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The Changes of Occurrence Patterns of Major Rice Insect Pests in Korea*

한국에 있어서 수도해충 발생 변천에 관하여

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ABSTRACT The extensive cultivation of new yielding varieties might give some distruption to the rice insect pest complex in Korea The population of *Nephottetix cincticeps* and *Laodelphax striatellus* has decreased in number since the extensive cultivation of new varieties, Tongil lines, in 1976. During the last 23 years, the rice insect pest population except for *Chilo suppressalis* drastically decreased, however, *C. suppressalis* population increased again in recent years. This tendency seems to be very closely correlated with the cultivation of new varieties, and a lot of fertilizations and insecticides applications.

KEY WORDS Rice insect pests, occurrence pattern, Tongil line, fertilization, insecticide

초 록 벼신품종의 광범위한 재배는 벼해충상의 변화에 영향을 주었을 것으로 사료된다. 끝동매미충과 애멸구의 발생은 통일계 신품종의 재배면적이 많이 증가하기 시작한 1976년 이후 급격히 감소하는 경향을 보여주었다. 한편, 최근 23년간 자료를 분석한 결과 전체적인 벼해충이 급격히 감소하였으나 이화명나방은 최근에 다시 증가하는 추세를 보이고 있다. 이러한 경향은 신품종재배와 과다한 시비 및 살충제의 대량살포와 깊은 관계가 있는 것으로 분석되었다.

검 색 어 벼해충, 발생양상, 통일계 품종, 시비, 살충제

Rice habitat insect species has been recorded 119 species in Korea until 1982. About 10 species have long been known as serious pests of rice. The rice insect fauna was drastically changed during the last three decades, especially in the case of the rice stem borer, *Chilo suppressalis*. This indigenous species is now no more belonged to the key pest group in the rice insect pests, which has been reconginzed as a chronical problem in rice pest management until early 1970's. However, the brown planthopper, *Nilaparvata lugens*, and the white backed planthopper, *Sogatella furcifera*, are long-range, windborne migrant from Southern China on winds associated with rainy season depressions. In 1988, a new species of rice pest which was the rice water weevil, *Lissorhoptrus oryzophilus*, was invaded from Japan. This insect has become an important rice pest nowadays.

On the other hand, a new variety, Tongil, which was developed using the process of crossing Indica and Japonica rice had been success-

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fully breeded and disseminated. During the 1970's Korean Government pursued effective programs to expand the Tongil line varieties. In course of this work, Korea produced the highest average rice yield per hectare (4.94 ton/ha) in 1977. The areas with the new varieties were rapidly increased to occupy up to 76.2% of national padding in 1978 from 22.9% in 1975. After new rice varieties were released throughout the country, the species diversity of the insect pests including natural enemies and the agroecosystem with relation to the cultural practices in the paddy field became a very simplified system. In accordance with these facts, the author collected the data of light trap of major insect pests from the basic forecasting stations in the country for 23 years. These collecting data were analysed by several statistic methods and were correlated with the release of new rice variety. Finally, some changes of insect population density in several periods from 1966 to 1988 were analysed.

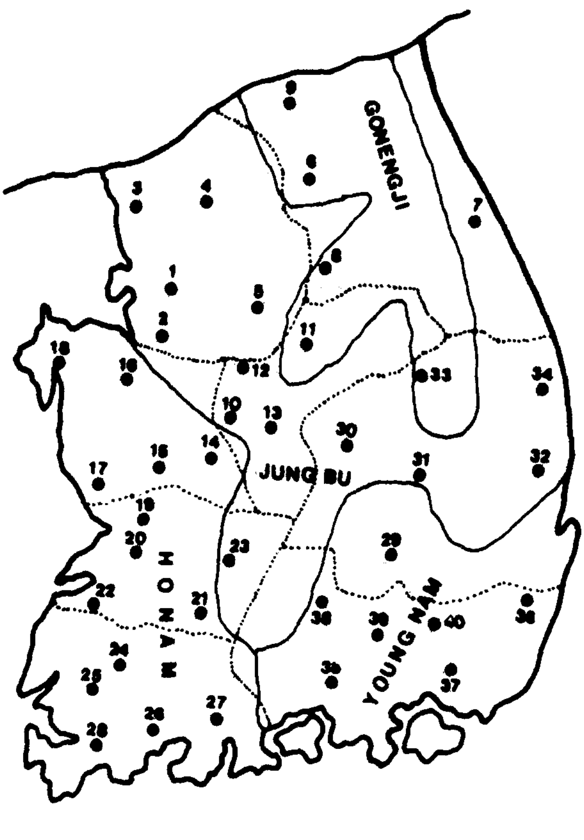

Fig. 1. Distribution map of light traps in different rice cultural areas in Korea(Basic forecasting units).

