Ecotypes of *Torymus (Syntomaspis) beneficus* YASUMATSU et KAMIJO (Hymenoptera: Torymidae) with Different Seasonal Prevalences of Adult Emergence¹

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(Received August 4, 1987)

It is known that the adult emergence curve of *Torymus (Syntomaspis) beneficus*, a native parasitoid of the chestnut gall wasp, *Dryocosmus kuriphilus*, has two peaks in the Ibaraki district. Samples of withered galls of *D. kuriphilus* were collected from various localities and placed in a meteorological screen in Fukuoka to investigate the seasonal prevalence of adult emergence of *T. (S.) beneficus*. It was evident that there were at least three ecotypes of the parasitoid with different curves of adult appearance. As these types were complicated in their geographical distributions, they should not be regarded as geographical ecotypes which have adapted to the climatic conditions in each locality. Alternatively, it was supposed that these types may have originated from different ecotypes of the same species which attacked different native cynipid hosts before *D. kuriphilus* was accidentally introduced into Japan.

INTRODUCTION

The chestnut gall wasp, *Dryocosmus kuriphilus* YASUMATSU was accidentally introduced into Japan from China around 1940 and spread throughout the country, becoming one of the most serious pests of chestnut trees. *Torymus (Syntomaspis) beneficus* YASUMATSU et KAMIJO is the most important native parasitoid and would probably have been a parasitoid of some native cynipids on *Quercus* spp. before the chestnut gall wasp arrived in Japan. *T. (S.) beneficus* is so closely related to *Torymus (Syntomaspis) sinensis* KAMIJO, an imported parasitoid of the gall wasp from China that the males of both species are hardly distinguishable morphologically, though a slight difference in the relative length of the flagellum is detectable (KAMIJO, 1982).

The author has been engaged in a colonization test of *T. (S.) sinensis* in an orchard in Kumamoto Prefecture since 1982 (MURAKAMI and KIYOTA, 1983; MURAKAMI et al., 1985, 1987). Fortunately, the morphological similarity of the two wasp species is practically not a problem in the release test because *T. (S.) sinensis* is easily distinguishable from *T. (S.) beneficus* by the difference in the period of adult emergence (MURAKAMI, 1981 a, b). That is, the time when half of the males have finished emerging is three or four weeks earlier in the latter species than in the former.

¹ This research is a part of the studies on development of new techniques for control of agricultural pests by biological means (1980-1984) sponsored by the Ministry of Agriculture, Forestry and Fisheries, Japan.

ÔTAKE (personal communication), however, pointed out that in Ibaraki Prefecture the adult emergence curve of *T. (S.) beneficus* had two explicit peaks, i.e., the first peak in late March and the second in late April, so that the second peak coincided with the emergence of *T. (S.) sinensis*. Therefore, ÔTAKE et al. (1984) could not distinguish between males of the two species and had to count males simply as a sex without separating the species in their research on the colonization of *T. (S.) sinensis* in Ibaraki. At that time, this author assumed that the Ibaraki population of *T. (S.) beneficus* would be a mixture of two ecotypes of the parasitoid with different seasonal prevalences of adult emergence and that these two ecotypes might be geographical ones adapted to northern and southern Japan, respectively. In order to check this, an investigation was conducted on the local populations of the parasitoid collected from different districts in Japan.

MATERIALS AND METHODS

Life histories of the host and the parasitoid. The host, *D. kuriphilus* is a univoltine and thelytokous cynipid wasp, and is distributed in Hokkaido, Honshu, Shikoku and Kyushu in Japan. Adults emerge from the chestnut galls from mid June to mid July in southwestern Japan, while in northern Japan they emerge from early July to August. Eggs are laid inside chestnut buds and hatch after a month, but larvae remain immature until the next spring. In spring, when chestnut buds begin to develop, the larvae resume their growth and galls begin to swell rapidly, and thereafter they advance to the pupal stage (TAMURA, 1960; ÔTAKE, 1980).

The parasitoid, *T. (S.) beneficus* is also univoltine and occurs in Hokkaido, Honshu, Shikoku and Kyushu. Adults emerge in early spring from withered galls which were formed in the spring of the previous year, and females oviposit in newly formed galls. After the eggs hatch in the galls, first instar larvae feed on the soft plant tissue of the wall of the cynipid larval chamber in the galls. When the larvae develop to the second instar, they feed ectoparasitically on mature larvae of the chestnut gall wasp. After a month they develop to the mature larval stage and enter into a long diapause until autumn in the gall chambers. During winter they pupate. This parasitoid also emerges from galls of *Andricus* sp. on leaves of *Quercus serrata* THUNBERG in Fukuoka (YASUMATSU and KAMIJO, 1979; MURAKAMI, 1981 a).

