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POPULATION ECOLOGY AND MANAGEMENT STRATEGY OF THE WHITE-BACKED PLANTHOPPER *SOGATELLA FURCIFERA* (HORVATH) IN SUBTROPICAL RICE

By

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CONTENTS

Summary

In the general introduction, the pest status shift of the white-backed planthopper *Sogatella furcifera* (Horvath) 1899, 100 years since it nominated, population ecology, wing-form, interactions with rice plants, interactions with natural enemies, injury-yield loss, chemical control and insecticides, outbreak-related process were briefly reviewed. Then the problem definition and objectives of the study were described: as to understand the process and pattern of population dynamics of the species in subtropical field, to find out the associations among variables in field, regional and technical scales, to assess the cost-effectiveness of early spray of insecticide, to optimize the management options. Finally in the introduction part, the outline of the dissertation was briefed.

The population biology and dynamics of the white-backed planthopper, *Sogatella furcifera* (Horvath) were investigated in a subtropical doubling rice ecosystem in hilly region Jinghua - Quzhou Basin, Zhejiang, China. The immigrants colonized to the first season rice during mid-June to early-July synchronizing with monsoon rain, and reproduce one and half consecutive generations with peak generation at the end of the season. The growth rate of the population from immigration to the peak ranked as 17 to 210 fold. Two complete and one uncomplete generations were identified in the second cropping season with maximum density located in either the immigration generation or the 2nd generation after immigration. The population growth rate from immigration to the 2nd generation varied from 0.8 in early-transplanted field to 31 fold in late-transplanted field. The adult planthopper exhibited a female-biased operational sex ratio (OSR) both in the light trap catching and field survey, probably resulted from higher mortality of male, higher attractiveness of unmated female and lower location of mated females. The parasitism of *S. furcifera* eggs by *Anagrus* spp. ranged from 0 to 33% while death caused by predation and unknown causes ranged from 0 to 44%, total mortality of eggs from 13 to 67% in the 1st season. The range of egg parasitism, unknown factor caused death and total mortality in the 2nd season was 0-25%, 0-70% and 0-70% respectively. The parasitism by Drynidae in macropters was higher than in brachypters, while the

parasitism by nematods in brachypters was higher than in macropters. Strepsiptera parasitoids had higher parasitism in the 2nd than in the 1st season rice. Parasitism by the Drynidae, nematods and Strepsiptera are important depression factor for the population dynamics. The survivor analysis showed most mortality occurred around hatching and cumulative egg-adult survivorship was estimated as 2-18 % in the 1st season rice and 1-7% in the 2nd season rice. The high parasitism of immigrants and high temperature might be the main factors influencing the low growth rate in early-transplanted rice in the 2nd season.

Population dynamics of the white-backed planthopper *Sogatella furcifera*, compared with the brown planthopper *Nilaparvata lugens* and the small brown planthopper *Laodelphax striatellus*, the green leafhopper *Nephotettix cincticeps* and the zig-zag leafhopper *Recilia dorsalis* in the **first** cropping season rice were investigated. The migratory *S. fucifera* and *Ni. lugens* preferred late-transplanted rice fields, i.e. "immigration windows". *S. furcifera*, *L. striatellus* and *Ne. cincticeps* could have 1 and 1/2 generations while *Ni. lugens* could develop <1 generation in the season. *S. furcifera* had the highest peak density, over season mean density and growth rate among the four species. Higher peak densities of *S. furcifera* were found in late-transplanted fields but not the growth rate. The peak population densities could be predicted by using previous seasonal peak densities for *S. furcifera*, *L. striatellus* and *Ne. cincticeps*. Severe density-dependent effect was detected in population growth and macropterous wing form percentage in *S. furcifera* but not in *L. striatellus*. Cumulative nymphal survivorship was calculated as 0.7-1.4% and ca. 1% for *S. furcifera* and *Ni. lugens* respectively.

