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ECONOMIC INJURY LEVELS FOR RICE INSECT PESTS

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Insect damage to plants sometimes results in recognized damage symptoms. In other cases the damage is not easily visible. It is often not known how much yield loss, if any, is caused by the damage. Plants may tolerate a little direct damage, but usually they suffer yield loss in varying degrees.

A fundamental principle of pest management is that pest populations are maintained at levels below those causing economic injury (Smith, 1969; Stern, 1973). The *economic injury level* (EIL) is the lowest pest population density that will cause economic damage. Economic damage is the amount of injury which will justify the cost of artificial control measures (Stern, 1966).

There is much practical benefit in understanding the relationship among insect population density, plant damage and yield loss. To prevent economic crop damage, insect pests must be controlled when their density reaches the economic threshold. The economic threshold is the pest density at which control measures should be determined to prevent an increasing pest population from reaching the EIL (Stern, 1966).

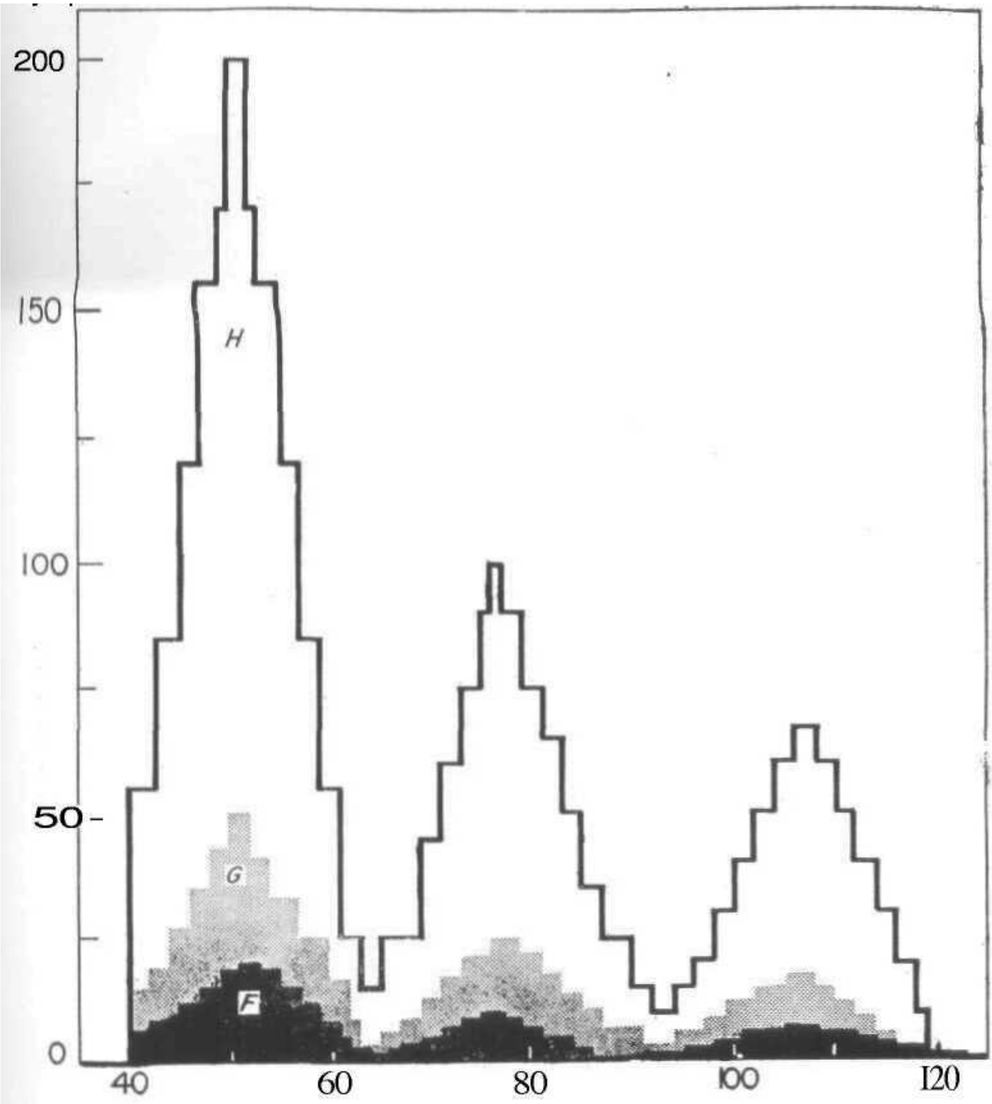
Economic injury levels for rice insect pests are poorly described, and therefore the same applies to economic thresholds. This fact prevents insecticides from being used efficiently.