Field collections of chestnut galls. The investigation was made for two successive seasons. From autumn to winter in 1983–1984 season, galls of *D. kuriphilus* were collected from chestnut trees in Aomori, Fukuoka and Kumamoto Prefectures. Another sample of galls was collected in Ibaraki Prefecture by Mr. S. MORIYA. The next season, from September to October in 1984, nine samples of galls were collected from Miyagi, Niigata, Fukui, Kanagawa, Gifu and Okayama Prefectures. As a control, a sample from Kumamoto Prefecture was collected in the same orchard as in the previous season (Table 1).

Investigation on parasitoid emergence. Galls collected from each locality were put into test tubes (3 cm in diameter and 20 cm long), plugged with cotton and placed in a wooden meteorological screen in an experimental field of the Institute of Biological Control, Kyushu University in Fukuoka. Parasitoid adults emerging from these galls were sexed and counted daily.

Table 1. Data on sample galls of *D. kuriphilus* collected for investigation

Season of investigation	Population code	Collection of sample galls		No. of galls collected
		Locality	Date	
1983-84	Aomori	Foot of Mt. Iwaki, Aomori Pref.	Oct. 1, 1983	604
	Ibaraki	Yatabe, Ibaraki Pref.	Jan. 25, 1984	3,166
	Fukuoka	Mt. Aburayama, Fukuoka Pref.	Feb. 11, 1984	344
	Kumamoto (control)	Ohzu, Kumamoto Pref.	Dec. 12, 1983	879
1984-85	Miyagi	Sendai, Miyagi Pref.	Sept. 20, 1984	1,169
	Niigata-a	Akadani, Shibata, Niigata Pref.	Sept. 21, 1984	403
	Niigata-b	Yonekura, Shibata, Niigata Pref.	Sept. 21, 1984	433
	Fukui-a	Mt. Asuwa, Fukui, Fukui Pref.	Sept. 22, 1984	295
	Fukui-b	Mt. Murakuni, Takefu, Fukui Pref.	Sept. 23, 1984	490
	Kanagawa	Mt. Oyama, Isehara, Kanagawa Pref.	Oct. 27, 1984	290
	Gifu	Ena-kyo, Ena, Gifu Pref.	Oct. 28, 1984	343
	Okayama-a	Wake, Okayama Pref.	Oct. 29, 1984	252
	Okayama-b	Yoshinaga, Okayama Pref.	Oct. 29, 1984	395
	Kumamoto (control)	Ohzu, Kumamoto Pref.	Dec. 20, 1984	800

RESULTS

Investigation in 1983-1984 season

Seasonal prevalences of adult wasp emergence in Fukuoka are shown in Fig. 1.

Fig. 1. Seasonal prevalence of adult emergence in each of the local *T. (S.) beneficus* populations in 1984. The observation was carried out in Fukuoka. A: Aomori, B: Ibaraki, C: Fukuoka, D: Kumamoto (control). Solid histogram: male, open histogram: female. Arrows indicate dates of 50% adult emergence.

From galls collected in Aomori Prefecture, 18 males and 37 females of *T. (S.) beneficus* emerged during late April to early May, dates of 50% emergence being April 25 for males and April 28 for females (Fig. 1A). From galls collected in Ibaraki Prefecture, most adults (46 males and 70 females) emerged within nearly the same period as the Aomori population. The dates of 50% emergence of adults which emerged after the date indicated by a vertical dashed line in Fig. 1B were April 24 for males and April 26 for females. It is noteworthy that in the Ibaraki population there were some wasps (2 males and 3 females) which emerged three to four weeks before the majority of wasps (Fig. 1B). In the Fukuoka and Kumamoto populations, however, all the adults (89 males and 106 females in Fukuoka; 30 males and 42 females in Kumamoto) emerged during the period from mid March to early April, almost one month earlier than those of the Aomori population. The dates of 50% emergence in the Fukuoka population were March 26 for males and April 1 for females, and those in the Kumamoto population were March 28 for males and April 4 for females (Fig. 1 C, D). This means that the time of the above-mentioned earlier emergence in the Ibaraki population was within the range of the emergence period in the Fukuoka and Kumamoto populations.

Investigation in 1984–1985 season

Seasonal prevalences of adult wasp emergence from galls which had been collected at nine localities are shown in Fig. 2, in comparison with the result of the Kumamoto population.

