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Yasumatsu, Keizo
Entomological Laboratory, Department of Agriculture, Kyushu University

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FURTHER INVESTIGATIONS ON THE HYMENOPTEROUS PARASITES OF *CEROPLASTES RUBENS* IN JAPAN*

KEIZÔ YASUMATSU

INTRODUCTION

As far as can be ascertained *Ceroplastes rubens* Maskell reached Japan without any of the natural enemies attacking it in its native country. Furthermore this scale insect attacks no less than 150 species of plants in Japan. Thus *Ceroplastes rubens* has become the first most important pest in horticulture in Japan, since not a single effective chemical control method applicable to this pest has ever been established. The wide range of host plants indicates the difficulty of its control even if the scales in the commercial orchards are satisfactorily controlled by some chemical methods. Therefore, there is also urgent need for the complete destruction of *Ceroplastes rubens* which are attached to a number of plant species in various places near or surrounding the commercial orchards.

. Since 1923, as written in the previous report (1949), not a single investigation has ever been made on the native parasites of this injurious scale insect up to the year 1946, when I noticed for the first time a progressive decrease in the population of *Ceroplastes rubens* in N. Kyushu and this phenomenon was ascribed to the activity of a parasitic Hymenoptera.

Increasing requirements in recent years for the control of this scale especially in Honshu and Shikoku emphasize the necessity of developing new approaches to the problem. Among the suggestions advanced is that the possibility of biological control by means of this native parasite should receive adequate attention.

* The expenses of the present study were born in part by a grant from the Ministry of Education.

What was known of the parasites of *Ceroplastes rubens* is Japan previous to the year 1947 has been reported in the previous paper (1949). This paper includes an account of my research for the native key parasite performed in 1949, 1950 and an early part of 1951.

RE-EXAMINATION OF THE KEY PARASITE

In Japan two species of the genus *Anicetus* have been recognized by Dr. T. Ishii (1928): *Anicetus annulatus* Timberlake and *A. ceroplastis* Ishii. When the key parasite of *Ceroplastes rubens* was first discovered in Kyushu, I determined it as *Anicetus annulatus* Timberlake with some hesitation, because at that time not a single available specimen of *A. annulatus* from U. S. A. was before me. During recent years doubts have been growing as to whether the key parasite is *A. annulatus*. Therefore, I sent my material to Dr. H. Compere in 1950 and begged him to compare them with the type of *A. annulatus*. Dr. Compere was so kind as to give me some information about the species and spared me some specimens of *A. annulatus* determined by him for my comparative study. On the other hand, Mr. Y. Miyamoto compared my specimens with the type of *A. ceroplastis* Ishii and informed me that the key parasite was identical with the type of *A. ceroplastis*, the only difference between the two species was seen in the length of the ovipositor and the original description made by Ishii was incorrect with respect to the ovipositor length. I was deeply astonished at this fact. The reason was that the original description made by Dr. Ishii did not agree with the character of the key parasite. Unfortunately the original description of *A. ceroplastis* is so inaccurate that it is almost impossible to detect the specimens of *A. ceroplastis* among the material of the genus *Anicetus* with the aid of his description.

Because of the necessity for accurate knowledge of this key parasite and because of the widespread interest in the race problem, I undertook the re-examination of the key parasite and came to the conclusion that there may be found many significant differences separating the two species besides the length of the ovipositor (Tables 1 and 2).

Table 1. Comparison of *A. ceroplastis* and *A. annulatus* (female sex).

annulatus	*ceroplastis*
Head, seen from above, about 1.7-times as broad as long.	Head, seen from above, about twice as broad as long.
Fronto-vertex 2.5 times as long as wide at the ocelli.	Fronto-vertex about three-times as long as broad.
Antennal scape subtriangular, maximum length: maximum width=1.5:1 (Fig. 1, B).	Antennal scape somewhat trapezoidal, maximum length: maximum width=1.4:1 (Fig. 1, D).
Mesoscutum slightly longer than scutellum.	Mesoscutum slightly shorter than or as long as scutellum.
Thorax with the notum moderately convex.	Thorax with the notum much more convex.
Thorax—length : width : hight = 20 : 14 : 11.	Thorax—length : width : hight = 20 : 18 : 17.
Pronotum without marking.	Pronotum with a brownish round spot.
Scutellum wider than long (Fig. 1, A).	Scutellum as long as wide (Fig. 1, c).
Scutellum with two pairs of still stouter longer black bristles, one pair near the apex, the other but slightly further apart just behind the middle, the disk also with a few fine hairs (Fig. 1, A).	Scutellum with many bristles and hairs, two pairs of stouter bristles near the apex (Fig. 1, C).

