Evolution of biological control of stored-product pests in China

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Abstract

This article summarizes the progress of studies on biological control of stored-product insects in the past two decades in China

Studies and application of natural enemies

As for introduction of natural enemies, in 1980, Huazhong Agricultural University introduced *Xylocoris flavipes* from South Pacific Stored-product Insects Laboratory, Research Center of United States Department of Agriculture. The ensuing breeding was successful. Researches were undertaking to study on the biological mechanism and predatory ability of the insect. It was subsequently introduced into Hunan Province, Sichuan Province and Guizhou Province In Hengyang, Hunan Province, Tianmen, Hubei Province, *X. flavipes* were released in grain storehouses and satisfactory control result was obtained. Especially, the elimination rate reached 80 – 95% on *R. Dominica* (Deng Wangxi, et al 1983). As for the predatory natural enemies, extensive studies have been carried out on the biological mechanism, ecology and predatory ability of *X. sp.*, *peregrinator biannulipes* as well as predatory mites when they were applied to control harmful mites living in fodder (Yao Kang, et al 1984; Wen Biran, et al. 1988; Deng Wangxi, et al. 1988; Weng Zhijian, et al. 1995) As for parasitic natural enemies, most reports were concentrated at *Bracon hebetor* which has a higher parasitic rate It can originate more than 10 generations in Xiamen, Wenzhou and other regions Most *Bracon hebetor* parasitizes on *P interpunctella* and *Ephestia elutella*. Studies have been conducted on its biological mechanism and control effects (Li Li, et al 1988; Huang Xinfei 1986; Wan Xiangxue; 1991). There were many reports about parasitic wasps on cockroaches' eggs There is a variety of parasitic wasp species, but the most ideal predator is *Tetrastichus hagenovii* (Gong Xinwen, et al. 1995; Li Jie, 1990) Furthermore, nation-wide local investigations were undertaken on the basis of national fauna survey of stored-product insects. The results reveal that the resource of natural enemies of stored-product insects is affluent in China and the distribution of the predatory and parasitic natural enemies mentioned above is very wide.

Studies on pathogen micro organisms

As for the studies on *Bacillus thuringiensis*, Zhang Hongyu (1998) conducted isolation analysis on *B thuringiensis* in warehouse Most H-serotype were H_4 and H_5, which occupy 36.1% and 23.8% of the total amount respectively. Studies were also conducted on the genetic variety of crystal protein of *B. thuringiensis* as well as RAPD analysis on the species poisonous to insects. Wang Yazhou (1990) used *B thuringiensis* to infect *P interpunctella* larvae and drew conclusion that the major cause of pathological changes is attributed to Bt's crystal poison and external poison 243 non-spore bacilli, spore bacilli and cocci were isolated from the infected nymphae of *Periplameta fuliginose*. In storehouse experiments, Zhang Hongwen (1987) applied 1% Bt7216 and 82-6(1)-2 emulsion to blend Chinese green beans to decrease the population density of *Callosobruchus chinensis* at the rate of 98%. The effect period could last for one year. Huang Yuanda (1988) isolated *P fuliginosa Densovirus* (PFDNV) from nymphae of *P. fuliginose*.

Experiments were undertaken to test the pathogenicity of 12 fungi from entomogenous fungi on *Coptotermes formosanus*. It was found that in 6.0×10^7 spores/ml sterilized suspension, 4 fungi have stronger pathogenicity The pathogenical rate of *Metarrhizium anisopliae sor* 37# is 100% (Cai Yiqiu, 1995) While *Steinernema carpocapsae* BW and *S. feltiae Otio* were applied to treat *Blattella germanica L* , the death rates were 70.0% and 70 0% respectively after 4 days (Yi Xianqun; 1993)

Insect pheromone

Since the 1970's, Nankai University, Sichuan University, Chengdu Institute of Organic Chemicals Research of Academy of Sciences of China and Jiangsu Pheromone Research Institute have started researches on pheromone synthesis of *Sitotroga cerealella*, *P. interpunctella and Trogodema spp*. Meng Yue, et al. (1993) reported a synthesis method, which could abridge reaction approaches

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and improve efficiency Aggregation pheromone was hence developed from *Crytolestes ferrugineus* and *C pusillus*. Pheromone from *C chinensis*, *S. zeamais* and *Stegobium paniceum* was isolated, collected and purified Biological activation analysis was undertaken(Wu Guixin, 1983; Huang Yuanda, 1985;Gu Zhonghuang, 1993)

