3. ECOLOGICAL STUDIES ON THE RICE STEM BORER (*CHILO SUPPRESSALIS* WALKER) IN TAIWAN (II): HOST PLANT SURVEY

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Introduction

Rice stem borer is polyphagous insect. Under natural environment, the rice plant is the main host. Besides, crops such as sugarcane, wheat, water oat, upland rice, Italian millet, Indian corn and other Graminaceous crops may occasionally be the temporary host. Sugarcane of Fu-tze cropping** may sometimes be reduced to be disaster by the rice stem borer in Taiwan.

Host plants of the rice stem borer

From literature and our investigations, host plants of the rice stem borer in the world may be summarized as follows (Table 1):

Table 1. Host plants of the rice stem borer.

Names	Locality	Reported by
Echinochloa sp.	Hawaii	Van Zwaluwenberg, 1926
Oryza latifolia (wild rice)	Japan	Tanaka, 1928
Oryza sativa (Rice)	China (mainland & Taiwan) Hawaii, India, Indochina Indonesia, Japan, Korea, Malaya, Pakistan, Phillippines	Numerous references under *C. simplex* and *C. oryzae*
Panicum miliaceum	China (Taiwan) Japan	Ku-sheng Kung, 1968 Kuwana, 1930
Phragmites communis	China (Taiwan) Japan	Kuwana, 1930
Saccharum fuscum	India	Fletcher and Ghosh, 1920
Saccharum officinarum	China (Taiwan)	Chia-hwa Tao, 1962
Typha latifolia (great reedmace)	Japan	Tanaka, 1928 Kuwana, 1930
Zizania aquatica	China Japan and China (Taiwan)	 Kuwana, 1930
Zea mays	China (Taiwan)	S.T. Yei, 1949
†*Musa sapientum*	China (Taiwan)	Chia-hwa Tao, 1964 Ku-sheng Kung, 1968
Triticum vulgare	China (Taiwan) (Mainland)	Chia-hwa Tao, 1964 S. Chen, 1939
†*Ananas comosus*	China (Taiwan)	Chia-hwa Tao, 1964

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** Fu-tze cropping: planting of crops in the same field as the first crop before the harvest of the first crop.

Table 1. (Continued)

Names	Locality	Reported by
†*Ipomoea batatas*	China (Taiwan)	Ku-sheng Kung, 1968
Pennisetum purpuem	China (Taiwan)	Ku-sheng Kung, 1968
†*Gossypium hirsutum*	China (Taiwan)	Ku-sheng Kung, 1968
†*Spomacoa olerace*	China (Taiwan)	Ku-sheng Kung, 1968
†*Brassica oleracea* L., Var. acephala. D.C.	China (Taiwan)	Ku-sheng Kung, 1968
Andropogon sorghum	China (Taiwan)	Ku-sheng Kung, 1969
Paspalum distichum	China (Taiwan)	Ku-sheng Kung, 1969

† These host plants can be destroyed by rice stem borer in laboratory, but the mortality of the larvae which were fed with such plants is higher than that of organism fed on rice plants; we have not obtained the complete life-cycle of the rice stem borer on these hosts yet.

Host plants for egg-laying

The latin square design experiments were conducted in a field wire cage to determine the preference or the host selection of the rice stem borer. 25 plants for egg-laying comprise 5 species of graminaceous plants, e.g. *Oryza sativa, Zea mays, Zizania aquatica, Triticum vulgare, Andropogon sorghum,* were employed in each replication. Two replications were completed.

A total of 84 females and 74 males newly emerged moths were inoculated in the 1st replication, and 78 females with 71 males were inoculated in the 2nd replication. The designs that were applied in this experiment and the numbers of egg-masses on different plants are given in Table 2 and Table 3.

Table 2. Design of Latin square and number of egg-masses on host plants laid by *Chilo suppressalis* Walker in the 1st replication.

Row \ Column	i	ii	iii	iv	v	Σ Row
I.	A 14 (3.87)*	D 0 (1.00)	B 0 (1.00)	E 0 (1.00)	C 1 (1.41)	(8.28)
II.	B 1 (1.41)	E 1 (1.41)	C 0 (1.00)	A 15 (4.00)	D 0 (1.00)	(8.82)
III.	D 0 (1.00)	A 10 (3.31)	E 0 (1.00)	C 0 (1.00)	B 0 (1.00)	(7.31)
IV.	C 0 (1.00)	B 0 (1.00)	A 5 (2.44)	D 1 (1.41)	E 1 (1.41)	(7.26)
V.	E 0 (1.00)	C 0 (1.00)	D 0 (1.00)	B 0 (1.00)	A 4 (2.23)	(6.23)
Σ Column	(8.28)	(7.72)	(6.44)	(8.41)	(7.05)	T=37.90

* Values in parentheses show the transformed number of egg-mass by the formula of $\sqrt{X_{ij}+1}$ because of the original data show a Poisson distribution here.