MATERIALS AND METHODS

Insect collections

The light traps(100W, incandescent lamp) were used for insect capture from 40 stations among 150 basic forecating stations throughout the country(Figure 1). Data were collected for 23 years from 1966 to 1988. Six insect pest species classified into three groups. The first group includes the striped stem borer(SSB), *Chilo suppressalis*, and the leaf folder(LF), *Cnaphalocrosis medinalis*. The second group contains the virus vectors which are the smaller brown planthopper(SBPH), *Laodelphax striatellus*, and the green rice leafhopper(GRLH), *Nephotettix cincticeps*. Finally, the white backed planthopper (WBPH), *Sogatella furcifera*, and the rice brown planthopper(BPH), *Nilaparvata lugens*, the long distance migratory species were in the third group.

Data collection and analysis

Data were collected from year books of the agriculture and forestry for acreages of varieties, fertilizer consumptions and amount of used insecticides throughout the country. Correlation coefficients were analyzed between the outbreaks of insects and the cultural practices including varieties, fertilizers and insecticides.

Changing trends of rice varieties

By the data compilation, changing trends of

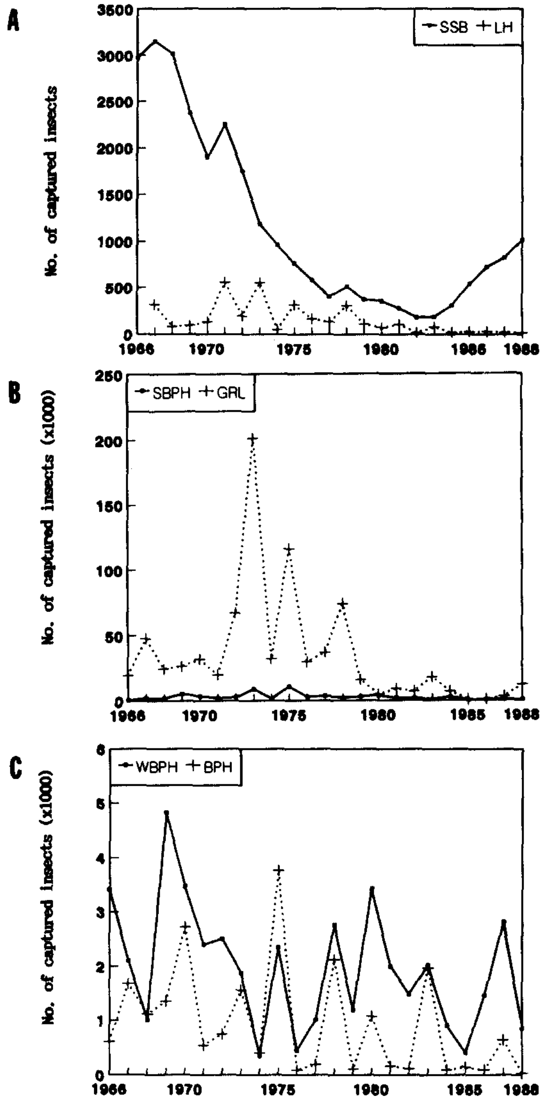

Fig. 2. Annual changes of insect population in different insects for 23 years(1966-1988);(A) striped stem borer(SSB) and leaf folder(LF), (B) smaller brown planthopper(SBPH) and green rice leafhopper(GRLH) and (C) white backed planthopper (WBPH) and brown planthopper(BPH).

rice varieties were divided into three periodic parts based on the release year of new rice varieties, Tongil type, crossed with Indica and Japonica type variety divisions of periodical are as follows;

Period I (1966-1971): 99.8-100% with Japonica type(Traditional cultivars)