Dyck *et al.* (1977) reviewed the available literature on economic injury levels for rice insects. In this paper we describe research done at the International Rice Research Institute estimate these levels.

Materials and Methods

Green leaf hopper *Nephotettix virescens* (Distant) nymphs, rice leaf folder *Cnaphalocrosis medinalis* (Guen) larvae and rice bug *Leptocorisa* spp. adults were caged on rice plants in the greenhouse or field. The insect density was frequently monitored to maintain the predetermined level for a defined period. It was found easier to use fixed densities than naturally fluctuating ones. Insect damage to the plants was observed at regular intervals. Grain weight was measured when the plants matured.

One greenhouse experiment was conducted with green leaf hoppers using controlled but fluctuating densities. This new approach simulated natural conditions, and included cumulative damage. The nymphal density on potted plants was artificially regulated according to a predetermined stylized


200
150
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120

pattern of three generations based on previous field observations. Eight treatments (A–H) were used, each differing from the others in the number of insecfs placed on the plants. The treatments F, G and H are represented in Fig. 1. The tiller number of all treatment hills was not significantly different from that of the control at the time of caging, about 40 days after seeding.

We found it very difficult using live larvae to replicate exact levels of stem borer damage at specified times. Therefore we developed a technique of simulating borer attack. A needle was inserted into a mother or productive tiller and manipulated carefully to destroy the growing point. Dead hearts or white heads later developed which looked the same a those caused by borers. The grain weight of treated and untreated plants was measured at plant maturity. The effect of simulated borer damage on plants was observed in both greenhouse and field. Insecticide was applied several times to the field crop to prevent natural damage by insects.

Several techniques to correlate plant damage from the whorl maggot *Hydrellia sasakii* (= *philippina*) Yuasa and Isnitani with yield loss were attempted. Plants damaged naturally in the field were brought to the greenhouse in pots, treated with insecticide and grown to maturity without further insect damage. Field crops were either treated with insecticide or left untreated during the first month after transplanting when most maggot damage occurred, and then all plants were regularly treated until harvest to prevent damage by other insects. Yield differences between plants treated or untreated during the first month should reflect crop loss caused by the whorl maggot. Also a greenhouse trial was conducted wherein female flies were caged on sesdlings. The number of eggs laid and amount of leaf damage that developed were noted.

Results and Discussion

Nephotettix virescens. When nymphs were caged on plants for 2 weeks, the plants were most susceptible to damage during the active tillering and late booting stages (Table 1). This result is similar to that found when plants were infested by the brown planthopper *Nilaparvata lugens* (Stal) (Dyck and Orlido, 1977). For *N. virescens,* loss in yield was correlated with fewer tillers and panicles. Very little irreparable damage was done by 2-week densities of 10 nymphs or less per tiller, except at the very sensitive stages. Two weeks is the approximate duration of the nymphal stage of a generation. Therefore the damage done to the plants in this experiment could represent the damage in the field caused by one generation of a given maximum density to a crop of a given age. In China a newly transplanted crop was reported to be more susceptible to green leafhoppers than tillering plants (Chiang, 1977) while Nirei and Nakazato (1975) noted that plants were vulnerable at the heading and mild stages. Takayama ef *al.* (1974) found that less than 20 insects per hill in the fourth emergence period of the pest in Japan were unimportant.

In the experiment with fluctuating nymphal density, many of the plants with the highest pest density were killed, and those that survived produced low yields. The leaves of plants haying a moderate infestation turned yellow and developed few panicles. The panicle number decreased and the percentage of unfilled grains increased as the pest density increased (Table 2). On the basis of percentage grain weight reduction, even plants with relatively low pest density appeared to suffer. But reductions of 14 and 18 per cent were not significant probably because grain production in potted plants is inherently variable, even with 22 replications. Experiments with field cages are needed to measure lower levels of grain loss. But *N. virescens* appears to inflict much more direct damage to rice than was earlier thought possible.

In another trial with caged insects on IR22 in the greenhouse where insect density fluctuated for 60 days, tiller and panicle number was significantly reduced only when the maximum pest density reached 12 insects per hill.