Since in the data given above there is no significantly different interaction between the treatment and replication, and it is desired to increase the degree of freedom in the error, a method for Latin Square Analysis of Variance without interaction between treatment and replication was applied. The results are given in Table 4.

Table 3. Design of Latin square and number of egg-masses on host-plants laid by *Chilo suppressalis* Walker in the 2nd replication.

Row \ Column	i	ii	iii	iv	v	$\sum$ Row
I	C 3 (2.00)*	E 0 (1.00)	D 0 (1.00)	B 0 (1.00)	A 16 (4.12)	(9.12)
II	B 1 (1.41)	A 15 (4.00)	E 0 (1.00)	C 0 (1.00)	D 0 (1.00)	(8.41)
III	D 0 (1.41)	B 0 (1.00)	C 0 (1.00)	A 8 (3.00)	E 0 (1.00)	(7.00)
IV	A 10 (3.31)	D 0 (1.00)	B 0 (1.00)	E 0 (1.00)	C 2 (1.73)	(8.04)
V	E 0 (1.00)	C 4 (2.23)	A 6 (2.64)	D 0 (1.00)	B 1 (1.41)	(8.28)
$\sum$ Column	(8.72)	(9.23)	(6.64)	(7.00)	(9.26)	T=40.85

* Values in parentheses show the transformed number of egg-masses by the formula of $\sqrt{X_{ij}+1}$, because of the original data show a Poisson distribution here.

Table 4. Analysis of Variance in egg-laying.

Sources of Variances	d. f.	Sum of Squares	Mean of Squares	F'S	Theoretical F'S	
					1%	5%
Replications	1	0.17	0.1700	0.81		3.24
Column within Replications	8	1.82	0.2255	1.68		2.29
Row within Replications	8	1.28	0.1600	1.18		3.23
Treatments (tests)	4	37.37	9.3425	66.25**	4.07	
Error (Residual)	28	3.97	0.1410			
Total	49	44.61				

It can be seen that the only variance which is significantly large compared with the residual variance is the treatments or tests variance. In other words the number of egg-masses laid by the *Chilo* moths on plant varies greatly according to the species of host plant. The difference of the number of egg-masses between each species of host plant is significantly different.

In order to understand the level or range of significant difference between each treatment or species of host plant, Duncan's method of Multiple Range Test is applied. The range of least significant difference is listed in Table 5 and the comparison of the mean of each treatment is listed in Table 6.

The results from the Duncan's Multiple Range Test here, indicate that among the five different species of host plants which were employed in this experiment, there is no significant difference among the host plants of *Z. aquatica, Z. mays, A. sorghum*, and *T. vulgare* for the female moths of *C. suppressalis* laying their egg-mass, though the number of egg-masses on water oat (*Z. aquatica*) is larger than the other three species of host plants. The only difference of the number of egg-masses on the host plant which is significantly large compared with the number of egg-masses on the other host plants is rice plant (*O. sativa*). It can be seen that the female moths of *C. suppressalis* select the rice plant as the preferred host plant to lay their egg-masses on.

Table 5. **Range of the least significant difference for M. R. T. in egg-laying.** $S\bar{x}=0.118$

$R\begin{pmatrix} dfE \\ P \\ ps \end{pmatrix}$ \ P	2	3	4	5
$R\begin{pmatrix} 28 \\ P \\ 0.5 \end{pmatrix}$	2.90	3.04	3.13	3.20
$R\begin{pmatrix} 28 \\ P \\ 0.01 \end{pmatrix}$	3.91	4.08	4.18	4.28
$\bar{D}\begin{pmatrix} P \\ 0.05 \end{pmatrix}^*$	0.3422	0.3587	0.3693	0.3776
$\bar{D}\begin{pmatrix} P \\ 0.01 \end{pmatrix}$	0.4613	0.4814	0.4932	0.5050

* $\bar{D}\begin{pmatrix} P \\ ps \end{pmatrix} = R\begin{pmatrix} dfE \\ P \\ ps \end{pmatrix} . S\bar{x}$

Table 6. **Comparison of the mean of each treatment in egg-laying.**

Treatment	Mean					
O, sativa = A	3.292	A				
Z. aquatica = C	1.337	1.955**	C			
Z. mays = B	1.123	2.169**	0.214	B		
A. sorghum = E	1.082	2.210**	0.255	0.041	E	
T. vulgare = D	1.041	2.251**	0.296	0.082	0.041	D