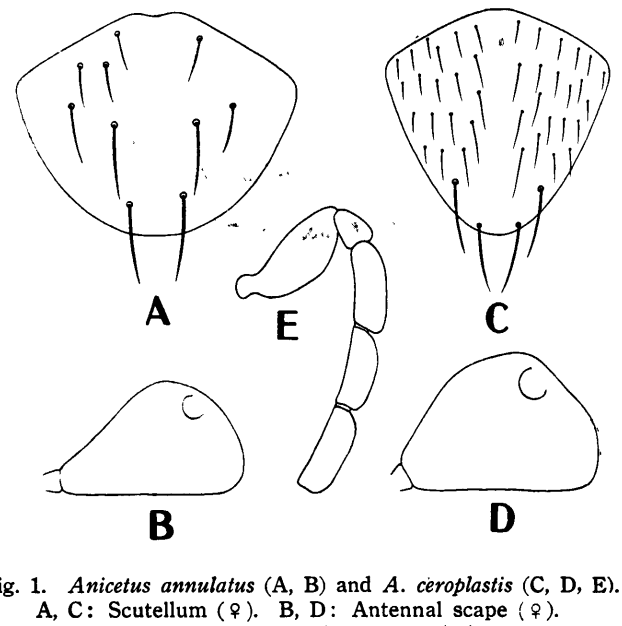

Fig. 1. *Anicetus annulatus* (A, B) and *A. ceroplastis* (C, D, E).
A, C: Scutellum (♀). B, D: Antennal scape (♀).
E: Five basal antennal segments (♂).

Metapleura with an oval to oblong spot on upper part.	Metapleura without an oval to oblong spot.
Hairs on mesoscutum pale coloured.	Hairs on mesoscutum all black.
Hairs on fore wing different (Fig. 2, B).	Hairs on fore wing also different (Fig. 2, A).
Hind wing narrow—length/width = 4.75.	Hind wing broader—length/width=3.33.
Ovipositor barely produced.	Ovipositor producing one-fifth the length of abdomen.
Abdomen slightly wider than thorax.	Abdomen almost as wide as thorax.
Hind tibia with two annuli, the first situated close to the base, the second just beyond the middle.	Hind tibia with three annuli, the first situated at the base.
General colour ochraceous orange.	General colour much darker, more strongly violaceously reflecting.

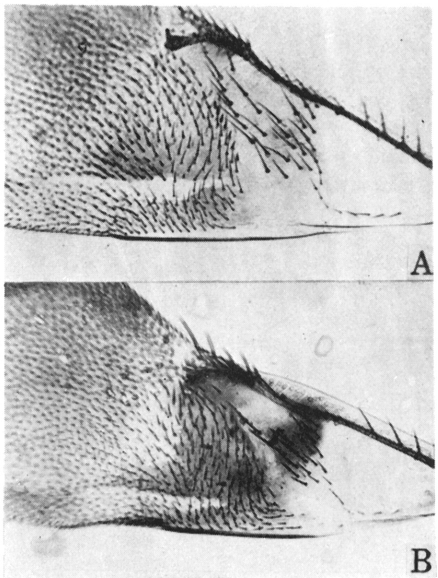

Fig. 2. Basal half of fore wings.
A: *Anicetus ceroplastis* (♀). B: *A. annulatus* (♀).

