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Effect of GCSC-BtA biocide on abundance and diversity of some cabbage pests as well as their natural enemies in southeastern China

Auswirkungen des Biozids GCSC-BtA auf die Abundanz und Diversität von einigen Kohlschädlingen und deren natürlichen Feinden in Südostchina

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Summary

Effect of GCSC-BtA (Germany-China Scientific Cooperation – *Bacillus thuringiensis* – Abamectin) biocide on abundance and diversity of some important cabbage pests, i. e., *Plutella xylostella* (L.) (Lep., Plutellidae), *Pieris rapae* (L.), (Lep., Pieridae), *Brevicoryne brassicae* (L.) (Hom., Aphididae), *Liriomyza sativae* Blanch. (Dip., Agromyzidae), *Phyllotreta vittata* Fabric. (Col., Chrysomelidae) as well as their natural enemies, i. e., *Apanteles plutellae* Kurdj. (Hym., Braconidae), *Erigonidium graminicola* (Sundv.) (Araneida, Linyphiidae), *Coccinella septempunctata* L. (Col., Coccinellidae), were determined in comparison to that of methomyl insecticide in cabbage fields in Fuzhou region of the southeastern China.

GCSC-BtA biocide showed high efficacy in reducing abundance of all the tested pest species while very low harmfulness to their natural enemies. GCSC-BtA treatment resulted in significantly lower abundance of all the pests with 10.32 % of *P. xylostella,* 6.10 % of *P. rapae,* 2.11 % of *B. brassicae,* 8.68 % of *L. sativae* as well as 1.02 % of *P. vittata,* as compared to methomyl treatment with 26.68, 26.33, 25.18, 33.89, 32.08 % or control with 62.99, 67.55, 71.74, 57.42, 46.41 %, respectively. On the other hand, abundance of all the natural enemies was significantly higher in GCSC-BtA treatments with 40.80, 32.42, 36.52 % for *E. graminicola, A. plutellae, C. septempunctata*, than in methomyl treatment with 9.53, 5.60, 12.87 %, respectively.

Species evenness of the different cabbage pests was in the range of 0.3302 to 0.8382 and of their enemies from 0.1017 to 0.8499. Both GCSC-BtA and methomyl resulted in higher species evenness of the two main pests *P. xylostella* as well as *B. brassicae* with values of 0.5231, 0.5221 and 0.4938, 0.5179 as compared to control with 0.4611, as well as 0.3302 in the control, respectively, while values for *P. rapae* was higher in control with 0.8382 than the biocide with 0.5886 or methomyl with 0.6811. Species evenness of *L. sativae* and *P. vittata* were not significantly different among the treated and non-treated treatments.

The biocide gave higher species evenness of the natural enemies than the methomyl or control treatments. The values were 0.7934 for *E. graminicola,* 0.6442 for *A. plutellae* as well as 0.8499 for *C. septempunctata* in the biocide treatment as compared to 0.3241, 0.1017, 0.4011 in the methomyl as well as 0.7520, 0.3907, 0.7775 in the control treatments, respectively.

After application, Shannon-Wiener diversity index was higher with a value of 2.4111 with GCSC-BtA treatment than 1.1859 with methomyl or 1.2166 in the control treatment. It can be concluded from this study that GCSC-BtA has high efficacy against cabbage pests and low harmfulness to their natural enemies as compared to methomyl.

Key words: GCSC-BtA; *Bacillus thuringiensis;* Abametin; species abundance; species evenness; species diversity; cabbage pests; natural enemies

Zusammenfassung

Die Auswirkung des Biozids GCSC-BtA (Germany-China Scientific Cooperation – *Bacillus thuringiensis*-Abamectin) auf die Abundanz und Diversität von einigen Kohlschädlingen, *Plutella xylostella* (L.) (Lep., Plutellidae), *Pieris rapae* (L.) (Lep., Pieridae), *Brevicoryne brassicae* (L.) (Hom., Aphididae), *Liriomyza sativae* Blanch. (Dip., Agromyzidae), *Phyllotreta vittata* Fabric. (Col., Chrysomelidae) sowie deren natürlichen Feinden *Apanteles plutellae* Kurdj. (Hym., Braconidae), *Erigonidium graminicola* (Sundv.) (Araneida, Linyphiidae), *Coccinella septempunctata* L. (Col., Coccinellidae) wurde im Vergleich zu dem Insektizid Methomyl in den Kohlfeldern der Fuzhou-Region in Südostchina untersucht.