Host plant for newly hatching larvae

The complete randomized design experiments were carried out in laboratory. Six different host plants were employed for this test, namely: *O. sativa*, *Z. aquatica*, *S. officinarum*, *A. sorghum*. *Z. mays* and *P. distichum*. The root of host plant which was 20–25 cm high was coated with wet-cotton and orderly arranged the host plants in a circle around in a petri-dish (15 cm in diameter). An egg-mass (about 150 eggs) which was ready for hatching was placed in the center of the petri-dish. Three replications were conducted. 4 days after the hatching of egg-mass, check the larvae on/in the host plants and take records. The results of this experiment were listed in the Table 7:

Based on the above data, the analysis of variance for a complete randomized design experiment is shown in Table 8.

It can be seen that the variance within treatments is significantly larger than the residual variance. In order to understand the level or range of significant difference between each treatment or species of host plants which was employed in this experiment, Duncan's Multiple Range Test is applied. The range of the least significant difference and the comparison of the mean of each treatment are listed in Table 9 and Table 10.

The results here show that among the six different species of host plants which

Table 7. Number of larvae on/in the host plant, 4 days after hatching, in a complete randomized design experiment.

Host plants	No. of larvae on/in host plant								Mean
	1st repl.		2nd repl.		3rd repl.		Total		
	Observation	Transformation	Observation	Transformation	Observation	Transformation	Observation	Transformation	
O. sativa	22	4.79	20	4.58	39	6.32	81	15.69	5.230
Z. aquatica	45	6.78	18	4.35	23	4.89	86	16.02	5.340
Z. mays	1	1.41	0	1.00	1	1.41	2	3.82	1.273
A. sorghum	1	1.41	0	1.00	0	1.00	1	3.41	1.136
S. officinarum	0	1.00	1	1.41	0	1.00	1	3.41	1.136
P. distichum	0	1.00	0	1.00	0	1.00	0	3.00	1.000
Total								45.35	

Table 8. Analysis of variance for newly hatching larvae.

Sources of variance	d.f.	Sum of squares	Mean of squares	F'S	Theoretical F'S 1%
Treatments	5	83.5354	16.7069	82.62**	5.06
Error (residual)	12	2.4266	0.2022		
Total	17	85.9611			

Table 9. Range of least significant difference for M.R.T. in newly hatching larvae.
$S\bar{x}=0.25$

$R\begin{pmatrix} dfE \\ P \\ ps \end{pmatrix}$ \ P	2	3	4	5	6
$R\begin{pmatrix} 12 \\ P \\ 0.05 \end{pmatrix}$	3.08	3.23	3.33	3.36	3.40
$R\begin{pmatrix} 12 \\ P \\ 0.01 \end{pmatrix}$	4.32	4.55	4.68	4.76	4.84
$\bar{D}\begin{pmatrix} P \\ 0.05 \end{pmatrix}$	0.7700	0.8075	0.8325	0.8400	0.85
$\bar{D}\begin{pmatrix} P \\ 0.01 \end{pmatrix}$	1.0800	1.1375	1.1700	1.1900	1.21

Table 10. Comparison of the mean of each treatment in newly hatching larvae.

Treatment	Mean						
Z. aquatica = B	5.340	B					
O. sativa = A	5.230	0.110	A				
Z. mays = C	1.273	4.067**	3.953**	C			
A. sorghum = D	1.136	4.204**	3.094**	0.137	D		
S. officinarum = E	1.136	4.204**	3.094**	0.137	0.000	E	
P. distichum = F	1.000	4.340**	4.230**	0.237	0.136	0.136	F

were selected by newly hatching larvae, the difference between rice (*O. sativa*) and water oat (*Z. aquatica*) is not significant and the differences between corn (*Z. mays*), sugarcane (*S. officinarum*), sorghum (*A. sorghum*) and weed (*P. distichum*) are not significant either. But either rice or water oat compared with other host plants which were employed here, the difference is very significant. Needless to say that the newly hatching larvae of *C. suppressalis* prefer water oat and rice to other plants they selected.

Host plant for the 4th instar larvae

The same species of host plants and arrangement as mentioned above were applied, but 100 larvae in the 4th instar were placed in the center of petri-dish instead of the egg-mass. Three replications were carried out. Two days after inoculating all the host

Table 11. Number of larvae bored into stem of host plant in a complete randomized design experiment.