Table 2. Comparison of *A. ceroplastis* and *A. annulatus* (male sex).

annulatus	*ceroplastis* (new to science)
Cheeks considerably longer than eyes.	Cheeks slightly shorter than eyes.
Antenna—the first funicle segment somewhat longer than the second to fourth. The first a half longer than wide. The fifth about twice as long	First funicle segment very slightly longer than the second, about as long as third to fourth. The first about three-times as long as wide.

as wide. The second to fifth each of deeply incised at the articulations so that the second to fourth are subtriangular. Club nearly as long as the last two funicle segments taken together.	The fifth more than three-times as long as wide. The second to fourth parallel-sided, but triangular in shape. Club shorter than the last two funicle segments taken together (Fig. 1, E).
Mesoscutum much longer or hardly a fourth wider than long.	Mesoscutum twice as broad as long.
Scutellum much shorter than mesoscutum.	Scutellum distinctly longer than mesoscutum.
Abdomen hardly wider than thorax.	Abdomen slightly wider than thorax.
Fore and mid-formora pale yellow. Basal third of the mid-tibiae fuscous.	Basal half of fore femora fuscous. Mid-femora fuscous except the base and the apex. Basal portion of mid-tibiae not fuscous.
Hind femora fuscous. Apex of all tarsi black.	Hind femora blackish except the apical portion. Apical tarsal segment of fore and hind legs brownish. Apex of mid-tarsi brownish.
Hosts: *Coccus hesperidum, Coccus pseudomagnoliarum, Eucalymnatus tesselatus, Pulvinaria* sp., *Saissetia hemisphaerica.*	Hosts: *Ceroplastes rubens, Ceroplastes ceriferus.*

Allotype (♂) and 52 paratopotypes (♂♂) of *Anicetus ceroplastis*—16. vi. 1950, Fukuoka, Prov. Chikuzen, Kyushu, reared by K. Yasumatsu from *Ceroplastes rubens.*

PERCENTAGE OF PARASITISM OF *Ceroplastes rubens* BY *Anicetus ceroplastis* IN VARIOUS DISTRICTS OF JAPAN

It was planned to continue the survey for three years (1949, 1950, 1951) to determine what species of parasites were present and most important in various districts of Japan. It was believed that such a survey would also yield information that would enable us to better utilize the native parasites known to attack *Ceroplastes rubens.* The results are summarized in Table 3.

Table 3. Parasitism of *Ceroplastes rubens* by *Anicetus ceroplastis* in different localities of Japan observed in 1949, 1950 and 1951.

Host plants of *Ceroplastes rubens*	Localities	No. of *C. rubens*	No. of *A. ceroplastis* emerged	Percentage of parasitism
Ilex integra	Mitaka-gun, Fuk.	2174	0	0.00
Diospyros Kaki	Mitaka-gun, Fuk.	1765	0	0.00
Citrus Unshu	Mitaka-gun, Fuk.	132	0	0.00
Citrus Unshu	Oi-gun, Fuk.	30	0	0.00
Diospyros Kaki	Onifu-gun, Fuk.	5976	0	0.00
Citrus Unshu	Onifu-gun, Fuk.	326	0	0.00