Stem borers- Simulated stem borer damage in the greenhouse and grain weight appeared to be curvilinearly related, and damage and grain weight reduction linearly related (Table 3). Gomez and Bernardo (1974) found the relationship between yield and percentage damage incidence to be exponential. Than Htun (1976) studied the relationship of *Tryporyza incertulas* (Walker) larval density to plant damage and grain reduction, and found a positive curvilinear relationship. Early infestations caused more damage than late ones. But Soejitno (1977) concluded that the relationship between damage and yield was linear, and suggested that each percentage unit of plant damage caused about 1 per cent yield reduction.

Damage at 40 days after seeding was partially compensated for by tiller production. However damage at 60 days could not be compensated, and was greater than expected (Table 3). The field results were rather similar to greenhouse results, except that at 40 days after seeding, damage to 10 per cent of all tillers decreased grain weight by only 5 per cent (Table 4). Plants can probably compensate better in the field than indoors. These results show greater yield loss than found in Malaysia where an infestation of one larva per four tillers on 65-day-old plants caused 46 per cent damaged tillers and significant yield loss of 12 per cent (Kok and Varghese, 1966). Koyama (1975) in Japan found that about 12 per cent leaf-sheath discolored stems from the first generation of borers produced 5 per cent dead heart. In Japan rice plants can recover somewhat from the attack of first-generation borers. Estimates of damage from the second generation give rather good estimates of yield loss (Ishikura, 1967).

The relationships between borers and damage, and damage and yield loss, are obviously rather complex. Many factors affect these relationships. Nevertheless a crude estimate of an EIL would have practical usefulness. Since it is difficult to relate larval density to yield loss for estimating an EIL, in the case of stem borers it is usual only to estimate the level of economic damage. If more than 5 per cent yield loss has a value greater than the cost of artificial control measures to prevent that loss, then 10-15 per cent dead hearts resulting from damage at 40 days after seeding is a level of economic damage. But this level changes greatly with plant age (Tables 3 and 4) suggesting that economic thresholds must change with crop age. Slight tiller damage during the reproductive period caused considerable grain weight reduction. Economic damage could occur when only 2 per cent of the tillers are damaged at 60 or 80 days. This lowering of economic damage level with crop age was suggested by Kobayashi *et al.* (1971), Liu (1977) and PCARR (1977).

That economic damage can occur at 10 per cent dead hearts or may be even less, has been suggested by several workers (Kobayashi *et al.,* 1971; Torii, 1971a and b; Pathak and Dyck, 1973; Israel and Rao. 1976: Chiang, 1977; Liu, 1977; PCARR, 1977). But Kiritani (1979) in reviewing work in Japan listed EIL values up to 23 per cent.

Cnaphalocrosis medinalis: Observations on a farmer's field in the Philippines showed that an infestation of leaf folders could reduce yield by at least 6 per cent. In an initial trial in the greenhouse with caged larvae on potted plants, a density of one larva per tiller resulted in more than 30 per cent yield loss. In a subsequent experiment plants were infested with young larvae at the beginning of the flowering period, and others were infested 1 week later. The results indicated that plants could tolerate some damage, but that an increasing insect density caused increasing leaf damage and grain weight reduction (Table 5). Economic damage certainly occurred when 10-15 leaves per hill were damaged during the flowering period,but further work in field cages is needed to observe the amount of damage that causes only 5 per cent yield loss. The data available suggest that the EIL is a larval density less than 1 or 2 larvae per 4 tillers.

Very little research has been done on EIL of leaf folders. Chaudhary and Bindra (1970) obtained a significant yield loss of 27 per cent when 23 larvae/sq m caused damage to 103 leaves/sq m.

Leptocorisa spp.: Several attempts to measure yield losses from rice bugs in greenhouse cages were unsuccessful because the losses were statistically insignificant except at very high levels of infestation. But the field cage technique did permit precise measurement of relatively small losses. When various densities of adult bugs were kept in 1 sq m cloth cages from crop flowering to harvest, the percentage of unfilled grains increased and yield decreased as the bug density increased (Table 6). Based on these results, the EIL would appear to be about 3 bugs/sq m present continuously from flowering to harvest. This figure is in general agreement with those found by Halteren and Sama (1976) and Rothschild (1970).