Period II-1(1972-1975): 77.1-88.6% with Japonica type(Rapidly increased Tong-il line varieties)

Period II-2(1976-1980): 23.8-56.1% with Japonica type(Tongil lines were mainly cultivated)

Period III-1(1981-1985): 65.7-73.5% with Japonica type(Decreased Tongil line varieties)

Period III-2(1986-1988): 77.9-82.1% with Japonica type(Tongil line was maintained under 25%)

RESULTS

Successional changing trends in the major insect pest of the rice plant

Nephottetix cincticeps and *Laodelphax striatellus* had been decreased in numbers, since the extensive cultivation of new varieties, Tongil lines, in 1976(Figure 2). These two insect species reached to the highest level in the period II-1 (1972-1975). However, the population of each rice insect drastically decreased to the low level during period III-1 and III-2(1981-1988), except *C. suppressalis* and *S. furcifera*. However, *C. suppressalis* gradually increased year by year during period III-2.

The complex of rice pest insects may be divided by economic aspects into two groups which are key pests and minor species group(Table 1). As shown in Table 1, *N. lugens*, *G. suppressalis*, *S. furcifera* and *L. oryzophilus* are belonged to key pests group. In 1988, *L. oryzophilus* has invaded from Japan to southern area in the country. Since they gave serious damages to the rice plant and rapidly spread to another place, they have become an important

Table 1. The changing patterns of the major rice insect pests during the given year periods

Group		Species	Period I	Period Ⅱ-1	Period Ⅱ-2	Period Ⅲ-1	Period Ⅲ-2	Remarks
Key pests	present	*Nilaparvata lugens*	****	****	****	***	***	Migratory (China)
		Chilo suppressalis	*****	***	**	**	***	Indigenous
		Sogatella furcifera	***	**	**	*	**	Migratory (China)
		Lissorhoptrus oryzophilus	–	–	–	–	*	Introduced (Japan)
	potential	*Laodelphax striatellus*	***	***	**	**	*	Indigenous
		Nephottetix cincticeps	**	***	**	*	*	Indigenous
Minor species	present	*Cnaphalocrocis medinalis*	**	**	*	*	*	Migratory (China)
		Hydrellia spp.	*	**	**	**	**	Indigenous
		Naranga aenescens	**	*	*	*	–	Indigenous
	extinct	*Recilia dorsalis*	***	*	–	–	–	Indigenous
		Susumia exigua	**	*	–	–	–	Indigenous

* indicates the relative economic importance.

pest insect in the country. In the other hands, *N. cincticeps* and *L. striatellus* have decreased in their economic importance after period III-1. *Cnaphalocrocis medinalis*, *Hydrellia* spp. and *Naranga aenescens* were classified in minor species group, although *Hydrellia* spp. was a very important pest in the period III-1 (Lee & Choi 1980). One of the interesting facts was that some insect pest species had disappeared in the paddy fields. For example, *Recilia dorsalis* and *Susumia exigua* could not be seen in the field since early 1980's. The rice insect fauna might gradually change in their populations, and indigenous species became the secondary pests or unimpotant pests after period II-2.

Factors affecting the outbreaks of rice insects

The extensive cultivation of new high yielding varieties might give some disruption to the rice insect pests complex. As shown in Figure 3, insect populations increased and maintained at the high level during period II-1 after releasing Tongil line in 1971. After 1975, however, their population and the cultivated area of Tongil line showed a very similar pattern. Tongil line required fertilizer over 1.4 times than conventional Japonica types. The high fertilizer applications might be related to increasing of pest populations. However, there were some negative effects to the insect population as increased used amount of silicated fertilizer application.

