE[2]	25.2	5.17	0.0	28.0	4.24	0.0	33.9	1.87	0.0
15-45 DAE	23.8	4.39	15.1	49.0	2.64	37.7	37.6	1.28	31.6
15-30 DAE	39.2	4.79	7.4	50.2	2.62	38.2	30.6	1.91	0.0
30-60 DAE	61.1	3.11	39.8	75.9	0.76	82.1	43.2	1.18	36.9
30-45 DAE	53.7	3.70	28.2	79.0	0.74	82.5	43.0	1.04	44.4
45-60 DAE	95.1	1.60	69.1	100.0	0.33	92.2	47.6	0.90	51.9
Zero Protection	100.0	0.19	96.3	100.0	0.00	100.0	55.5	0.75	59.9
SE	±3.46	±0.259		±3.46	±0.259		±3.46	±0.259	
CV (%)	18	26		18	26		18	26	

1. Avoidable loss (%) = $\frac{\text{Yield in intensive protected plot} - \text{Yield in a particular treatment}}{\text{Yield in intensive protected plot}} \times 100$
2. DAE denotes days after emergence.

protection, ranged between 56.6 and 70.8% in two years. Maximum grain yield was obtained when the crop was protected between 15 and 60 DAE, however, maximum differences in yield levels were recorded between zero protection and early stages of protection (15-30 DAE).

In 1984, with increase in protection level treatments, different levels of stem borer infestation and corresponding grain yields were noticed in all three genotypes tested (Table 2). In susceptible genotypes CSH 1 and ICSV 1, 100% infestation was observed and negligible grain yield was realized in zero-protection treatment. In resistant genotype IS 2205, however, maximum infestation was 55.5% and some grain yield was obtained (0.75 t ha^{-1}). Although under protected conditions, CSH 1 and ICSV 1

Table 3. Effect of protection levels on stem borer infestation, grain yield, and avoidable losses in sorghum, Hisar, rainy season 1985.

	ICSV 1			PS 28157-1		
Treatment	Deadhearts (%)	Grain yield (t ha^{-1})	Avoidable loss (%)[1]	Deadhearts (%)	Grain yield (t ha^{-1})	Avoidable loss (%)
Protection between						
15-60 DAE[2]	15.9	3.57	0.0	6.4	4.45	0.0
15-45 DAE	8.1	2.32	35.0	4.1	3.26	26.7
15-30 DAE	19.5	2.68	24.9	6.7	3.35	24.7
30-60 DAE	36.5	0.72	79.8	14.7	1.68	62.2
30-45 DAE	36.6	0.84	76.5	16.7	1.21	72.8
Zero protection	80.3	0.01	99.7	45.7	0.73	83.6
SE	±4.66	±0.667		±4.66	±0.667	
CV (%)	26	16		26	16	

1. Avoidable loss (%) = $\frac{\text{Yield in intensive protected plot} - \text{Yield in a particular treatment}}{\text{Yield in intensive protected plot}} \times 100$
2. DAE denotes days after emergence.

yielded significantly higher than the resistant genotype under zero protection IS 2205 outyielded both susceptible genotypes Maximum infestation and grain yield differences were obtained between zero protected and early protected (15-30 DAE) treatments, which were similar to the 1982 83 results

In 1985 80% deadhearts were recorded on susceptible ICSV 1 compared with 45 7% on resistant PS 28157-1 in zero-protected treatments (Table 3) Here again in zero-protected treatment there was no grain yield in the susceptible genotype while some yield was obtained from the resistant genotype even under no protection Minimum avoidable losses were observed when the crop was protected between 15 and 30 DAE

Four years of data on the effect of protection levels indicates that the maximum control of stem borer and subsequently higher grain yield was obtained when the crop was protected between 15 and 30 DAE This is the crop stage at which borer infestation results in deadheart formation which is the primary damage symptom related with grain yield reduction (Taneja and Leuschner 1985) There was no trend observed in stem tunneling as a parameter influencing yield within different protection levels in any of the genotypes tested during 1983 85