Host plants	No. of larvae bored into stem of host plant								Mean
	1st repl.		2nd repl.		3rd repl.		Total		
	Obser-vation	Transfor-mation	Obser-vation	Transfor-mation	Obser-vation	Transfor-mation	Obser-vation	Transfor-mation	
O. sativa	18	4.35	14	3.87	39	6.32	71	14.54	4.846
Z. aquatica	35	6.00	18	4.35	23	4.89	76	15.24	5.080
Z. mays	1	1.41	0	1.00	1	1.41	2	3.82	1.273
A. sorghum	1	1.41	0	1.00	0	1.00	1	3.41	1.136
S. officinarum	0	1.00	1	1.41	0	1.00	1	3.41	1.136
P. distichum	0	1.00	0	1.00	0	1.00	0	3.00	1.000
Total									

Table 12. Analysis of Variance for the 4th instar larvae.

Sources of variance	d.f.	Sum of squares	Mean of squares	F'S	Theoretical F'S 1%
Treatments	5	58.7673	11.7534	27.59**	5.06
Error (residual)	12	5.1229	0.4260		
Total	17	63.8902			

plants were checked. The results and analysis of variance are shown in Table 11 and Table 12.

Here again the variance within treatments is significantly larger than the residual variance. Then following Duncan's Multiple Range Test, the range of the least significant difference and the comparison of the mean of each treatment are listed in Table 13 and Table 14.

Table 13. Range of the least significant differences for M. R. T. in the 4th instar larvae.

$S\bar{x}=0.37$

$R\begin{pmatrix} dfE \\ P \\ ps \end{pmatrix}$ \ P	2	3	4	5	6
$R\begin{pmatrix} 12 \\ P \\ 0.05 \end{pmatrix}$	3.08	3.23	3.33	3.36	3.40
$R\begin{pmatrix} 12 \\ P \\ 0.01 \end{pmatrix}$	4.32	4.55	4.68	4.76	4.84
$\bar{D}\begin{pmatrix} P \\ 0.05 \end{pmatrix}$	1.1396	1.1951	1.2321	1.2432	1.2580
$\bar{D}\begin{pmatrix} P \\ 0.01 \end{pmatrix}$	1.5984	1.6835	1.7316	1.7612	1.7908

Table 14. Comparison of the mean of each treatment in the 4th instar larvae.

Treatment	Mean						
Z. aquatica = B	5.080	B					
O. sativa = A	4.846	0.234	A				
Z. mays = C	1.273	3.807**	3.573**	C			
A. sorghum = D	1.136	3.944**	3.710**	0.137	D		
S. officinarum = E	1.136	3.944**	3.710**	0.137	0	E	
P. distichum = F	1.000	4.080**	3.846**	0.273	0.136	0.136	F

The results here is exactly like the results from the previous experiment. There is no significant difference between rice and water oat, and no significant difference among corn, sugarcane, sorghum and weed, but when either rice or water oat was compared with the other host plants the difference is very significant. In other words, the 4th instar larvae of *C. suppressalis* prefer water oat and rice to other plants.

Discussion

F. B. Calora: You mentioned that at present *Chilo suppressalis* is the most predominant species of borers in Taiwan while *Tryporyza incertulas* used to be the most important species before. What is your opinion about this shift in the predominant species?

Ku-Sheng Kung: The reason for this phenomenon has not been investigated but the following factors may be involved.

1) The change in the agricultural system. The environmental resistance against *T. incertulas* was increased by applying fertilizers and improved irrigation system to rice crop. Moreover, new effective systemic insecticides were used to control *T. incertulas* whereas no attention was paid to *Chilo suppressalis* control.
2) As the life cycle of *Chilo suppressalis* is different from *T. incertulas* it might be possible that the parasites and predators of *Chilo* were killed by the insecticides used for the control of *T. incertulas* and thus the population of *Chilo* increased unchecked.
3) Due to severe competition between the two species of borers.

M. D. Pathak: Do you have information on the ability of *C. suppressalis* to complete life cycle on the host plant that you studied?

Ku-Sheng Kung: Yes, the pest successfully completed its life cycle on the host plants other than rice e.g. water oat (*Zizamia aquatica*) and sugarcane (*Saccharum officinarum*).

M. D. Pathak: Is *Chilo suppressalis* a polyphagous species?

Ku-Sheng Kung: Yes.

N. Kimura: Have you studied the effect of moonlight on light trap catches?

Ku-Sheng Kung: The light trap catches are affected by the temperature, humidity and wind velocity rather than the moonlight. I don't know any method by which the effect of moonlight may be excluded from the light trap data.

S. Areekul: Has any one studied the competition phenomena between the *T. incertulas* and *C. suppressalis?*

Ku-Sheng Kung: Not that I know of.

S. Areekul: Have you compared the resistance against insecticides between the two species of borers?

Ku-Sheng Kung: No.