Extensive and intensive use of insecticides was followed by the adverse effects to the

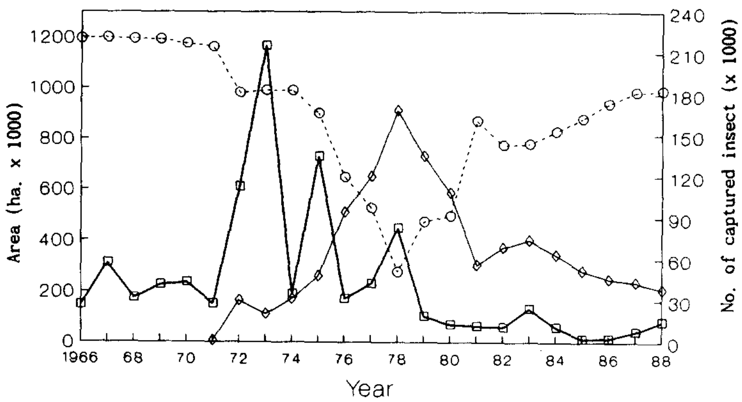

Fig. 3 Annual changing trends in outbreaks of total number of rice insect pests(-⊟-) and area of cultivation with japonica(-⊖-) and Tongil line varieties(-◇-).

yields of rice including residue in food and soil. Extensive use of insecticides also disrupted populations of nontarget organisms and valuable natural enemies (Kiritani 1971, 1972, Yushima *et al.* 1973). And it also brought resurgence phenomenon of the insects pests and has induced the development of insect resistance to some of insecticides (Hama & Iwata 1973, Hama 1975).

Most of insecticides which belong to an organic phosphate group were seriously induced resurgence and resistance to insect pests (Heinrichs 1977). As shown in Table 2 the increasing consumption of inseticides to rice paddies was continuously increased 0.51 kg, 2.24 kg and 3.03 kg per ha in 1960's, 1970's and 1980's, respectively. Continuously, total inputs of insecticide increased and the yield of rice went up to 4.94 ton per ha. In recent years (1986-1988), the consumption of carbamate insecticides increased to a half of the total insecticides consumption (7.3→43.7%) and otherwise, organic chemicals were from 83.8% down to 31.5%. During the last 23 years, the rice insect pests populations except for *C. supperssalis* drastically decreased, however, *C. suppressalis* was population declined again in recent years. This tendency has been related very closely with the intensive cultivation of new variety througout the country. Figure 4 shows that the poputation of *C. suppressalis* is highly correlated with rice varieties, fertilizers and insecticides. Consequently, indigenous species(so-called K-strategy species), *L. striattelus* and *N. cincticeps* were affected by the intensive cultivation of practices.

Some ecological changes of *Chilo suppressalis*

Table 3 summarized the ecological changing patterns of *C. suppressalis* for 23 years (1966-1988). Decreasing trend in population of the striped rice borer was recognized in every year until 1982, and then increasing trend in it has again started since 1983. The inclining of the population of *C. suppressalis* is still now continuing during the last five years(1984-1988). This trend seem almost to be correlated with the period which was released with a new high yielding variety, Tongil line. Especially, the population of the second generation moths was increasing since 1984. As shown in Table 3, increasing populations of both generations were recognized in the recent couple of years (1986-1988).

The population of 2nd generation moth has increased more than two times of first generation in 1988. The date at 50% of collected moths became 18 and 11 days earlier in the 1st and 2nd generations, respectively. The duration of moth occurrence became for 36 days and 7 days shorter than in both generations comparing with the population in period of 1966-1971, respectively. Especially, occurrence of the moths in the 1st generation drastically shorter than 2nd generation. Thus, as shown in Table 3, the 1st moth occurrence of both generation was no more earlier in the recent 3 years(1986-1988).

DISCUSSION

In general, fauna of rice insect pests may be strongly affected by rice varieties and/or insecticide applications. Moreover, cultural practices of rice plant are important factors affecting the pest populations, which Kiritani(1979) reviewed that the rice stem borers and the grass hoppers

Table 2. Annual amount of chemical fertilizer and insecticide used, cultivation rate of Tongil line and rice yield per ha between 1966 and 1988