Artificial infestation Stem borer infestation (deadhearts) and grain yield with various borer densities at different stages of infestation during 1985 are presented in Figure 1 Infestation at 15 DAE resulted in maximum damage and subsequent yield reduction in both resistant PS 28157-1 and susceptible ICSV 1 genotypes At this stage of infestation there was no significant difference between various borer densities (4 8 and 12 larvae plant $^{-1}$) in terms of damage and grain yield for either genotype However infestations at 20 DAE showed linear increase in borer damage and decrease in grain yield as insect density increased In resistant genotypes infestation was lower at all borer densities and corresponding grain yields were higher than in the susceptible genotype Infestations carried out 30 DAE and later did not result in deadheart formation however grain yield decreased in infested plots at 30 DAE At 40 DAE infestation there was no decrease in grain yield

In 1986 similar infestations and grain yield reductions resulted when 4 8 and 12 larvae were introduced per plant However with the inclusion of two more infestation levels (1 and 2 larvae per plant) some trend was observed even at 15 DAE infestations (Fig 2) Deadheart expression decreased as the infestation was delayed Avoidable losses increased with the increase in borer density and decreased as the infestation was delayed (Table 4) Also avoidable losses were lower in resistant genotypes than in

Table 4 Estimation of avoidable losses due to stem borer infestation in sorghum, ICRISAT Center, rainy season 1986

	Avoidable loss (%)[1]					
	ICSV 1			PS 28157 1		
Insect density	15 DAE[2]	20 DAE	30 DAE	15 DAE	20 DAE	30 DAE
Larval infestation (Larvae plant $^{-1}$)						
1	31.7	28.0	25.2	13.1	15.9	3.0
2	48.0	38.4	41.1	29.3	28.1	9.8
4	70.2	41.2	43.0	45.9	31.1	9.8
	86.5	54.4	55.6	79.9	50.5	24.8
12	84.9	56.8	58.9	86.1	48.3	28.6
Egg infestation (% plants with eggs)						
10	23.4	21.3	15.3	22.0	5.5	2.2
20	52.3	37.8	25.9	41.4	20.9	14.9
33	69.3	53.0	32.2	48.9	22.8	22.4
50	61.5	59.1	51.4	57.3	39.0	36.8

1 Avoidable loss (%) $= \frac{\text{Yield in intensive protected plot} - \text{Yield in a particular treatment}}{\text{Yield in intensive protected plot}} \times 100$

2 DAE denotes days after emergence

the susceptible genotypes in almost all treatments

With egg infestation, borer damage was less than that incurred with larval infestation Even with 50% plants infested with egg masses 15 DAE, the maximum damage was 68% deadhearts in ICSV 1 and 59% in PS 28157-1 (Fig 3) There was a linear relationship between damage and borer density increase in borer density increased damage, and correspondingly decreased the grain yield Resistant genotypes showed less borer damage and higher grain yield in all the treatment levels With egg infestation, as in larval infestation, borer damage decreased as the infestation was delayed Similarly, avoidable losses increased as borer density increased, and decreased as infestation was delayed (Table 4)

Data from natural and artificial infestation indi

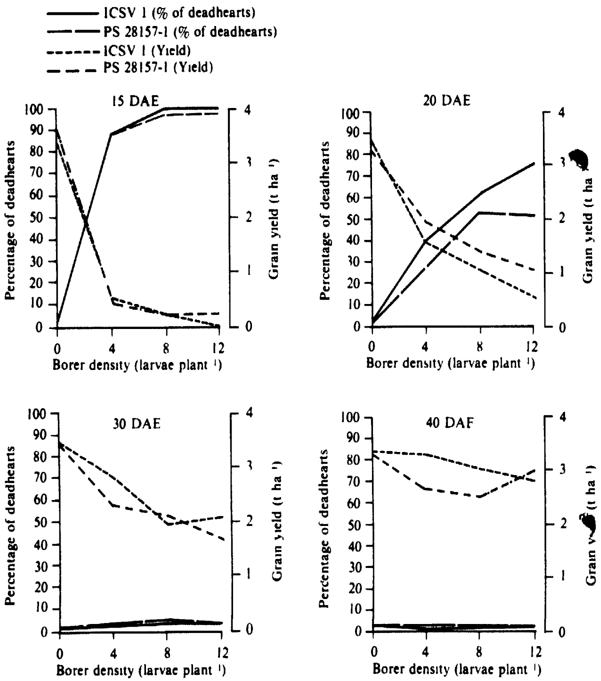

Figure 1. Relationship between stem borer density, infestation, and yield under artificial infestation, ICRISAT Center, rainy season 1985.