Ilex integra	Onifu-gun, Fuk.	579	0	0.00
Citrus Unshu	Onifu-gun, Fuk.	731	0	0.00
Diospyros Kaki	Onifu-gun, Fuk.	992	0	0.00
Citrus Unshu	Uchiura, Si.	313	0	0.00
Eurya japonica var. *montana*	Kanaya, Si.	272	0	0.00
Ilex integra	Kanaya, Si.	256	0	0.00
Thea sinensis	Kanaya, Si.	154	0	0.00
Diospyros Kaki	Kanaya, Si.	443	0	0.00
Gardenia jasminoides var. *grandiflora*	Kanaya, Si.	227	0	0.00
Citrus Unshu	Kanaya, Si.	849	0	0.00
Citrus Unshu	Chita-gun, Ai.	451	0	0.00
Citrus Unshu	Chita-gun, Ai.	260	0	0.00
Citrus Unshu	Chita-gun, Ai.	1500	0	0.00
Citrus Unshu	Atsumi-gun, Ai.	160	0	0.00
Citrus Unshu	Atsumi-gun, Ai.	416	0	0.00
Eurya japonica var. *montana*	Chita-gun, Ai.	950	0	0.00
Eurya japonica var. *montana*	Chita-gun, Ai.	315	0	0.00
Ilex integra	Chita-gun, Ai.	672	0	0.00
Ilex integra	Chita-gun, Ai.	450	0	0.00
Citrus Unshu	Unebi-machi, Na.	5080	0	0.00
Diospyros Kaki	Ryumon, Wa.	89692	0	0.00
Citrus Unshu	Ryumon, Wa.	153310	0	0.00
Daphniphyllum macropodum	Takatsuki, Os.	9	0	0.00
Camellia japonica var. *hortensis*	Minami-kawachi, Os.	34	0	0.00
Diospyros Kaki	Takatsuki, Os.	329	0	0.00
Diospyros Kaki	Minami-kawachi, Os.	52	0	0.00
Varia	Ikeda, Os.	2230	0	0.00
Gardenia jasminoides var. *grandiflora*	Ikeda, Os.	211	0	0.00
Ilex latifolia	Ikeda, Os.	67	0	0.00
Citrus Unshu	Ikeda, Os.	70	0	0.00
Eurya sp.	Ikeda, Os.	23	0	0.00
Cercidiphyllum japonicum	Ikeda, Os.	92	0	0.00
Euonymus alatus	Ikeda, Os.	410	0	0.00
Fastia japonica	Ikeda, Os.	104	0	0.00
Daphniphyllum macropodum	Ikeda, Os.	258	0	0.00
Diospyros Kaki	Ikeda, Os.	398	0	0.00
Camellia japonica var. *hortensis*	Ikeda, Os.	268	0	0.00
Ilex integra	Ikeda, Os.	2024	0	0.00
Ilex integra	Nishinomiya, Hy.	288	0	0.00
Pyracantha angustifolia	Nishinomiya, Hy.	293	0	0.00

Citrus Unshu	Akomachi, Hy.	3925	0	0.00
Citrus Unshu	Sumoto, Hy.	559	0	0.00
Diospyros Kaki	Okayama, Ok.	9607	0	0.00
Thea sinensis	Mitsuki-gun, Hi.	969	0	0.00
Citrus Unshu	Mitsuki-gun, Hi.	324	0	0.00
Diospyros Kaki	Mitsuki-gun, Hi.	5525	0	0.00
Diospyros Kaki	Hiroshima, Hi.	27825	0	0.00
Citrus Unshu	Jigoze, Hi.	490	0	0.00
Diospyros Kaki	Mino-gun, Sim.	46	0	0.00
Diospyros Kaki	Anno-gun, Sim.	18	0	0.00
Citrus sp.	Anno-gun, Sim.	111	0	0.00
Camellia Sasanqua	Izumo, Sim.	415	0	0.00
Varia	Hikawa-gun, Sim.	684	0	0.00
Ilex integra	Hikawa-gun, Sim.	472	0	0.00
Diospyros Kaki	Hikawa-gun, Sim.	167	0	0.00
Camellia japonica var. *hortensis*	Hikawa-gun, Sim.	24	0	0.00
Citrus Unshu	Hikawa-gun, Sim.	255	0	0.00
Ilex serrata var. *Sieboldi*	Hikawa-gun, Sim.	575	0	0.00
Citrus Unshu	Yanai, Ya.	45	0	0.00
Camellia japonica var. *hortensis*	Yanai, Ya.	100	0	0.00
Diospyros Kaki	Naka-gun, Ya.	200	0	0.00
Citrus Unshu	Iwakuni, Ya.	63	0	0.00
Diospyros Kaki	Hagi, Ya.	28	0	0.00
Citrus Unshu	Hagi, Ya.	1183	0	0.00
Citrus Unshu	Oshima, Ya.	7726	0	0.00
Citrus Unshu	Matsuyama, Eh.	456	7	1.53
Fortunella sp.	Sasaguri, Fu.	3352	1740	over 52.33
Citrus Unshu	Tachibana, Fu.	567	140	over 24.67
Varia	Kokura, Fu.	1133	316	over 27.90
Citrus Unshu, varia	Tanushimaru, Fu.	573	260	over 45.37
Citrus Unshu	Fukuma, Fu.	539	220	over 40.81
Ilex Oldhami	Orio, Fu.	739	182	over 29.23
Fortunella sp.	Miyajidake, Fu.	783	118	over 15.07
Citrus Unshu	Takeo, Sa.	1126	204	over 18.11
Citrus Unshu	Saga, Sa.	546	152	over 27.83