As for the studies and application of pheromone in stored-product Lepidoptera insects, most reports were concerned about *S cerealella* and *P. interpunctella*. One application in storehouse can eliminate insects for a whole year. 'Gossyplure' of *Pectinophora gossypiella* was used in storehouse to attract *S. cerealella* and *Homalopsycha agglutinata* and many other pests (Gao Jintang, 1985; Li Zhengfan, 1986; Huang Yuanda, 1986; Zhao Zhiwu, 1989; Zhang Zhixiu, 1994). Shanghai Grain Research Institute (1979) used sex attractant of *P. interpunctella* in melon seeds, mushrooms and agaric storehouses, the insect population density reduced 80.4% in 4 months; Sheng Zhaopeng, et al (1994) used IMM of *P interpunctella* in IC to trap insects in herb storehouses, 290 insects were captured in 16 days; field tests in storehouses were conducted on lasiotrap of *Lasioderma serricorne*, DL 1/DL.2 of *R dominica*, E-Trogo and Z-Trogo of *Trogoderma* and the results showed that these 4 pheromones can trap corresponding stored-product insects. *L. serricorne's* pheromone has the most satisfactory effect. In experiment, 'Sitophilater' showed strong aggregation reaction to *S granaris* The attraction is enhanced while plant oil is blended with pheromone to trap *R dominica* and *Trogoderma spp*.

F88, an analogue of trail pheromone sifted from 31 fungi, has strong attraction to *Coptotertmes formosanus*, *Odonototermes formosanus*, *Macrotermes barneyi* (He Xiamei, et al 1997; Luo Junze, et al ,1998)

Insect growth regulator

Yao Kang, et al (1981) used 500ppm Precoceme and juvenile hormone 738 to treat *R dominica* eggs. The population reduction rates are 100% and 85.1% respectively Zhang Guoliang, et al. (1987) conducted experiments on 34 side products of insect juvenile hormone The result showed that the restraint rate to the second generation of *S zeamais* adults reached above 90% while 50ppm 6520, ZR512 and 6515 were used Small tests in storehouses showed that ZR512, 6515 and 6520 under 50ppm have better restraint effects on *S. zeamais*, *T castaneum* and book louse Wei Chaosheng (1990) used bait 400 times pure hydrojuvenile pheromone to breed *Blattella germanica* young and old nymphae for one time 100% of the treated numphae were deformed and lost reproduction ability for the whole life cycle. 1000 − 2500 times bait made the deformation rate 61 − 80%.

5ppm Dimilin TH6040 can completely restrain the reproduction of *Tribolium confusum* 10ppm can restrain the reproduction of *S zeamais* thoroughly and the treated wheat was kept intact 10ppm solution of Dimilin blended with Chinese green beans at the proportion of 5,10, 15 and 30ppm can efficiently control the reproduction of *C chinensis* and 30ppm can completely restrain the reproduction 5ppm has an efficiency rate of 98.7% (Zhang Jiwu, 1980)

Studies on the resistance and mechanism of stored grain to insects

The studies were focused on rice, then wheat, corn and beans. Zhang Hongyu (1993) studied resistance of 22 varieties of rice against *S zeamais* The research revealed that there were several significant characteristic effects, namely, the cracked glume rate, thousand kernel weight, breadth and pubescence density of grain, contents of amylose, crude protein and fat, on maize weevil The more of cracked glume rate and thousand kernel weight, the more favorable for damage of maize weevil; the more maize weevil eggs were laid on rice grain with higher cracked glume rate, the broader width and less pubescence. Higher amylose content and cracked glune rate were beneficial to development of this insect pest. Contrarily, high crude protein and fat were unfavorable for its development Other characters(including grain length, ratio of length to width, husk thickness and sugar concn) were not related to resistance Wu Hongji, et al (1993) tested the resistance mechanism of 53 rice species to *S. zeamais* 39 species has the high resistance ability, medium 3 and sensitive 11 The sensitive coefficient is positively relative to the gapped glume rate of grain and irrelevant to rough protein

Fuzzy clustering analysis was carried out to determine the resistance of rice species to *S. zeamais* according to sex ratio, egg no laid/100 grains, population/100 eggs, net weight loss rate (%), sensitive coefficient and survival rate Five categories were figured out 7 species including 87156 and Huageng 2 # are prominently resistant species, which occupy 31.82%; 4 species including II46 and Xiushui48 are sensitive species (Zhang Hongyu, 1993). The sequence is grain > milled rice (brown rice according to resistance to maize weevil Sequence of sensitive species is milled rice > grain > brown rice (Zhang Hongyu, 1993) Deng Zhengjian (1993) reported the resistance of 42 species of rice to *R. dominica* including 15 resistant species and 16 media . The gapped glume rate is positively relevant to sensitive coefficients and weight loss rate

Wu Rongzong (1994) reported that the gapped glume rate is the major factor to affect the resistance of stored rice to *S cerealella*. It shows very apparent positive relation to adult emergence rate, sensitive coefficients and weight loss rate and very apparent negative relation to the development cycle of *S cerealella* ($p < 0.01$) Therefore, the

resistance to *S. cerealella* can be estimated according to the gapped glume rate. Sensitive species have higher gapped glume rate than the resistant species, which attract more early hatched larvae to habitat and is favorable to larvae to get into the rice. Besides, resistance is positively relevant to rough protein. The fineness of rice is obviously relevant to adult emergence rate, sensitiveness and the gapped glume rate.

