COTTON BOLLWORM CONTROL IN NORTH CHINA IN 1995

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Abstract

The cotton bollworm has become the most serious pest and caused a redistri-bution of China's cotton producing region. In 1995, it occurred in outbreaks again in North China. The numbers of the cumulative eggs on 100 cotton plants (ca. 15-19 square meters) were 1,000-5,000, 200-500, and 1,000-4,000 during the 2nd, 3rd, and 4th generations, respectively. In general, the population levels of the first three generations in 1995 were much higher than those in 1994, but lower than those in 1992 and 1993. Research progress was made in control strategy and tactics. The community-wide unified control strategy was demonstrated and extended in a larger area resulting in a better control of the pest. It is estimated that the national lint yield was 4-4.25 million tons for the season.

Introduction

The cotton bollworm, *Helicoverpa armigera* (Hubner), has become the No. 1 pest and a limiting factor of cotton production in China. In the following, we report in brief the history of the problem and the occurrence and control in North China in 1995.

History of Bollworm Problem in North China

The cotton bollworm was first detected and reported in China in 1934 (Liu, 1934a; 1934b). By the end of the 1940's, the infestations had been found in cotton and tobacco fields in Zhejiang and a few of other provinces. In the 1950's, although the population increased in some areas in North China, it was still a minor cotton pest ranked behind the cotton aphid, *Aphis gossypii*, spider mite, *Tetranychus urticae*, pink bollworm, *Pectinophora gossypiella*, and plant bugs (mainly *Lygus lucorum*, *Adelphocoris lineolatus*, *A. fasciaticollis* and *A. suturalis*). In the 1960's, it became the most serious fruit pest in cotton followed by the plant bugs. In the next decade, it increased to be a major pest in cotton only behind the cotton aphid. In the 1980's, it kept increasing to be the most serious cotton pest. Since 1992, the pest has become the number one pest and a key limiting factor of cotton production in the country.

In 1934, when the bollworm was first recorded in China, it infested some upland cotton fields near Hangzhou City in Zhejiang Province. These upland cotton varieties were introduced from the United States and the "square eater" looked like the bollworm native to America. This would be a reason why the pest had been called "American cotton bollworm" for decades. The cotton area in Zhejiang Province has belonged to the Yangtze River Valley Cotton Region. At that time, the bollworm was found more frequently in the eastern area in China. Since the 1950's, it has damaged cotton in all five of the China cotton production regions, but especially in the North China (Yellow River Valley) Cotton Region. There are usually four generations per year with an incomplete fifth generation in some years in North China. Table 1 gives the highest numbers of cumulative eggs of the 2nd generation (mostly during middle and late June) on 100 cotton plants (ca. 15-19 square meters) in Shandong Province since 1950.

In the 1950's, few control measures were needed. In the 1960's, it was required to control the 2nd generation in most years. In the next two decades, sprays with chemical insecticides against the 2nd and 3rd generations were normally initiated. In 1990 and 1991, control of the 4th generation was added. Since 1992, the growers have sprayed all four of the generations with applications up to over 20 times during a four-month period from June to September (Sheng, 1993a; Sheng et al., 1994a). Even so, the cotton yield loss was still too great to bear: 10-20% were commonly seen; 50-80% were not rare; a portion of the growers even abandoned the crop entirely. This was the case in 1992. At the same time, many other crops such as corn, tomato, beans, peanut, wheat, vegetables, flowers and fruit trees, were damaged. The situation has been changing to some extent in the next two growing seasons. However, the total yield from the region declined dramati-cally (partly because of the decreased planting acreage). For example, the total lint yield in Shandong Province was merely 0.68 and 0.41 million tons in 1992 and 1993 compared to 1.7 and 1.4 million tons in 1984 and 1991, respectively.