Fu.: Fukuoka Prefecture, Kyushu. Sa.: Saga Pref., Kyushu. Fuk.: Fukui Pref., Honshu. Si: Shizuoka Pref., Honshu. Ai.: Aichi Pref., Honshu. Wa.: Wakayama Pref., Honshu. Os.: Osaka Pref., Honshu. Hy.: Hyogo Pref., Honshu. Ok.: Okayama Pref., Honshu. Hi.: Hiroshima Pref., Honshu. Sim.: Shimane Pref., Honshu. Ya.: Yamaguchi Pref., Honshu. Eh.: Ehime Pref., Shikoku.

Besides the materials summarized in the table I have had the good fortune of examining other material from Isahaya, Nagasaki

Prefecture, Nozumura, Yatsushiro-gun, Kumamoto Prefecture, Ichiki-machi, Kajiki-machi and Tarumi-machi, Kagoshima Prefecture and numerous places of Fukuoka Prefecture. In the fall of 1949 I visited Nozumura where six citrus orchards were situated side by side, each differing in tree and cultural conditions together with the topographical position. Several years before these citrus orchards were said to have been heavily infested with *Ceroplastes rubens*, but during the past three years there has been a remarkable decrease in the population of the scales. My careful examination revealed that out of six orchards five were quite free from *Ceroplastes rubens* and in the remaining one orchard a number of exit holes of the parasites could be recognized, though not heavily infested with the scales.

The survey covering these years showed that only a parasite, *Anicetus ceroplastis*, was exclusively the most numerous parasite of *Ceroplastes rubens* in Kyushu, accounting for over 95 per cent of all parasites reared from the host scales. And it is very interesting to note that this parasite was not found in any district of Honshu and Shikoku except in some places where it seemed to have been imported from Kyushu several years ago together with the host scales attached to young citrus plants. These findings led to colonization experiments with *Anicetus ceroplastis* in several localities in Honshu, Shikoku and Kyushu where this parasite is not found or the percentage of parasitism is very low.

ON A POSSIBLE NEW RACE OF *Anicetus ceroplastis* PARASITIC ON *Ceroplastes rubens*

In 1941 Professor H. S. Smith expressed the following valuable opinion concerning the biological control of insect pests: "Before the possibilities of the biological control method of pest suppression have been exhausted, the probable existence of races having varying characteristics in parts of a parasite's range will have to be given consideration in connection with the attempt to establish a species in a new habitat." Several especially interesting examples of racial segregation among Hymenopterous insects are given as follows: a Korean race of *Tiphia popilliavora* Rohwer parasitic on *Popillia japonica* Newman, a New Jersy race of *Macrocentrus ancylivorus* Rohwer parasitic on *Grapholitha molesta*

Busck, a Chinese race of *Aspidiotiphagus citrinus* (Crawford) parasitic on *Aonidiella aurantii* (Maskell), a Formosan race of *Prospaltella perniciosi* Tower and a Chinese race of *Comperiella bifasciata* Howard parasitic on the same scale. Thus in 1950 Dr. S. E. Flanders wrote " the discovery that *Comperiella bifasciata*, *Prospaltella perniciosi*, and *Aspidiotiphagus citrinus* consist of host-limited races finally establishes the principle that in parasite importation programs cognizance must be taken of this phenomenon. The host specificity of a parasite species in one region is not necessary the same as that in another."

The remarkable fact that during the past few years there has been a progressive decrease in the population of *Ceroplastes rubens* in Kyushu and the existence of the key parasite, *Anicetus ceroplastis*, has been of utmost importance in destroying this scale which might be of extreme importance in the biological control problem of this scale in various places in Honshu and Shikoku.