Das Biozid GCSC-BtA hatte eine höhere Wirkung bzw. eine deutliche Reduzierung der Abundanz von Kohlschädlingen und eine schonende Wirkung auf die natürlichen Feinde. GCSC-BtA zeigte in den behandelten Parzellen eine Abundanz von 10,32 % für *P. xylostelle,* 6,10 % für *P. rapae,* 2,11 % für *B. brassicae,* 8,68 % für *L. sativae* und 1,02 % für *P. vittata* im Vergleich zum Insektizid Methomyl von 26,68; 26,33; 25,18; 33,89; 32,08 % bzw. in der Kontrolle von 62,99; 67,55; 71,74; 57,42; 46,41 %. Durch die Behandlung mit GCSC-BtA konnte dagegen eine erhöhte Abundanz der natürlichen Feinde mit Werten von 40,80; 32,42; und 36,52 % für *E. graminicola, A. plutellae* und *C. septempunctata* im Gegensatz zum Insektizid Methomyl mit Werten von 9,53; 5,60 und 12,87 % ermittelt werden.

Die Spezies evenness der getesteten Kohlschädlinge variierte von 0,3302 bis 0,8382 und bei den natürlichen Feinden von 0,1017 bis 0,8499. Das Biozid und Methomyl bewirkten im Vergleich zur Kontrolle eine höhere Spezies evenness bei den Hauptschädlingen *P. xylostella* sowie *B. brassicae* mit Werten von 0,5231 und 0,5221 bzw. 0,4938 und 0,5179. Bei *P. rapae* waren dagegen die Werte mit 0,8382 in der Kontrolle höher als beim Biozid mit 0,5886 oder bei Methomyl mit 0,6811. Die Spezies evenness von *L. sativae* und *P. vittata* zeigte keine Signifikanz zwischen den Behandlungen und der Kontrolle. Das Biozid hatte gegenüber Methomyl und der Kontrolle eine höhere Spezies evenness der natürlichen Feinde mit Werten von 0,7934 für *E. graminicola,* 0,6442 für *A. plutellae* und 0,8499 für *C. septempunctata.* Bei Methomyl lagen die Werte bei 0,3241; 0,1017 bzw. 0,6442 und bei der Kontrolle bei 0.7520; 0,3907 bzw. 0,7775.

Nach den Applikationen war der Shannon-Wiener Diversitäts-Index bei den mit GCSC-BtA behandelten Parzellen mit einem Wert von 2,4111 höher als bei Methomyl bzw. der Kontrolle mit Werten von 1,1859 und 1,2166. Aus diesen Ergebnissen konnte geschlossen werden, dass GCSC-BtA eine höhere Wirkung auf die Kohlschädlinge und einen geringeren Einfluss auf die natürlichen Feinde im Vergleich zu Methomyl hatte.

Stichwörter: GCSC-BtA; *Bacillus thuringiensis;* Abamectin; Abundanz; Populationsdichte; Spezies evenness; Diversität; Kohlschädlinge; Natürliche Feinde

1 Introduction

Heavy insecticide application against pests in cabbage fields was a common practice in Fuzhou region of the southeastern China (Liu and Sengonca 2002), which disturbed pest and their natural enemies balance and so the enemies were not able to suppress pests from causing damages to cabbage crop (Zhao et al. 1994). Later on, broad-spectrum insecticides were used to control cabbage pest complex (Sengonca et al. 2001). But it did not solve the problem too and the pests developed resistances against the frequently used insecticides (Ninsin et al. 2000). Furthermore, insecticides greatly affected the arthropod community structure.