The bollworm has a great impact on cotton production in China (Sheng, 1996a). Its outbreaks decreased the cotton acreage in North China. On the other hand, the domestic demand of raw cotton has encouraged the planting in an area where the bollworm population is relatively low. Xinjiang Autonomous Region is such an area. Lint yields in this region were 0.08, 0.19, 0.64, 0.68 and 0.90 (estimated) million tons in 1980, 1984, 1991, 1993 and 1995, respectively. According to the Ministry of Agriculture, 2.9%, 11.3% and 21% (estimated) of the national production came from this autonomy in 1980, 1991 and 1995, respectively. That is to say, the bollworm has caused a redistribution of China's cotton producing regions. However, this pest is increasing in most cotton regions in China. In Xinjiang, the highest number of cumulative eggs for one generation on 100 cotton plants (ca. 8-11 square meters) increased by 10 fold in the recent

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years. This is a bad omen. Obviously, a better control is in urgent need for recovering cotton production in North China and promoting the growing in the other regions of the country.

Occurrence in 1995

As a whole, the bollworm occurred at the medium to high level in North China in 1994, much lower than in 1992 and 1993. The population densities of the first three generations were close to the level averaged over the previous 13 years. However, the 4th generation made a new record with the number of cumulative eggs on 100 cotton plants (ca. 15-19 square meters) being one to ten thousands in most areas in the region (Sheng, 1995a).

The densities of diapausing pupae sampled in November 1994 were very high. In Henan, Anhui, Jiangsu, and Shanxi Provinces, the densities were the highest in local records while in Shandong and Hebei they were the second highest only behind those in 1992. For example, the number of the pupae per square meter averaged at 1.13 in Gaotang County, Shandong Province in 1994, 3.2 fold of the mean in 1982-1994, 62% of that in 1992. The weather during winter 1994 and spring 1995 was favorable resulting in very low overwintering mortalities, mostly less than 20%. It was 70-90% in the pre-vious season. These factors led to outbreaks of the 1st and 2nd generations. Data in Table 2 show the egg densities of 2nd generation in cotton in North China in 1995. It should be pointed out that these data came from the pre-fixed systematically sampled sites and so can hardly catch the highest records. In fact, in this growing season, the highest numbers were 13,458 and 12,544 reported from Shandong and Shaanxi Provinces, respectively (Shaanxi was not a heavily infested area before). Generally speaking, the egg and larval densities of 1st and 2nd generation in North China in 1995 were much higher than those in 1994 but lower than those in 1992 and 1993. We had predicted the outbreaks before (Sheng, 1995a; 1995b).

There was a notable change in the occurrence densities among the areas in the region. In 1992, Dezhou and Liaocheng Prefectures in the northwestern area in Shandong Province, Hengshui and Shijiazhuang Prefectures in the southern area in Hebei Province and Anyang and Xinxiang Prefectures in the northeastern area in Henan Province formed a central area of the outbreaks, while the other areas got fewer and fewer eggs as it was farther from the "core". However, since then, the densities decreased in the core but increased in the outside. This was the case of the 2nd generation in 1995. For example, we saw the same highest egg density levels in Shandong and Shaanxi Provinces, 13,458 v. 12,544 sampled on 100 spring-planted cotton plants, equal to 34% and 230% of the local numbers in 1992, respectively. The increases were also found in Shanxi, Anhui and Jiangsu Provinces. We think a main reason for this change is the decreased cotton acreage in the central area and increased acreage in the outside in the North China Cotton Region.

The 3rd generation occurred at high levels with the cumulative eggs being 200-500 per 100 cotton plants in most areas of the region. Usually, a part of the 3rd generation moths fly from cotton to corn and other crops. So, in cotton, the egg density of 3rd generation is lower than that of 2nd or 4th generation. But, the damage by this generation is much more harmful to yield if the number of eggs or larvae is constant, because the plant is at the yield-forming stage and the compensatory ability is minimized. For example, without control, a density of 300 eggs of the 2nd generation on 100 plants causes little damage to the resultant yield, but the same density of the 3rd generation will cause a significant yield loss (normally ca. 10-15%. see also Sheng, 1987). Another reason for the 3rd generation decrease is the rainfall during July in North China. In this season, we experienced heavy rains in summer. Similar to the previous two generations, the 3rd generation densities in most areas in 1995 were lower than those in 1992 and 1993 but higher than those in 1994.