Anicetus ceroplastis was hitherto known as a parasite of *Ceroplastes ceriferus* (Anderson), occurring both in Honshu and Kyushu. The field evidence proved that *Ceroplastes rubens* in Honshu and Shikoku were entirely free from the parasitization of *Anicetus ceroplastis*. Further the evidence that is seen extensively in Kyushu is quite striking, and this phenomenon has appeared in *Anicetus ceroplastis* very shortly before 1946. This may have been due to the possibility that the gene for parasitizing *Ceroplastes rubens* arose by mutation. These circumstances support the fact that more than one mutant must have arisen at practically the same time at different foci throughout Kyushu except for some localities, because it is scarcely conceivable that spread of this mutant or a new race of *Anicetus ceroplastis* would have occurred from a single mutant or focus (Fukuoka Prefecture) and spread to Saga, Kumamoto, Nagasaki, Kagoshima, Oita and probably to Miyazaki Prefectures.

Fluctuation in the populations of *Ceroplastes rubens* are often influenced by such factors as climatic, tree and some cultural conditions. During the war almost all the orchards in Japan were neglected, and the fruit trees received little or no proper attention for a considerable period. There has been no noticeable difference in climate on Honshu, Shikoku and Kyushu where the scale has had no insecticidal control during these years. Notwithstanding only in Kyushu the population of *Ceroplastes rubens* has reduced prominently in recent years.

Taking these in consideration, it should be noted at this point that there may be no objection to the claim that a progressive decrease in the population of this scale in Kyushu has been shown in almost all cases by the activity of a new race of *Anicetus ceroplastis.*

EMERGENCE AND NUMBER OF GENERATIONS OF *Anicetus ceroplastis*

A summary of the data upon the emergence and number of generations of *Anicetus ceroplastis* for 1949 and 1950 in Fukuoka is given in Figure 3. The hibernation period is spent as a larva within the scale insect. The full-grown larvae may be found even at the later part of March. In April and the first part of May some larvae are already pupated. Adult *Anicetus ceroplastis* starts emerging the later part of May and continues until the first part of July. For the second generation, emergence starts the middle part of August and continues until the middle part of October.

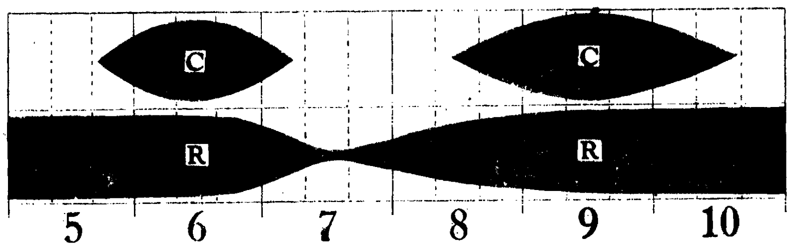

Fig. 3. Relation between *Anicetus ceroplastis* and its host, *Ceroplastes rubens,* in Kyushu. Somewhat schematic. C: Emergence of *Anicetus ceroplastis.* The extremes of each area represent approximately the first and last periods of emergence, while the widest portion represents the peak of emergence. R: Existence of *Ceroplastes rubens* scales which will become hosts of the parasite, *Anicetus ceroplastes,* in warmer seasons. 5: May. 6: June. 7: July. 8: August. 9: September. 10: October.

In Japan *Ceroplastes rubens* has but one generation a year. The oviposition occurs in May, June, July, or even in August. In Kyushu the hatching of the young individuals takes place continuously from about the middle of May to August, a period of about three months or more. Next, it is interesting to speculate on why *Anicetus ceroplastis* persists year after year in Kyushu. Experiments have shown that the parasite will oviposit in scales almost any stages of development except the youngest one which is still uncovered by wax. Thus adult parasites of the first generation must search for the scales that are adequate enough for oviposition, but those emerged comparatively later must have a period of waiting before oviposition until the new scale larvae become available. The longevity of *Anicetus ceroplastis* seems to be sufficient to enable them to bridge the gap between their emergence and the occurrence of scales of the new generation that are large enough for oviposition. With the appearance of the adequate host larvae (perhaps the middle or later part of July and the first part of August) adult *Anicetus ceroplastis* begins to parasitize. The irregularity of oviposition or growth in the part of *Ceroplastes rubens* appears to answer one of the main reasons for the success of *Anicetus ceroplastis* to maintain itself in early summer season. Adult parasites of the second generation can find the host larvae without difficulties, or the emergence of the parasites seems to coincide completely with the development of the new host scales.