The population dynamics of three species of planthoppers and two species of leafhoppers WBPH colonized the **second** season rice immediately after rice transplanted, earlier than BPH and SBPH, but without difference in immigration peak time. WBPH had higher initial density, high peak density in generation 1 than others species. There were four patterns of population dynamics (I, II, III, IV) of the planthoppers and leafhoppers with maximum peak densities in generation 2, 1, 3 and immigration generation. The percentages of the four patterns were 60, 25, 15 and 0% in WBPH, 21, 3, 76 and 0% in BPH, 23, 36, 36 and 6% in

SBPH and 22, 67, 11 and 0% in GLH. WBPH was dominant species in the early season (<60 DAT, days after transplanting), while BPH was in the late season (>60 DAT). SBPH was only occupying 10-20% in first 20 DAT. Good predictability of peak density of future generation on the base of previous generation was detected in all first four species but the best one was in SBPH. The significant density-dependent population growth rate were examined in most connective and across generations of WBPH, BPH and SBPH, but only one in the initial - generation 1 in GLH. The wing-form differentiation of WBPH and BPH was density- and rice growth stage dependent and the macroptery percentage in the 1st generation affected the population growth rate in WBPH. SBPH was not the density-dependent but increase of macroptery with growth stage of rice. The main characteristics of WBPH population dynamics in subtropical region were higher initial density with 60% possibility being temperate pattern and 25% tropical pattern, therefore it could be explained as transmission phrase from tropical to temperate. The possible causes might be the trade-off between the influence of natural enemies and immigration.

The complex influence of rice variety, fertilization and insecticides on the population dynamics of *Sogatella furcifera* (Horvath), *Nilaparvata lugens* (Stal), *Laodelphax striatellus* (Homoptera: Delphacidae) and their natural enemies was studied on single cropping rice. *S. furcifera* population immigrated to *japonica* Xiushui 11 (X11) much higher than to *indica-japonica* hybrid Xieyou 413 (XY413), while egg density population peak of successive generation was higher in XY413 due to higher growth rate. Spray of triazophos in mid season resulted in high mortality of spiders thereby induced successive *S. furcifera* and *N. lugens* resurgence in treated plots earlier than unsprayed plots through reducing the density of predators and therefore increase of planthopper survival. Spray also postponed the appearance of parasitoids assemblages. Fertilization timing affected rice vegetation development, unfertilized plots received more immigrants of *S. furcifera*. detritivores populations emerged firstly, followed by parasitoids and predators, and finally herbivores in XY413 plots. but followed by parasitoids and herbivores and predators last in X11 plots. Spray postponed the cumulative proportion of parasitoids. The negative relationship between population

growth rate from generation 1 to 2 of *S. furcifera* and density of spiders during correspondent period implying the potential of predators in natural control of the rice planthoppers. The possible mechanism of positive significant correlation between population growth rate from immigration to generation 1 and predators' density during the period was discussed.

Two field investigations were carried out in Lanxi, Zhejiang, to test the hypothesis that early spray of specific insecticides for controlling the stem borers may cause planthopper resurgence caused by reducing the density of predators. Results showed that spray of triazophos alone induced higher *Sogatella furcifera*, *Laodelphax striatellus* population size in the 1st season rice and *S. furcifera*, *Nilaparvata lugens* and *L. striatellus* in one of the two fields in the second season rice. The reduced densities of spiders in the triazophos treated plots might be one of the main causes resulting in resurgence. Furthermore, spray of the insecticide during earlier season did not affect the residue density of the target insect and the larvae parasitism in harvesting time was also reduced. Therefore earlier spraying of triazophos probably is not an adjusted way for whole management practice for rice growing.

According to the historical recording, the white-backed planthopper *Sogatella furcifera* (Horvath) (Homoptera: Delphacidae) has become an abundant species since mid 1970s, a decade later than the brown planthopper *Nilaparvata lugens*. Long term annual light trap catches in 3 Stations showed that the abundance of *S. furcifera* fluctuated yearly and there was a peak during first 5 years of 1980s. Some sites in Zhejiang province always catch significant higher number of adults of *S. furcifera* than others. Most positive significant correlation pairs were in a direction of southwest to northeast lines across the province. There is no positive in any lag but negative in a lag of 9 years significant periodical cycling in the long-term data from Songyang Station. The seasonal dynamics could be pictured in 3 groups with different population growth type. At the regional level, the incidence of *S. furcifera* is affected in a complex way by rice variety, cropping system, fertilization, and insecticide application. Proportion of hybrid rice and single season rice in a season were significantly correlated to the incidence of the planthopper in some years and spatial scale. At the field level, correspondent analysis showed that

different classes of seasonal average density of *S. furcifera* was linked to rice variety, plant spacing, transplanting date, insecticides application, and so on. Spray of insecticides increased likely the grand average seasonal density of *S. furcifera*, *N. lugens*, compared to unsprayed fields. Higher yield obtained in sprayed fields were resulted from control of rice sheath blight but not from insecticide, in the range of occurrence of insects in the experiment fields.The interactions among agricultural technical components and *S. furcifera* occurrence and their implications in management were discussed.