The result from insecticide malathion bait sprays to control the pest *Bactrocera dorsalis* (Hendel) (Dip., Tephritidae), and *Bactrocera cucurbitae* (Coquillett) (Dip., Tephritidae) in sweet maize in Hawaii, USA showed that significant reductions in overall species richness and diversity occurred in malathion bait-treated maize comparing to the untreated site (Messing et al. 1995). Miller (1992) reported that the biocide *Bacillus thuringiensis* against the tortricid *Choristoneura occidentalis* Freeman (Lep., Tortricidae) fed on *Ceanothus velutinus* in the field in Oregon, USA never disturbed insect community parameters comparing species in a guild of non-target leaf-feeding Lepidoptera in the treated and untreated sites. Shelton et al. (1996) stated that care should be taken in selecting insecticides and biocides for an IPM program to obtain high efficacy in suppression of pests and little harmfulness to ecosystem at the same time.

In the last few years, efforts have been made to develop a new type of biocide, based on "Germany-China Scientific Cooperation (GCSC)" research, Bt-toxin biochemically conjugated with Abamectin and named GCSC-BtA, which has high efficacy in controlling cabbage pest like *Plutella xylostella* (L.) (Lep., Plutellidae) and others from different arthropod orders (Sengonca and Liu 2001; Sengonca et al. 2001) and less toxicity to its parasitoid *Apanteles plutellae* Kurdj. (Hym., Braconidae) (Sengonca and Liu 2001) as well as predators, e. g., *Erigonidium graminicola* (Sundv.) (Araneida, Linyphiidae), *Coccinella septempunctata* L. (Col., Coccinellidae), in comparison to the commercial insecticides (Liu and Sengonca 2002; Sengonca and Liu 2002). Furthermore, it was successfully used as an essential part of integrated cabbage pest management in cabbage fields in Fuzhou, China (Sengonca and Liu 2002). But effect of GCSC-BtA biocide on arthropod community parameters remained unknown.

The present paper deals with effect of GCSC-BtA biocide on abundance and diversity of cabbage pests as well as their natural enemies in cabbage fields in southeastern China. The aim of study was to compare the effect of GCSC-BtA biocide and methomyl insecticide treatments on pest as well as natural enemies species abundance, evenness and diversity in cabbage fields. The results would be used in developing a sound control strategy in cabbage pest management.

2 Materials and methods

The field experiments were conducted from April to June 2001 in the experimental farm of Fujian Acadmy of Agricultural Sciences, Yongtai county, Fuzhou. The cabbage crop selected for the experiments was a common head cabbage *(B. oleracea* var. *capitata).* The cabbage field comprised three treatments, each treatment had three replicates each with 300 m^2 area. In the first treatment, 16000 IU GCSC-BtA biocide was applied, produced by Germany-China Scientific Cooperation research laboratory in China; in the second 20 % EC methomyl insecticide, produced by Shanghai pesticide Factory, China; and in the third control with normal water. The pesticides were prepared in field dosage by diluting 1000 times with normal water, and applied in the 5^{th} week of sampling. Normal water was applied at the same time in the control treatment. From each replicate, 30 cabbage plants were randomly sampled every week, so that a total of 90 samples was taken from each treatment. The numbers of main pests, *P. xylostella, Pieris rapae* (L.), (Lep., Pieridae), *Brevicoryne brassicae* (L.) (Hom., Aphididae), *Lirimoyza sativae* Blanch. (Dip., Agromyzidae), *Phyllotreta vittata* Fabric. (Col., Chrysomelidae) and their enemies, *E. graminicola, A. plutellae, C. septempunctata* were recorded on these plants. The sampling started 1 week after transplanting and ended 1 week before harvesting.

For the analysis of cabbage pests abundances, the mean number of individuals of each species in each treatment was averaged from the three replicates each 30 plants. The total cumulated individuals of each pest species was summed from the mean individuals during the 7 sampling weeks. The abundance for each pest in each treatment was defined as the percentage of the total (Mackenzie and Averill 1995).

For the analysis of species evenness, the equation of $J' = H' / \ln (S)$ was used after Price (1978), where H' is the "Shannon-Wiener diversity index", which is shown in the equation of $H' = -\Sigma Pi \ln Pi$, where Pi is the proportion of the total category comprised of species i in the sample, and S is species richness, calculated according to the method cited by Lobo and Martin (2002). Comparison of each pest species was based on Tukey's Multiple Range Test, conducted on species evenness at the cumulated mean number of individuals of treatments, during the seven sampling periods. Because of the nature of the test, the probability level for acceptance among the treatment differences was set at $P < 0.01$ (Hollander and Wolfe 1973).