An outbreak of the 4th generation overlapping with the incomplete 5th gener-ation was seen in North China in 1995. The cumulative eggs per 100 cotton plants reached over one thousand reported from most areas. In some areas, the number was as high as 2,000-4,000 cumulated on 100 cotton plants, especially the late-maturing plants. This situation was similar to that in the previous growing season.

At the same time, the bollworm is increasing in the other four cotton regions in China. In many locations of the Yangtze River Valley, Northeastern, and Northwestern Cotton Regions, the population densities made the local records this season. For example, in Wuwei County, Anhui Province, belonging to the Yangtze River Valley Cotton Region, the cumulative number of eggs per 100 cotton plants reached 150 for the 2nd generation, which was not found before. The seasonal population pattern in this region is very low in the early but very high in the late season. The same level of infestation of the 2nd generation was sampled in Liaoning Province belonging to the Northeastern Cotton Region. Even in Xinjiang in the Northwestern Cotton Region, the highest number of cumulative eggs of one generation on 100 cotton plants (ca. 5-8 square meters because of much higher plant densities in the desert area) was at the level of one thousand in some fields in Kashe and Tulufan Prefectures in early August.

As mentioned above, the population densities are commonly high in late season in the Yangtze River Valley. In Hubei Province, outbreaks of the 4th and 5th generations in 1995 season were reported. Generally, the cumulative eggs of one generation sampled on 100 cotton plants were 1,000-2,000. For the 5th generation, this density made a local record. High levels of these late populations are hard to suppress and very harmful to the young bolls.

Control In 1995

After suffering from huge losses in 1992, the Chinese State Government initiated a series of activities to promote solutions. Cooperation between many research institutes, universities, government's sections and companies was established. The CAS (Chinese Academy of Sciences) sponsored a project, "Study on Strategies and Tactics for Reducing Cotton Bollworm Disaster," led by the author. This research team estimated the growers' losses at 7.5-10 billion yuan (US$ 1.2-1.7 billion) in 1992, analyzed the factors of outbreaks and large-scale control failures (Sheng, 1993a), pointed out an incomplete fifth generation occurring in the northern areas in the North China Cotton Region (Sheng, 1993b), and predicted the population increasing in the coming years (Sheng, 1992; Sheng et al., 1993). It also improved some application techniques of control measures, evaluated the chemical control (Sheng & Xuan 1994), worked out a key, i. e., community-wide unified control strategy, to the problem (Sheng et al., 1994b), assembled sets of control measures for different areas, and set an example of community-wide unified control in Wenshang County, Shandong Province, in 1993 and 1994 (Sheng et al., 1995a). At the same time, other teams made good progresse in research and extension.

In respect to research, the CAS team achieved a number of results in 1995. First, we predicted the population dynamics correctly (Sheng, 1995a; 1995b). Secondly, the community-wide unified control strategy was developed, including the theory and practices (Xuan et al. in press). Thirdly, we improved the design of pheromone traps and application methods (Cui, J. R. et al., 1995; Fan et al., 1995; Meng et al., 1995). Fourthly, a few of sets of insecticides were renewed, which is believed to be good for control and decreasing or delaying the resistance to insecticides (Zeng, et al., 1995a; 1995b). At the same time, other teams got some good results, including protecting and utilizing natural enemies (Wen et al., 1995), monitoring and management of the resistance (Feng, et al., 1995a), mixing of chemical insecticides (Zhang, 1995), research and production of NPV emulsive suspension formulation (Zhang, G. Yue et al., 1995), bioassay for toxicities of highly effective B.t. strains (Feng et al., 1995b; Wu et al. 1995) trapping moths by mercury vapor lamps(Zhang, G. Yi et al., 1995) and searching for resistant varieties.

The community-wide unified control has two parts: social organization and technology. Under government's supervision and with some agreements between a local government and the IPM experts and growers, the individual growers are organized. Control actions are directed by the experts and their field crew and done by the village trainees. The part of technology includes mainly decision-making and control agents. Monitoring is carried out by the experts, technicians and field crew (Sheng, 1995a; Sheng, et al., 1994a). A control decision has at least four components: when, where, what, and how to use a control agent. "How" here means not only the application methods but also the implementation. This permits the major control measures to be applied timely and on a large scale in a community (such as a county). Essentially, community-wide unified control is a social technology by which many parties in the community can be integrated. It has proven effective in a small-crop-owners country as China.