Hydrellia sasakii · Ferino (1968) estimated that yield loss due to the whorl maggot could reach 1.4 t/ha in the field and 22 per cent in the greenhouse. In a greenhouse trial at IRRI losses of 18 to 34 per cent were significant. But attempts to correlate fly density, egg density, insect damage to leaves and plant tiller number gave inconclusive results (Dyck *et al.*, 1977). Several field experiments in the Philippines were also unable to clarify the insect's relationship to plant damage and yield loss. It is difficult to create a valid comparison between a damaged and an undamaged plot in the field. However, based on work in Japan, economic damage would occur when 17 per cent of the leaves were clearly damaged (Okamoto, 1973).

Table 1

Grain yield response of IR 22 in the greenhouse to direct damage by various densities of green leafhopper *Nephotettix virescens* nymphs caged for 2 weeks on plants of different ages

Insects caged[a] (no./tiller)	Yield (g/hill)						
	28-41 DS[b]	42-55 DS	56-69 DS	70-83 DS	84-97 DS	98-111 DS	112-125 DS
0.0 (control)	8	28	16	12	15	11	12
0.1	10	16*	12	16	16	10	14
0.2	8	23	17	15	8*	12	12
0.5	8	24	13	15	10*	9	12
1	10	20*	16	12	10	8	14
2	8	19*	12	8	9*	8	14
5	10	21*	13	7	10	8	15
10	9	23	10	S	10	8	14
25	4	13*	8	10	7*	8	12
50	3	4*	5*	8	4*	9	14
100	0*	1*	1*	6	3*	8	8

* Significantly different from the control at the 5% level.

[a] Where number is less than one, one insect per tiller was caged for a fraction of 2 weeks, e. g. one insect per tiller for 1.4 days (0.1 x 14).

[b] Age of plant (days after seeding) during infestation. Each plant was infested for not more than 2 weeks throughout its entire growth.

Table 2

Effect of fluctuating nymphal density of green leafhopper *Nephotettix virescens* on grain weight of IR 22 in a greenhouse[a].

Designation	Treatment[b] Max nymphal density (no./hill) First generation	Second generation	Third generation	Panicles[c] (no./hill)	Unfilled grain (%)	Grain wt (g/hill)	Grain reduction (%)
A (Control)	0	0	0	16 a	25 a	26.9 a	
B	2	1	1	14 ab	27 a	23.2 ab	14
C	3	2	1	14 ab	26 a	22.0 ab	18
D	6	3	2	11 bc	37 b	16.6 bc	38
E	12	6	4	11 bc	41 b	15.6 c	42
F	20	10	7	10 c	41 b	14.8 c	46
G	50	25	17	6 d	48 c	6.5 d	76
H	200	100	67	2 e	62 c	2.5 e	91

a In a column, means followed by the same letter are not significantly different at the 5% level.
b Treatments described further in text and Figure 1.
c Measured at 90 days after seeding.

Table 3

Loss of grain weight caused by simulated[a] stem borer damage in a greenhouse at two plant ages. Variety, IR 26.

Damaged tillers (% of total)	of productive tillers)	Grain wt[b] (g)	Grain wt reduction
Damaged at 40 days after seeding			
0	0	38 a	
10	4	34 b	10
20	8	32 c	15
30	11	32 c	15
50	21	28 d	25
Damaged at 60 days after seeding			
0	0	74 a	—
2	4	69 b	7
6	7	63 bc	16
10	10	55 cd	26
16	18	46 d	38
26	36	34 e	54

a Dead hearts were caused by killing the growing point of tillers with a needle.
b Measured for single hills (40 days after seeding; or for two hills (60 days). Any two means followed by the same letter are not significantly different at the 5% level.

Table 4
Loss of grain weight caused by simulated • stem borer damage in the field at three plant ages. Variety, IR 25.

Damaged tillers (% of total)	Damaged tillers (% of productive tillers)	Grain wt b (g/2 hills)	Grain wt reduction (%)
	Damaged at 40 days after seeding		
0	0	73 a	—
5	5	70 a	5
10	11	70 a	5
15	17	58 b	21
25	31	53 b	28
50	77	48 b	34
	Damaged at 60 days after seeding		
D	0	77 a	—
2	3	68 b	11
6	8	60 c	22
10	14	57 c	25
16	22	54 c	30
26	38	44 d	42
	Damaged at 80 days after seeding		
0	0	78 a	—
2	3	66 b	16
6	8	63 bc	20
10	15	58 cd	26
16	22	52 d	34
26	40	41 e	48

a Dead hearts or white heads were caused by killing the growing point of tillers with a needle.
b Any to means followed by the same letter are not significantly different at the 5% level.