For the analysis of pest diversity, the data was divided into two categories: before application during 1^{st}–5^{th} sampling weeks and after application during 6^{th}–7^{th} sampling weeks. Diversity among the three experimental treatments between the two categories was evaluated by comparing the Shannon-Wiener diversity indexes (Price 1978). Nested ANOVA and Tukey's Multiple Range Test were applied where appropriate to compare the diversity indexes.

3 Results

3.1 Species abundance

The results showed significant differences (P < 0.01) in abundance of the pests and enemies among the different treatments (Table 1). Among the pests, *P. xylostella* and *B. brassicae* were more abundant than *P. rapae, L. sativae* and *P. vittata,* while among the enemies *A. plutellae* and *E. graminicola* dominated *C. septempunctata.*

Abundance of all the pest species was significantly lower in the GCSC-BtA treatments, where it was 10.32 % for *P. xylostella,* 6.10 % for *P. rapae,* 2.11 % for *B. brassicae*, 8.68 % for *L. sativae* and 1.02 % for *P. vittata* than in the mythomyl as well as control treatments. Pest abundance was 26.68, 26.33, 25.18, 33.89, 32.08 % in the methomyl while 62.99, 67.55, 71.74, 57.42, 46.41 % in the control, respectively.

Abundance of all the natural enemies, on the other hand, was significantly higher in the GCSC-BtA treatments than in the methomyl-treated but lower than in the control for *A. plutellae* and *C. septempunctata.* Abundance of the enemies in the biocide treatments was 40.80 % for *E. graminicola,* 32.42 % for *A. plutellae* and 36.52 % for *C. septempunctata* while in the methomyl treatments it was 9.53, 5.60 and 12.87 %, respectively. In control, abundance of the enemies species was 49.66, 61.96 and 50.59 %, respectively.

3.2 Species evenness

Analysis of the species evenness data showed significant differences (P < 0.01) among the different treatments (Table 2). The species evenness index of pests and their natural enemies ranged from 0.1017 to 0.8499. The variations in species evenness could be divided into three types: Firstly, species evenness of some pests was not affected by the biocide and insecticide treatments and, thus, remained similar in all the three experimental plots, which included *L. sativae* and *P. vittata* (P > 0.01). Secondly, the species evenness was similarly affected by treatments of biocide and insecticide (P > 0.01), but remained much higher than that in the control plot (P < 0.01), which included *P. xylostella* and *B. brassicae.* Finally, species evenness was differently affected by the two treatments and, thus, there was found significant differences among the three treatments (P < 0.01), which included *P. rapae, E. graminicola, A. plutellae* and *C. septempunctata.*

Table 1. Cumulated mean individuals of some cabbage pests and their natural enemies during seven sampling weeks in the GCSC-BtA as well as methomyl and control treatments in the cabbage field in southeastern China in 2001

Arthropod species	Total cumulated no.	Cumulated mean individuals					
		No.			%		
		GCSC-BtA	Methomyl	Control	GCSC-BtA	Methomyl	Control
Pests							
Plutella xylostella	384.5	39.7	102.6	242.2	10.32 B	26.68 C	62.99 A
Pieris rapae	52.4	3.2	13.8	35.4	6.10 B	26.33 C	67.55 A
Brevicoryne brassicae	1891.5	40.0	476.4	1357.1	2.11 B	25.18 C	71.74 A
Liriomyza sativae	35.7	3.1	12.1	20.5	8.68 B	33.89 C	57.42 A
Phyllotreta vittata	29.3	6.3	9.4	13.6	1.02 B	32.08 C	46.41 A
Natural enemies							
Erigonidium graminicola	59.8	24.4	5.7	29.7	40.80 A	9.53 B	49.66 A
Apanteles plutellae	72.1	23.7	4.1	45.3	32.42 B	5.60 C	61.96 A
Coccinella septempunctata	33.4	12.2	4.3	16.9	36.52 B	12.87 C	50.59 A

Values of each category in rows indicate after testing by ANOVA F test; Values in rows followed by different letters are significantly different at P ≤ 0.01 (Tukey's Multiple Range Test)