LIBERATION OF *Anicetus ceroplastis*

Our previous report and the decrease in the population of *Ceroplastes rubens* in Kyushu stimulated the liberation and colonization of a Kyushuan race of *Anicetus ceroplastis* by many prefectural entomologists and some of the growers in Honshu and Shikoku. From 1948 to 1951 a number of *Ceroplastes rubens* harboured *Anicetus ceroplastis* were distributed from Kyushu to almost all the prefectures of Honshu and Shikoku where the damage of *Citrus*, *Diospyros* and *Thea* plants by this scale is severe, although it is, as yet, too early to estimate their value as controlling agents in those districts (Fig. 4).

In preparation for transportation, branches and twigs infested with parasitized or non-parasitized scales were cut into 10 to 20 cm. in length and loosely wrapped in paper so as to prevent rubbing. These were then loosely packed in heavy paper cartons

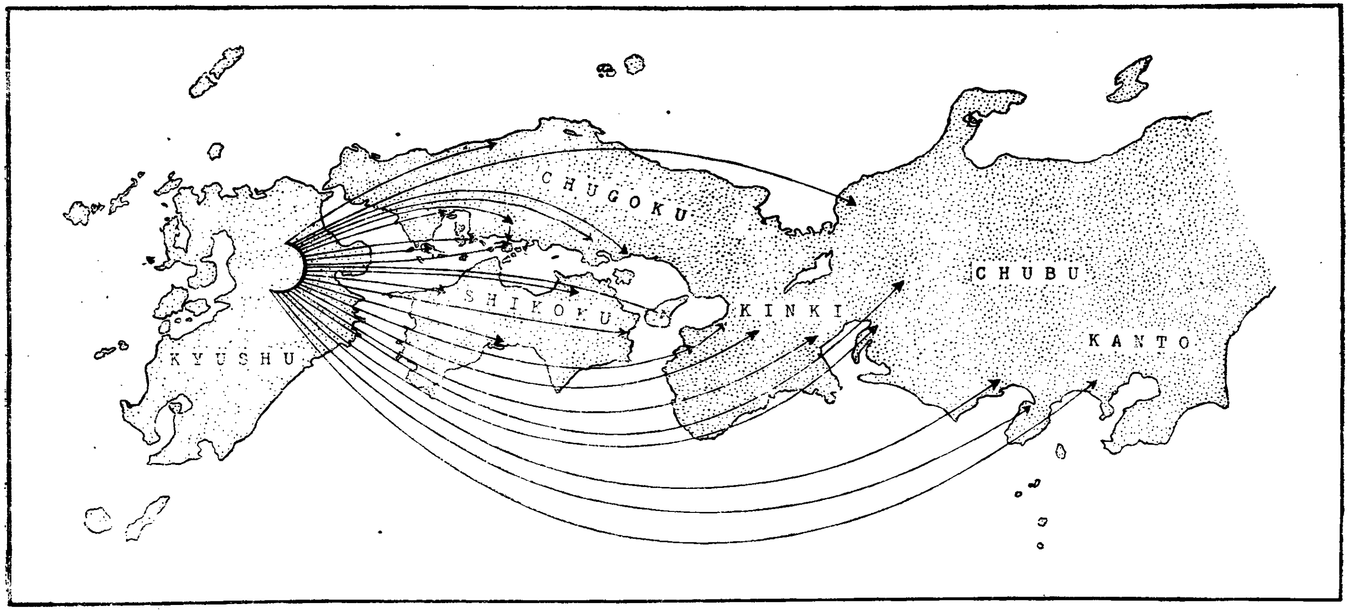

Fig. 4. The internal movement (1948—1951) of *Anicetus ceroplastis,* an Encytid parasite of *Ceroplastes rubens*, following its first liberation to Shizuoka Province in 1948.

or in wooden boxes, sealed, tightly wrapped, securely roped and sent to the stations by registered mail. Upon receiving the material, the twigs or branches were put into the glass vials so to await the emergence of adult parasites. Every day the parasites after emergence were transferred from the vials containing infested twigs to other vials and fed with diluted honey for several days before liberation.