The significant association of between the white-backed planthopper *Sogatella furcifera* severity in subtropical mainland Asia and warm (El Nino phase of the El Nino/Southern Osicillation (ENSO)) was identified. The association was mediated by increasing summer precipitation in the year immediately following the ENSO events. Summer precipitation was significantly positive correlated to immigration of *S. furcifera*, which was further positive correlated to the severity in rice fields.

A comparison of the effects of intraspecific competition between the white-backed planthopper (WBPH) *Sogatella furcifera* and the zigzag leafhopper (ZLH) *Recilia dorsalis*, as representatives of eruptive and latent auchenorrhycha (Homoptera) species on rice, was carried out in laboratory. Crowding during the nymphal stage extended the duration of development of WBPH but not of ZLH. The nymphal survival rate of WBPH, sex ratio, preoviposition period and fecundity of both species were however not affected. The brachypterous percentage of WBPH and nymphal survival of ZLH were significantly reduced under high nymphal density. Crowding during the adult stage reduced fecundity and longevity significantly of both species. Fecundity and longevity were further reduced when combined with high densities during the nymphal stage. Age-specific life table analysis showed that the integrated effect of crowding on ZLH is stronger than on WBPH. The mechanism of eruptive and latent species' response to crowding during nymph and adult stages is not clearly expressed as a significant difference in fecundity. It is better described as the variation in the intrinsic rate of increase (r_m). Therefore the construction of an age-specific life table is helpful, and perhaps necessary, to understand these effects. The results showed that the main ecological characteristics of ZLH,

as a latent species were its longer immature period, lower total fecundity and decreased and retailed rate of oviposition, hence the lower r_m, as compared with WBPH.

The sucking rates of the white-backed planthopper (WBPH) *Sogatella furcifera* (Homoptera: Delphacidae) were examined under a series of conditions in the laboratory. The sucking rate increased with the age of the planthopper, the relative proportions of 1st instar to 5th instar, macropterous male and female to the macropterous female adult (set as standard insect (SI)) were 0.19, 0.27, 0.37, 0.49, 0.59, 0.69 and 1, respectively. The SI sucked in maximum rate in tillering stage of rice. In *indica* rice varities, the SI did higher sucking rate than in *japonica* varieties. The effect of temperature on the sucking rate could be described by an exponential quadratic equation. A power equation with good fitting (W=0.0001$S^{1.8107}$ could be used to transfer the relative sucking rate in area (S) to absolute dry weight (W) of the hopper's execution honey dew. The field cage injury - yield loss assessment showed that the yield loss mainly due to decreased filling percentage of kernels and kernel weights rather than No. of panicles and spikelets per panicle. Finally, the results gained from the experiment were integrated to a formula linking yield loss percentage and sucking equivalent.

A simulation model of the white-backed planthopper (WBPH) *Sogatella furcifera* (Horvath) population dynamics on the first season rice in Zhejinag province, China, was constructed using field population data together with information from the documents. In this paper the model is described and its predictions are compared with independent sets of field data. For nine data sets from 1983 to 1989, representing a 11-fold range of WBPH peak densities, the time at peak of the WBPH population was predicted within 5 days in all nine cases (accuracy of observations 5 days). The peak density of the population was predicted within 20% of the observed one in seven cases. Model parameters were varied within real limits in order to determine the sensitivity of the model. The model was sensitive to changes in pattern and amount of immigration. Simulation

analysis showed that the earlier and the more the major immigration does, the larger the peak density is, and the reverse is true. A very short concentrated period and high level of WBPH immigration should resulted in damaging WBPH population. Temperature condition has no significant effect on peak population of WBPH in the first season rice.

The dynamic programming approach was applied to select the optimal management strategies, expressed as multi-dimensional and dynamic economic thresholds (MDDETs) for controlling white-backed planthopper (WBPH), *Sogatella furcifera*, a major insect pest of rice, on **first season rice** crop in Zhejiang, China. The results can be used to guide chemical WBPH control. The difference of economic thresholds between conventional and hybrid *indica* rice cultivars were also compared. The robust analysis on the parameters indicated that the decision, expressed as economic thresholds, ate relatively robust in a range of stage population growth rates, injury coefficient, but most sensitive to the changes of the combination of spray (insecticide plus labour) cost and expected gross income (grain price times yield).

Key words: ecology, eruptive species, population ecology, management decision-making, *Sogatella furicfera* (Horvath), systems approach, subtropical excosystem