Table 2. Pest and natural enemies species evenness index *(J')* in the GCSC-BtA as well as methomyl and control treatments in the cabbage field in southeastern China in 2001

Arthropod species	Species evenness index *(J')* in		
	GCSC-BtA	Methomyl	Control
Pests			
Plutella xylostella	0.5231 ± 0.0443B	0.4938 ± 0.0409B	0.4611 ± 0.0371A
Pieris rapae	0.5886 ± 0.0520B	0.6811 ± 0.0627C	0.8382 ± 0.0811A
Brevicoryne brassicae	0.5221 ± 0.0442B	0.5179 ± 0.0437B	0.3302 ± 0.0196A
Liriomyza sativae	0.4078 ± 0.0309A	0.4436 ± 0.0350A	0.4796 ± 0.0392A
Phyllotreta vittata	0.8044 ± 0.0771A	0.8086 ± 0.0776A	0.8090 ± 0.0777A
Natural enemies			
Erigonidium graminicola	0.7934 ± 0.0759B	0.3241 ± 0.0294C	0.7520 ± 0.0710A
Apanteles plutellae	0.6442 ± 0.0584B	0.1017 ± 0.0168C	0.3907 ± 0.0289A
Coccinella septempunctata	0.8499 ± 0.0824B	0.4011 ± 0.0367C	0.7775 ± 0.0740A

Values of each category in rows indicate after testing at P ≤ 0.01 by ANOVA F test; Values in rows followed by different letters are significantly different at Tukey's Multiple Range Test

GCSC-BtA treatment resulted in significantly higher species evenness values for all the natural enemies species than with methomyl or in control. With the biocide treatment, species evenness values of *E. graminicola, A. plutellae* as well as *C. septempunctata* were 0.7934, 0.6442 and 0.8499, respectively, while in the methomyl and control plots, these values were 0.3241, 0.1017, 0.4011 and 0.7520, 0.3907, 0.7775, respectively.

3.3 Shannon-Wiener diversity index

The species diversity was measured by the Shannon-Wiener diversity index in the two treating categories, i. e., before treatment during 1st–5th weeks and after treatment during 6th–7th weeks in all the three experimental plots (Table 3). There results showed that no differences were found among the three treatments before treatment. But, after treatment, GCSC-BtA resulted in significantly higher index value (P < 0.01) of 2.4111 as compared to 1.1859 with methomyl or 1.2166 in control.

Table 3. Shannon-Wiener diversity index *(H')* in the GCSC-BtA as well as methomyl and control treatments in the cabbage field in southeastern China in 2001

Treating category	Shannon-Wiener diversity index *(H')* in the experimental plots with		
	GCSC-BtA	Methomyl	Control
Before application during 1–5 week	1.9875 ± 0.2713 A	2.1364 ± 0.2945 A	2.2626 ± 0.3134 A
After application during 6–7 week	2.4111 ± 0.3476 B	1.1859 ± 0.1291 A	1.2166 ± 0.1654 A

$H' = -\Sigma\, Pi \ln Pi$ where *Pi* is the proportion of the *i*th species in the sample. Values of each category in rows indicate after testing at P ≤ 0.01 by ANOVA F test; Values in columns followed by different letters are significantly different at Tukey's Multiple Range Test

4 Discussion

The results of the present experiments showed significant differences in abundance of the pests among the different treatments. Abundance of the all the pest species was significantly low (1.02–10.32 %) in the GCSC-BtA treatments than in the mythomyl (25.18–33.89 %) as well as control (46.41–71.74 %) treatments. Abundance of the natural enemies, on the other hand, was significantly higher in the GCSC-BtA treatment (32.42–40.80 %) than methomyl (5.60–12.87 %) but lower than control

(49.66–61.96 %). *B. brassicae* and *P. xylostella* dominated among the pest species while *A. plutellae* and *E. graminicola* among the enemies.