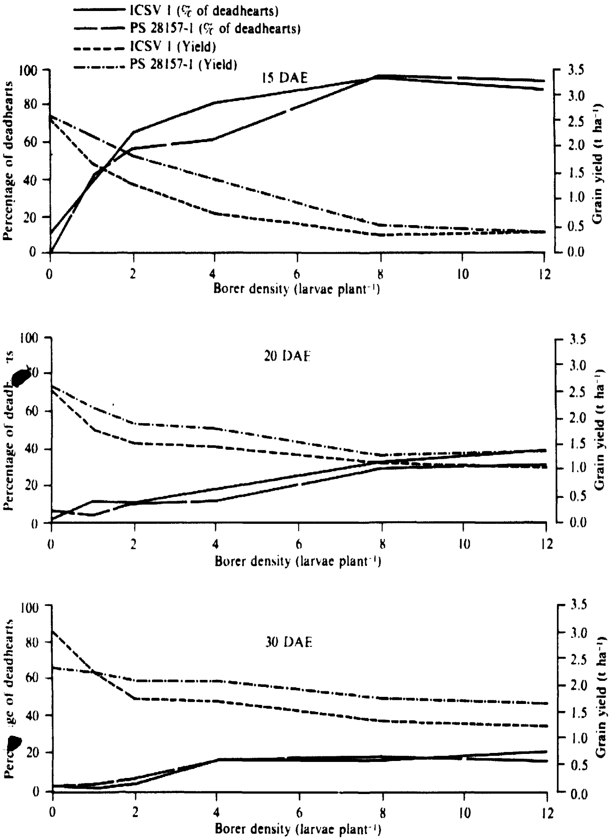

Figure 2. Relationship between stem borer density, infestation, and grain yield under artificial infestation using larvae, ICRISAT Center, rainy season 1986.

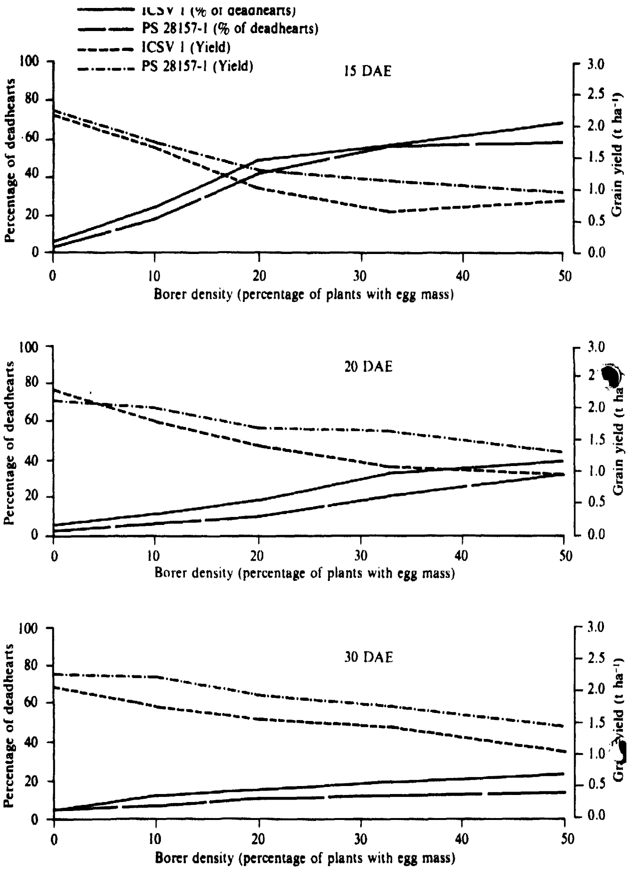

Figure 3. Relationship between stem borer density, infestation, and grain yield under artificial infestation using egg masses, ICRISAT Center, rainy season 1986.

cates that early infestation by stem borer is crucial, results in deadheart formation, and causes grain yield reduction. This has also been observed by Singh et al. 1968, and Taneja and Leuschner 1985.