In 1995, our pilot demonstration was conducted in more counties in Shandong and Anhui Provinces. In these model counties, the 1st generation was reduced by the sprays directed to the wheat aphids in May. The 2nd generation was controlled by means of moth-trapping with sex pheromone and light, sprays of B.t. suspension and chemical insecticides. Not much effort was made against the 3rd generation, partly due to the heavy rains. Moth-trapping and one or two chemical sprays were enough. For control of the 4th and the overlapping 5th generations, 2-4 sprays with highly-effective insecticides were initiated. In this control protocol, 8-10 sprays in a season are recommended.

These demonstrations have resulted in sound control at rational costs. For example, in Lingbi County, Anhui Province (county town located at 33.6 N. degrees, 117.6 E. degrees, in the southern part of the Yellow River Valley Cotton Region), the bollworm damage was so serious that the cotton yield was reduced by 40% or more in 1994, and the unit lint yield was only 480 kg/ha. Again, in 1995, the pest occurred in outbreaks. The numbers of cum-ulative eggs of 2nd, 3rd, and 4th overlapping 5th generations on 100 cotton plants were 1,000-2,000, 200-500 and 1,000-2,000, respectively. Due to the implementation of community-wide unified control, a set of effective, economical and environmentally-safe control agents was applied timely to most fields. Trapping moths with sex pheromone and light was used for the 2nd and 3rd generation control. One or two sprays of B.t. and one or two sprays of chemical insecticides (methomyl and/or parathion-methyl + phoxim) were made for the 2nd generation. One or two applications of pyrethroids and/or their mixture were done against the 3rd generation. For the suppression of the 4th and 5th generations, 2-4 sprays of the mixture (mainly organophosphates with pyrethroids) were made. By the means of agreements between the county governments, Institute of Zoology, growers and other parties, all the actions were unified. The total cost of materials was about 600-900 yuan (ca. US$ 75-100 per hectare, equal to 4-6% of the gross return). The population densities were reduced to around the ET levels (300, 50 and 100 eggs accumulated on 100 plants for the 2nd, 3rd and 4th generations, respec-tively. Sheng, 1987). The growers got a record harvest and the county-wide lint yield increased to 990 kg/ha. This is

116% higher than that in 1994. The county's cotton production situation changed very much.

More importantly, from the view-point of disaster reduction, the Chinese State Government adopted the fundamental strategy of community-wide unified control. In 1995, 1/3 of the cotton acreage was required to implement the strategy. This had a good impact on the control in areas near a demonstration area. As a whole, all the four or five generations were put under control in the country. As a result, the bollworm damage was reduced to a low level. The national unit yield should be close to the normal, and the total lint production is estimated at 4-4.25 million tons (The heavy summer rains in Shandong Provinces would have hampered yields), which will be close to or a little less than the domestic demand.

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Table 1. The highest number of cumulative eggs of 2nd generation sampled on 100 cotton plants (ca. 15-19 square meters) in Shandong Province since 1950 (Data from Shandong Plant Protection Station).

Decade or Year	No. of Cumul. Eggs per 100 Cotton Plants
1950's	200-300 (estimated)
1960's	925
1970's	1,351
1980's	2,000 (estimated)
1992	40,730
1993	29,100
1994	600-800 (estimated)
1995	13,458

Table 2. Number of cumulative eggs of 2nd generation sampled on 100 cotton plants (ca. 15-19 square meters) in North China Cotton Region in 1995 (Data from the six Provincial Plant Protection Stations) (Sheng, 1996b).

Province	No. of Stations	No. of Cumul. Eggs per 100 Plants	
		Mean	Range
Hebei	13	2,085	230-3,069
Henan	11	791	261-2,292
Shandong	12	1,905	236-5,000
Shanxi	7	535	145-2,011
Jiangsu	4	728	?
Anhui	2	798	?