Period	Year	Chemical fertilizer		Insecticede (M/T per ha)	Area of Tongil line cultivation (% of total rice cultivated area)	Rice yield per ha (ton)
		Nitrogen(M/T) (M/T per ha)	Silicated(M/T) (M/T per ha)			
Period I	1966	62,849(52.4)	20.0(0.016)	304(0.25)	0	3.20
	1967	63,105(52.4)	19.0(0.015)	446(0.37)	0	2.94
	1968	90,160(80.0)	6.0(0.005)	599(0.49)	0	2.79
	1969	95,848(80.0)	7.0(0.006)	768(0.64)	0	3.36
	1970	ς4,680(80.0)	14.0(0.012)	890(0.75)	0	3.30
	1971	117,800(100.0)	23.0(0.020)	635(0.54)	0.2	3.37
	Ave.	87,407(52.4)	14.8(0.012)	607(0.51)	0	3.16
Period II-1	1972	117,800(100.0)	22.0(0.018)	1,422(1.21)	15.9	3.34
	1973	116,970(100.0)	26.0(0.22)	1,724(1.47)	10.4	3.58
	1974	118,910(100.0)	80.0(0.067)	1,588(1.34)	15.2	3.71
	1975	119,810(100.0)	175.0(0.146)	2,426(2.02)	22.9	3.86
	Ave.	118,372(100.0)	75.6(0.063)	1,990(1.51)	16.1	3.62
Period II-2	1976	119,620(100.0)	267.0(0.223)	3,597(3.01)	43.9	4.33
	1977	120,830(100.0)	300.0(0.248)	2,651(2.19)	54.6	4.94
	1978	121,910(100.0)	300.0(0.246)	3,544(2.91)	76.2	4.74
	1979	122,420(100.0)	350.0(0.286)	4,040(3.30)	60.8	4.53
	1980	121,980(100.0)	280.0(0.230)	3,337(2.74)	49.5	2.89
	Ave.	121,352(100.0)	299.4(0.247)	3,434(2.83)	57.0	4.29
Period III-1	1981	181,845(150.0)	382.0(0.315)	3,406(2.81)	26.5	4.17
	1982	176,400(150.0)	282.0(0.240)	3,277(2.79)	32.9	4.38
	1983	182,955(150.0)	301.0(0.248)	3,333(2.73)	34.3	4.42
	1984	183,705(150.0)	308.0(0.252)	3,989(3.26)	30.0	4.63
	1985	181,800(150.0)	383.0(0.302)	4,396(3.57)	27.8	4.56
	Ave.	181,341(150.0)	331.2(0.271)	3,680(3.03)	30.3	4.43
Period III-2	1986	184,091(150.0)	312.0(0.253)	4,594(3.73)	22.1	4.54
	1987	188,865(150.0)	306.0(0.243)	4,957(2.54)	19.6	4.36
	1988	188,565(150.0)	304.0(0.242)	4,164(3.02)	17.9	4.81
	Ave.	187,174(150.0)	307.3(0.246)	4,572(3.10)	19.9	4.57

* This data collected from Year Book series (MAFF; 1967～1989).

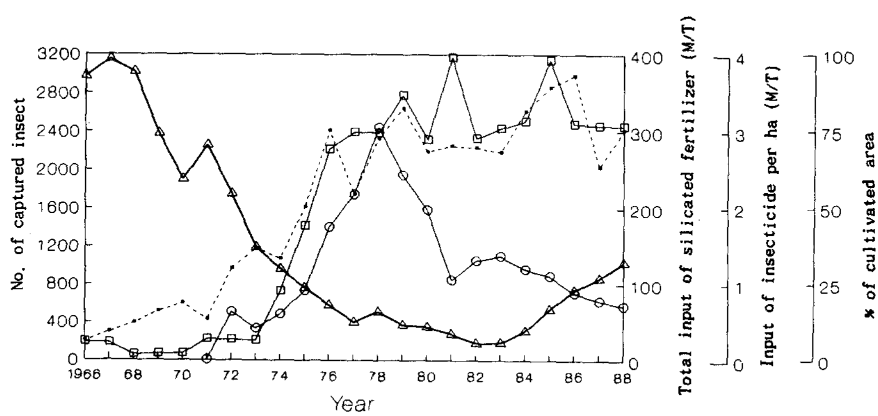

Fig. 4. Annual changing trends in outbreaks of *C. suppressalis*(—△—) and cultivation of Tongil line(—⊖—), consumption of insecticides (—●—) and silicated fertilizer(—⊞—).