Pearl Millet

Date of sowing trial. Initial crop damage caused by *Coniesta* infestation is usually observed as deadhearts of seedlings, attributed to feeding activities of young larvae of the first generation (Harris 1962). Leaf feeding symptoms have not been recorded in this species.

At Kamboinsé and Sadoré, there were no significant differences between varieties in deadheart formation but differences were observed between sowing dates, with the late crop showing a higher proportion of deadhearts than the early crop. At both locations, stem damage increased with a delay [illegible]wing.

[illegible]iller infestation and internode damage were much higher on the third-sown crop (mean of 84.3 and 44.3% at Kamboinsé; 84.7 and 40.8% at Sadoré) than on the first crop (mean of 64.8 and 2.6% at Kamboinsé, 26.5 and 1.5% at Sadoré). Grain yield data were confounded by bird damage but data collected on tiller productivity also indicated a corresponding increase in nonproductive tillers with a delay in sowing.

Insecticide trial. Although planted in mid-June 1985, this trial experienced a low level of borer infestation. No significant differences were observed in crop damage within varieties for the insecticide protected and nonprotected treatments (Table 5). However, between varieties, Nigeria Composite was infested more than the local cultivar. It was also observed that low levels of borer infestation resulted in a slight yield increase of the nonprotected treatment over the control (Nigeria Composite 11.9%, Sadoré local 1.3%). Similar results were obtained earlier by Harris (1962), although in a separate experiment with high levels of borer attack he recorded a grain yield loss of 15%.

Conclusions

In sorghum, maximum control of stem borer infestation was obtained when the crop was protected between 15 and 30 DAE by the application of carbofuran granules in the leaf whorls. This protection also afforded significantly higher grain yields. Under artificial infestation, resistant genotypes showed a consistent advantage in avoiding grain yield loss. Infestations at 15 DAE resulted in maximum damage and subsequent yield reductions in all genotypes tested. Data from both natural and artificial infestation indicates that early infestation by stem borer is the most damaging and results in greatest reduction of yield.

With pearl millet, trials in Burkina Faso and Niger have shown that early sowing results in greater tiller productivity and higher yields. Trials with insecticide control proved inconclusive in estimating yield loss in millet. Additional work in this area might be useful.

Table 5. Assessment of crop loss caused by infestation of *Coniesta ignefusalis* in two millet cultivars, Sadoré, Niger 1985.

	Cultivar/treatment				
	Nigeria Composite		Sadoré Local		
[illegible]ameters measured	Protected control	Non-protected	Protected control	Non-protected	Mean ± SE
No. of larvae/stem (50 DAS[1])	1.5	3.0	0.0	0.2	1.2 ± 0.72
Infested stems (%) (50 DAS)	8.3	10.8	1.7	3.3	5.8 ± 2.10
Internodes tunneled (%) (50 DAE[2])	1.4	2.6	0.3	0.6	1.2 ± 0.60
No.of larvae/stem (at harvest)	11.5	11.2	6.3	7.5	9.1 ± 1.49
Infested stems (%) (at harvest)	28.0	37.3	17.3	23.0	26.4 ± 2.87
Internodes tunneled (%) (at harvest)	4.9	8.5	2.6	3.4	4.8 ± 0.52
Grain yield (kg ha^{-1})	1856	2076	1414	1432	1720 ± 372
Yield loss (%)		11.9[3]		1.3	

1. DAS denotes days after sowing.
2. DAE denotes days after emergence.
3. Indicates yield advantage of nonprotected over protected control.

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