Crossbreed rice has higher sensitiveness to insects than normal rice The gapped glume rate of crossbreed rice is high and is vulnerable to early hatched larvae. The gapped glume rate is highly relevant to the adult emergence, weight loss rate and sensitive coefficients. (Li Manping, el 1994)

The method of testing the resistance of stored rice to *S cerealella*: culutre100 rice implanted with 50 eggs under the experimental conditions of 27℃ and RH75% (Wang Heying, 1995). Wu Hongji, et al (1994) reported the resistance to a variety of insects of stored rice He indicated that 12 species showed resistance to *S. cerealella*, *R. dominica* and *S zeamais* Vietnam fragrant rice, CI12273, Mudgo have medium resistance, among which 7 species have resistance to *Nilarparvata lugens* Deng Wangxi, et al. (1988) reported that *S zeamais* is reluctant to breed and lay eggs on hard corn and pro-hard-corn. It has much less progeny on these types of corns On the contrary, it shows strong fondness of Machi corn and sweet corn and intend to breed and lay eggs on these types of corn Deng Wangxi, et al (1989) tested the resistance of 24 stored wheat variety to *S. zeamais*. 1425 and other resistant varieties were cutin type. Sensitive varieties including B128-179 were powder type E Wheat9 # and E Wheat1 # were medium type. The variety with hard and cutin shells and small size have higher resistance Starch and fat were analyzed (Qian Zuxiang, 1990 and 1991). Chen Qien(1991) reported that *C maculatus* develops fast, has more progeny and larger population density in green beans which contain less starch and fat Yellow beans and black beans are on the contrary

Genetic control

Application of ^{60}Coγ-ray irradiation to control insects consists of two aspects of work. One is to use certain amount of irradiation to directly eliminate the insects This method is wide applied in food, herb and archive departments The animal and plant quarantine departments use this method to treat dangerous and harmful biological stored material. There were lots of such reports. The emphasis of the application is the variety of insects, fatal dosage for different stage of the same species and the impact on the storehouses. The application of ^{60}Coγ-ray in studies of sterilization of insects is focused on *P interpunctella*, *C. chinensis*, *S granarius* and *Trogoderma granarium* As for *P. interpunctella*, Chen Lizheng (1981) reported that 5.7 krad ^{60}Coγ-ray irradiation can cause partial late stage larvae to pupate to adults without reproduction ability

Under 1.7 – 1.9 Krad, sterile female and male adults could be cultured They could mate with normal adults and lay eggs. But their hatched larvae could not pupate finally. Yang Changju (1993, 1995) used 1, 3, 5, 7 and 10 Krad ^{60}Coγ-ray to irradiate 4 – 5-day old male pupae of *P. interpunctella*. Under 1,3 and 5 Krad, the hatch rates of the test group's F_1 generation are 56.6%, 80.8% and 74 0%, lower than that of the corresponding group. 15 mutated species were resulted such as transparent wing adult and red eye type While using ^{60}Coγ-ray to irradiate *S. granarius*, the sterilization dosage is determined at 110Gy for male and 140 Gy for the female The recommended ratio between released sterile *S. granarius* and target *S granarius* is 50 – 100 1 Average times of mating of the irradiated male adults are apparently lower than that of the normal ones, the female's keep the same. (Zhou Yongshu, et al, 1994) While 0.5, 1, 2, 3, 4 and 6 Krad ^{60}Coγ-ray irradiating *C chinensis*, the sterilization rates of the irradiated female adults are 89.1%, 89.1%, 92.1%, 92.2%, 93.5% and 95.2% (Yang Changju, 1993). While 2.0 Krad ^{60}Coγ-ray was applied to irradiate *Trogoderma oryzae* adults, the eggs laid didn't hatch; under 1.5 – 2.5 Krad, the adults didn't lay eggs; while 0.5 Krad on larvae, partial larvae could pupate to adults but didn't lay eggs Under 0.6 – 12 Krad, the insects could develop to mature larvae but couldn't pupate. Under 0.8 – 1.0 Krad, the larvae pupated to adults and laid eggs. Small number of larvae could be hatched out but they could not pupate(Zhang Xinyue,1993) The genetic studies about the genetic mechanism of crossbreeding of *Sitophilus zeamais* and *S oryzae* was initiated in early 1980's(Luo Luyi, 1983; Yang Zhiyuan, 1986; Huangpei, et al 1986; Wu Guoxiong 1986)

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