Table 3. An ecological changing patterns of *Chilo supperssalis* W. during the last twenty three years (1966-1988)

Year	No. of moth occurred				Ratio of I gen. (%)	Date in 50% occurred		Date of Ist occurred		Duration in	
	I gen.	II gen.	Total	II/I		I gen.	II gen.	I gen.	II gen.	I gen.	II gen.
1966	2,368	607	2,975	0.256	79.6	Jun 29	Aug 26	May 17	Aug 7	84	53
1967	2,502	649	3,151	0.259	79.4	Jun 19	Aug 19	May 12	Aug 1	83	55
1968	2,397	620	3,017	0.259	79.5	Jun 27	Aug 26	May 12	Aug 4	90	58
1969	1,741	636	2,377	0.365	73.2	Jun 27	Aug 29	May 14	Aug 8	86	56
1970	1,427	474	1,901	0.332	75.1	Jun 13	Aug 18	May 11	Aug 4	71	41
1971	1,731	526	2,257	0.304	76.7	Jun 14	Aug 16	May 11	Aug 31	86	44
Ave.	1,893	546	2,439	0.289	77.6	Jun 21	Aug 22	May 12	Aug 4	83	51
1972	1,465	283	1,748	0.193	83.8	Jun 9	Aug 14	May 4	Jul 30	75	6
1973	862	326	1,188	0.378	72.6	Jun 8	Aug 10	May 3	Jul 24	68	47
1974	529	337	966	0.536	65.1	Jun 15	Aug 20	May 12	Aug 1	64	48
1975	535	231	766	0.432	69.8	Jun 10	Aug 12	May 7	Jul 26	68	48
Ave.	848	294	1,142	0.342	74.3	Jun 11	Aug 14	May 7	Jul 28	69	47
1976	412	170	582	0.413	70.8	Jun 1	Aug 18	May 7	Jul 28	66	49
1977	267	136	403	0.509	66.3	Jun 4	Aug 9	May 5	Jul 22	60	48
1978	260	253	513	0.973	50.7	Jun 9	Aug 11	May 9	Jul 27	59	46
1979	190	183	373	0.963	50.9	Jun 9	Aug 12	May 11	Jul 28	60	50
1980	176	181	357	1.028	49.3	Jun 9	Aug 14	May 14	Jul 30	56	41
Ave.	261	185	446	0.709	58.5	Jun 6	Aug 13	May 9	Jul 27	60	47
1981	141	138	279	0.979	50.5	Jun 9	Aug 11	May 8	Jul 29	57	36
1982	94	87	181	0.926	51.9	Jun 7	Aug 7	May 9	Jul 23	52	42
1983	99	89	188	0.899	52.7	Jun 1	Aug 15	May 7	Jul 29	53	41
1984	111	196	307	0.766	36.2	Jun 3	Aug 10	May 10	Jul 24	49	43
1985	206	332	538	0.611	38.3	Jun 9	Aug 10	May 5	Jul 24	58	45
Ave.	125	165	290	1.320	43.1	Jun 6	Aug 10	May 8	Jul 26	54	41
1986	263	477	740	1.814	35.5	May 30	Aug 10	May 7	Jul 24	45	41
1987	355	509	864	1.434	41.1	Jun 4	Aug 12	May 7	Jul 21	47	43
1988	334	699	1,032	2.093	32.4	Jun 7	Aug 10	May 8	Jul 23	49	46
Ave.	317	562	879	1.780	36.3	Jun 3	Aug 11	May 7	Jul 23	47	43

were almost disappeared or decreased in numbers and went down to the minor group of insects. The analysis of trends in outbreak of rice insect pests has revealed of these reasons why these trends continuously happen through the last quarter century. That is, the analysis data have indicated that uses of concentrated chemical insecticides for control of the indigenous speces, the rice stem borer, *C. suppressalis*, including virus vectors, *L. striatellus* and *N. cincticeps*. Effects to breed high yields of rice and highly resistant varieties to the rice pests and to the fungus diseases have been made in the country. The high yield varieties have been cultivated in order to increase their yields with a lot of chemical fertilizer throughout the country. Their cultivation practices were also changed as one of early transplanting way. As above mentioned, it seemed that complicated measures for rice planting have brought with a resistancy of insect pest against chemical insecticides as one of many other problems. Kiritani (1979) suggested that the successful control of the key pest might work in favour of other potential pests creating another conditions which were encouraged their multiplication. He suggested that such a problem to be solved should be turned to use of natural enemies than chemical insecticides. In these regards, it has come to turn in direction of optimization for the integrated pest management, as soon as possible.