Methomyl insecticide was normally applied to control cabbage pests in this southeast China (Liu and Sengonca 2002). Although it suppressed the major pest to some degrees, the population still remained high to cause economic damages. One reason could be development of pest resistance against this pesticide (Hama 1986) or that natural enemies were killed (Nemoto 1993). Sengonca and Liu (2002) introduced GCSC-BtA biocide for the management of cabbage pests in China. The present results revealed that this biocide significantly reduced the populations of all the cabbage pest species. Although Sengonca and Liu (2001) and Liu and Sengonca (2002) have confirmed high efficacy in controlling the cabbage pests and less side-effects to their natural enemies in the laboratory. It has, however, negatively affected natural enemy populations of *A. plutellae* and *C. septempunctata* but populations of these species were still significantly higher than with methomyl treatment.

The results of the species evenness showed significant differences among the different treatments. The species evenness index of pests and their natural enemies ranged from 0.1017 to 0.8499. Species evenness of *L. sativae* and *P. vittata* pests was not affected in all the three experimental plots. Species evenness of all the pest species was not significantly different between GCSC-BtA and methomyl except for *P. rapae,* but it was significantly different between the treated and control for *P xylostella, P. rapae* and *B. brassicae.* Species evenness is an important characteristic of a species, which determines its severity and outbreaks. According to Wieber et al. (1996), pest outbreak was not expected to happen in the definite period when species evenness was high. Lower pest species evenness poses a risk of break out (Hammond 1995). Species evenness could be affected by many ecological factors, for example, Parmenter et al. (1991) examined the colonization and community development of Orthoptera on a series of re-vegetated coal mines surfaces in Wyoming to find that the mine sites exhibited lower index values for species evenness than the undisturbed site. Felland and Pitre (1991) determined the effect of irrigation on diversity and density of foliage-inhabiting arthropods for late-maturing wide-row soybean during a 3-year study in the alluvial plain (Delta) in Mississippi and concluded that herbivore species evenness was greater and predator evenness lower in irrigated than in dry-land soybean at the most severely stressed site. Jin et al. (1990) reported that in rice fields in China species evenness for the pests were smaller than those for their natural enemies. They further said that insecticide application declined species evenness for the pests more than that of their nature enemies. Miller (1992) applied *Bacillus thuringiensis* subsp. *kurstaki* against the tortricid *Choristoneura occidentalis* Freeman (Lep., Tortricidae) on the tree, *Ceanothus velutinus,* but found no affect on species evenness in the tested ecosystem. Thus, species evenness is an integrated index that is related to those factors affecting the population in the ecosystem.

The Shannon-Wiener diversity index in insect community is a measurement for comparing utility of the provided resources for the community. The higher diversity index reflects the more complicate community with better use of resources and less risk for insect outbreak (Morimoto 1992). Shannon-Wiener diversity index of the species diversity before and after treatments in the present experiments showed that application of GCSC-BtA resulted in a higher index than methomyl or control. In the methomyl as well as control plot, the diversity index decreased as the abundance of pests increased, which resulted in greater pest damage. Zhao et al. (1985) also reported similar results in insect community diversity in citrus orchards. According to them, diversity index increased in early May and decreased during late June, which caused higher damages to citrus. The diversity index of cabbage pests and their natural enemies ranged from 1.1859 to 2.2626, which was similar to that observed by Zhao et al. (1994) in Chongqing City, China, in insect community diversity in the cabbage field with a range of 1.231 to 2.1024. GCSC-BtA biocide increased diversity index from 1.9875 before treatment to 2.4111 after treatment, which was expected to keep the community stable enough to avoid pest outbreak. In contrast, methomyl insecticide applied in the same location greatly decreased the diversity index from 2.1364 before application to 1.1859 after application, which led to pest rampancy causing damage to cabbage crop. Earlier researchers have reported varying results on diversity index. Miller (1992) used *Bacillus thuringiensis* subsp. *kurstaki* against the tortricid *C. occidentalis* and observed no difference in the diversity index before and after application. Jin et al. (1990) demonstrated in paddy cultivation that insecticides reduced diversity index after application resulting in decrease of the stability of natural enemy communities and increase of pests. MESSING et al. (1995) applied malathion bait sprays to control *B. dorsalis* and *B. cucurbitae,* which resulted in significant reduction in overall species diversity index in the treated site as compared to the untreated one.

It can be concluded from the present study that GCSC-BtA has high efficacy in minimizing damage by cabbage pests and at the same time is harmless to their natural enemies. Further benefits with its application are that it increases species evenness and diversity index of the arthropod species complex.

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