In 1985, the adult emergence in the Kumamoto population was 9 to 14 days earlier than in the previous year, because of the warmer winter in 1984–1985. The dates of 50% emergence were March 14 and March 26 for males and females, respectively (Fig. 2D). The emergence periods of populations Niigata-a, Niigata-b, Fukui-a, Fukui-b and Kanagawa were nearly the same as that of the Kumamoto population. The dates of 50% emergence of male adults in these populations ranged from March 17 to 21 and those of females from March 27 to 29 (Fig. 2F, G, H, I, J). In the Miyagi and Okayama-a populations, the emergence was one or two weeks later than in the Kumamoto population. The dates of 50% emergence of male adults were March 27 for both populations and those of females were April 2 and 4 for the Miyagi and Okayama-a populations, respectively (Fig. 2E, L). Adult emergence in the Gifu and Okayama-b populations had two peaks. The first peaks were nearly the same in the time of appearance as those in the Miyagi and Okayama-a populations. The second peaks were rather small and about 19 to 25 days after the earlier ones. When the emergence curves were separated into two parts at the points indicated by the vertical dashed lines in Fig. 2K and M, the dates of 50% emergence in the respective parts were as follows: the first part in the Gifu population, May 25 in male and April 1 in female; that in the Okayama-b population, May 26 in male and April 4 in female; the second part in the Gifu population, April 18 in male and April 23 in female; that in the Okayama-b population, April 20 in male and April 23 in female (Fig. 2 K, M).

DISCUSSION

Results of investigations during two seasons suggested that there were at least three types of *T. (S.) beneficus* in Japan with different periods of adult emergence. Adults of the Fukuoka and Kumamoto populations (Figs. 1 C, D, and 2 D) emerged early, and this

Fig. 2. Seasonal prevalence of adult emergence in each of the local *T. (S.) beneficus* populations in 1985. The observation was carried out in Fukuoka. E: Miyagi, F: Niigata-a, G: Niigata-b, H: Fukui-a, I: Fukui-b, J: Kanagawa, K: Gifu, L: Okayama-a, M: Okayama-b, D: Kumamoto (control). For other legends see Fig. 1.

type of emergence was tentatively designated as Kyushu type. The populations Niigata-a, Niigata-b, Fukui-a, Fukui-b and Kanagawa (Figs. 2 F, G, H, I, J) are also regarded as the Kyushu type. On the contrary, the appearance of adults in the Aomori population (Fig. 1 A) was nearly one month later than that in the Kyushu type, and is designated as the Aomori type. The time of adult emergence in the Miyagi and Okayama-a populations (Fig. 2 E, L) was intermediate.

The Ibaraki, Gifu and Okayama-b populations seem to consist of two of the three different types mentioned above. It is likely that the Ibaraki population (Fig. 1 B) mainly consists of the Aomori type, and a small amount of either of the other two types, the Kyushu or the intermediate type, is mixed in. The Gifu and Okayama-b populations (Fig. 2 K, M) are considered to be mixtures of the intermediate and Aomori types.

Geographical distributions of these three types are shown in Fig. 3. In the Ibaraki

Fig. 3. Geographical distribution of Aomori type (open circles), Kyushu type (solid circles) and intermediate type (shaded circles) of *T. (S.) beneficus*. 1: Aomori, 2: Miyagi, 3: Niigata, 4: Fukui, 5: Ibaraki, 6: Kanagawa, 7: Gifu, 8: Okayama, 9: Fukuoka, 10: Kumamoto.

population the group of early emerging wasps is regarded as of the Kyushu type for convenience sake in this figure. As indicated, the distributions of these types were too complicated to be regarded as the result of climatic inclination. Therefore, they should not be regarded as geographical ecotypes which have adapted to the climatic conditions in each locality.

Alternatively, it is supposed that these types may have originated from different ecotypes of the same species which attack different native hosts at each locality. Then, owing to the accidental introduction of the chestnut gall wasp, each of the types might have come to attack this new host in the course of the expansion of the host's geographical distribution. The original host of the Kyushu type is considered to be the *Andricus* sp., a gall maker on the leaf of *Quercus serrata*, which was earlier recorded as a host of the parasitoid by YASUMATSU and KAMIJO (1979) and MURAKAMI (1981 a). The origins of two other types have not yet been determined.

ACKNOWLEDGEMENTS

The author thanks the following persons for their assistance in collecting sample galls from the various localities shown in parentheses. Mr. K. FURIHATA (Aomori), Mr. M. MAEDA and Mr. T. KIDOKORO (Miyagi), Mr. S. SAKURAI (Niigata), Dr. A. ÔTAKE and Mr. S. MORIYA (Ibaraki), Mr. T. HIRAMATSU (Okayama), Mr. M. UEMURA and Mr. Y. GYOUTOKU (Kumamoto).

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