Several practices which are high density, high fertility and high insecticides, were followed since high yielding varieties of rice were introduced throughout countries, what has been changed in rice insect pest population. After releasing the new Tongil line varieties with extensive changes of cultural practices, the patterns of outbreaks of the rice insect pests were obviously changed. Monoculture of isogenic variety over extensive areas decreased and simplified with ecological diversity, so that the another potential pest species could outbreake. And the high density of rice planting and the high fertility encouraged for increasing of the pest population. Another increasing of different pest species might be depended on the heavy use of insecticides. A close correlation between annual consumption of nitrogen, silicated fertilizers and insecticides including intensive cultivation of new rice varieties and populations of the rice stem borer, *C. suppressalis* and the rice leaf folder was observed. However, any correlations with any other spesies were not recognized (Table 4). Otherwise, the cultivated area of barley was significantly simple linear correlated with population of *C. suppressalis*, *C. medinalis* and *N. cincticeps* as showed in Table 4.

The factors affecting to the population fluctuation of *C. suppressalis* were considered with some changing of the environmental factors including the plantation of Tongil line, cultural practices, natural enemies and climatic conditions, etc. These environmental factors were considered as the reason why populations of the rice stem borer were greatly affected. Ishikura (1982) reviewed and concluded that the declining of the stem borer population was mainly caused by the resulting from continuing spray of insecticides for the longterm period. In fact, a single control measure of the rice stem borer by insecticides reached maximum level of effects in recent years, so that its population went up again. A more detailed analysis done by Song *et al.*(1982) and Kim *et al.*(1988), revealed that the decreasing tendency of the first generation moth was due to the early transplanting and harvesting. Therefore, it seemed that the late coming-out population could not accomplish up their whole life cycle within the same season.

Table 4. Analysis of correlations with some factors affecting to the populations of rice insect pests for 23 years(1966-88)

Species	% of cultivated area		Consumption amount		
	Tongil line	Barley	Nitrogen	Silicated	Insecticide
Chilo suppressalis	r=0.7654**	r=0.746**	r=0.739**	r=0.858**	r=0.887**
Cnaphalocrocis medinalis	r=0.179	r=0.707**	r=0.502*	r=0.509*	r=0.489*
Laodelphax striatellus	r=0.035	r=0.478*	r=0.315	r=0.288	r=0.193
Nephotettix cincticeps	r=0.073	r=0.672**	r=0.342	r=0.400	r=0.272
Sogatella furcifera	r=0.257	r=0.347	r=0.386	r=0.415	r=0.463
Nilaparvata lugens	r=0.139	r=0.508*	r=0.339	r=0.385	r=0.298

** and * mean simple linear correlation coefficients(r) at 1% and 5% levels of significance, respectively.

Consequently, delaying populations of their life cycle could not be complete development due to lack of rice stems. To shorten the harvesting time of rice accelerated to the way of suppressing population for the long term period. Emura and Kojima(1981) reported that another negative factor, in the case of early harvesting, was a energy loss for their long overwintering period. On the other hand, the population of second generation was not much decreased in comparing with first generation moth, because it could be explained that the new variety, Tongil, has a heavy panicles type and a high responses to nitrogen fertilizer. The high density and high tillering could be given them a chance to disperse easily and for shelters from high temperature conditions at young larvae stage (Hyun & Lee 1975). These all of above factors could be effected positively to increased populations.

Pathak(1964) and Shim(1965) have reported that Japonica X Indica type was so more susceptible to stem borer insect than the Japonica type, so that the larvae could well grow in the feeding of Japonica X Indica type. The first occurrence and 50% catched date of moth were closely related with early transplanting practice after cultivation on new variety (Park & Kim, 1982, Kim *et al.* 1986). The shortening of occurrence days was followed by the early transplanting and harvesting with cultivation of new variety. In all of point of view, it seemed that stem borer population went up again as in the 1960's since in the cardinal year of 1982-83. However, when the uses of insecticides were reduced, another new problems will come again. Therefore, it seems that a importance of integrated control will be needed in the future.

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