Larval density (tillers/larva)	Damaged leaves[b] (no./hill)	CO	Unfilled grains (%)	Grain wt[c] (g/hill)	Grain wt reduction (%)
		Infested at 77 DS			
No infestation	O a	0	43	28.5 a	—
10	6 b	7	48	29.4 a	0
8	7 b	8	48	29.6 a	0
6	11 c	13	51	25.4 ab	11
4	15 d	15	54	24.0 bc	16
2	19 e	23	50	20.4 c	28
		Infested at 84 DS			
No infestation	O a	0	39	32.3 ab	—
10	3 b	5	41	32.2 ab	0
8	5 c	7	40	33.7 a	0
6	6 d	9	43	29.7 ab	8
4	8 e	12	48	29.3 b	9
2	13 f	18	44	24.2 c	25

Bug density (no./sq m)	Unfilled grains (%)	Yield (g/sq m)	Yield loss (%)
0	28 a	453 a	—
1	30 a	438 ab	3
2	36 b	440 ab	3
4	37 b	411 b	9
8	43 c	360 c	21

സംഗ്രഹം

നെല്ലിൽ, കീടബാധ എത്രത്തോളമായാൽ അപകടരഹിതമായിരിക്കും എന്നു നിർണ്ണയിക്കുന്നതിനായി കാര്യമായ ഗവേഷണങ്ങളൊന്നും നടന്നു കാണുന്നില്ല. നെഫോടെററിക്സ് വൈറെസെൻസ്, ഹൈഡ്രെല്ലിയാ സസാക്കി എന്നീ കീടങ്ങളുടെ കാര്യത്തിൽ നടത്തിയ പ്രാരംഭ ഗവേഷണങ്ങളിൽനിന്നും കാര്യമായ നിഗമനങ്ങളിലൊന്നും എത്തിച്ചേരാൻ കഴിഞ്ഞിട്ടില്ല, എന്നിരിക്കലും, ലെപ്റ്റോകൊറൈസാ സ്പീഷീസിൽപ്പെട്ട കീടങ്ങൾ ഒരു ച. മീററിന് 3 എണ്ണം വീതമുണ്ടാകുന്നത് അപകടകരമല്ല എന്ന് കണ്ടിട്ടുണ്ട്. നഫെലോക്രോസിസ് മെഡിനാലിസ് എന്ന കീടത്തിൻെറ ഒന്നോ rocsneo ലാർവകൾ 4 ചിനപ്പുകൾക്ക് എന്നതോതിൽ ഉണ്ടായിരിക്കുന്നതും അപായകരമല്ല. നെൽച്ചെടികൾ കതിരിടുന്ന അവസരത്തിൽ ഒരു ചുവട്ടിലെ 10–15 ഇലകളിൽവരെ ഇലചുരുട്ടിപ്പുഴുക്കളുടെ ആക്രമണമുണ്ടാകുന്നത് കനത്ത സാമ്പത്തിക നഷ്ടത്തിനിടയാക്കും. വിത്തു വിതച്ച് 40 ദിവസമാകുമ്പോൾ തണ്ടുതുരപ്പൻപ്പുഴുക്കളുടെ ആക്രമണമുണ്ടായാൽ അത് 10-15% വരെ വെള്ളക്കൂമ്പിനുമിടയാക്കും. ആക്രമണം 60–80 ദിവസമാകുമ്പോഴാണെങ്കിൽ 2% വെൺകതിരുകളായിരിക്കും ഫലം. നെല്ലിൽ എത്രത്തോളം കീടബാധയാകാമെന്നുള്ളതിനെപ്പററി കൂടുതൽ ഗവേഷണങ്ങൾ ഇനിയും നടത്തേണ്ടതായാണിരിക്കുന്നത്. പ്രത്യേകിച്ചും അവിടവിടെയായി ആക്രമിക്കുന്ന കീടങ്ങളുടെ കാര്യത്തിലും. നെൽച്ചെടികൾക്ക് താരതമ്യേന ഉയർന്ന പ്രതിരോധ ശേഷിയുള്ള കീടങ്ങളുടെ കാര്യത്തിലും.

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