In order to determine the effectiveness of *Anicetus ceroplastis* experimentally in orchards the parasites were introduced into Tsukumi district, Oita Prefecture, Kyushu. About 400 adults of *Anicetus ceroplastis* were liberated in two Citrus orchards in Tsukumi. Both sexes were liberated, but approximately one-half were females.

Colony 1 (Citrus orchard, Citrus Experiment Station).

Colonized 80 adult females on June 20, 1948. A few days after liberation a heavy storm occurred. Not a single adult parasite was recognizable after the storm, and all the parasites seemed to have been killed by the strong wind and heavy rain. Before liberation in 1948 *Anicetus ceroplastis* was not present. In the summer of 1950 I was astonished at the fact that the parasite had successfully established there and could find a number of adult females and males in the orchard. Recolonized in June, 1950, with about 200 females.

Colony 2 (Grower's Citrus orchard).

Colonized with 120 adult females on June 20, 1941. Several parasites were seen even after the heavy storm. Before liberation in 1948 *Anicetus ceroplastis* was not present. During subsequent years the parasites increased steadily. For the two years period of 1948—1949 it parasitized about 13 per cent of *Ceroplastes rubens*.

Thus in no case did the parasite colonies fail to establish themselves.

EFFECT OF SOME INSECTICIDES ON *Anicetus ceroplastis*

During recent years the problem of the effect of insecticides to the natural enemies has become more and more important. It is common knowledge that insecticides have a detrimental effect on the parasite-predator populations. In 1947 Dr. G. C. Ullyett classified the adverse effect of insecticides on parasites and predators as follows: a) direct destruction of the parasites or predators by the insecticide; b) destruction of hosts containing developing parasite progeny; c) a repellent effect of the insecticide which keep natural enemies away from the environment of the host; d) decrease in longevity and extent of oviposition by female parasites in sprayed crops; and e) reduction in parasitism and in the increase in predator populations due to decreased host density. Especially the period of newer synthetic organic compounds throw us many difficult problems in the field of biological control. For example the following authors discussed the direct effect of insecticides on parasite-predator population: Annand (1942), Boyce (1950), Clausen (1936), Collins (1934), Cox and Daniel (1935), Cox (1942), Daniel (1935), DeBach (1946, '47), Driggers and Peppers (1936), Ewart and DeBach (1947), Ewing and Evy (1943), Flanders (1942, '43), Gaines (1946), Griffiths and Stearns (1947), Griffiths and Thompson (1947), Griffiths and Fisher (1949), Haug and Peterson (1938), Henderson (1943), Hills (1934), Hodgkiss and Parrot (1914), Holloway and al. (1942), Hough and al. (1945), Hough (1946), Isley (1946), Iyatomi (1949, '51), Jancke (1935), Michelbacher and al. (1946), Myrburgh (1948), Nakayama (1936), Nel (1942), Newcomer and al. (1946), Newson and Smith (1949), Rings and Weaver (1948), Schread and Garman (1934), Smith and Fontenot (1942), Smith and Driggers (1944), Speyer (1936), Summerland and Steiner (1943), Toyoshima (1949), Tsutsui (1949), Walton and Whitehead (1944), Watson (1912), Wheeler and La Plante (1946), Woglum and al. (1947), Yothers and al. (1935), Yothers (1947). And the following cases were reported: HCN gas on *Cryptolaemus montrouzieri* (to control California red scale), tartar emetic on *Comperiella bifasciata* (yellow scale), sulphur dust on *Comperiella bifasciata* (yellow scale), sulphur dust on *Metaphycus helvolus* and *luteolus* (black scale and soft scale), lime-sulphur on parasites (San Jose scale), derris on *Hippodamia convergens*, calcium arsenate on Coccinellidae and Chrysopidae (cotton pests), BHC plus sulphur, Toxaphen plus sulphur or calcium arsenate plus nicotine on *Geocoris punctipes* and *Orius insidiosus* (cotton pests), dormant sprays on parasites (San Jose scale, etc.), kerosene emulsion on parasites (citrus blackfly), arsenical sprays on *Ascogaster carpocapsae* (codling moth), lead arsenate, lead arsenate plus lime, summer-oil emulsion or nicotine-bentonite on *Trichogramma* (codling moth), DDT on *Pseudaphycus* (Comstock mealy bug), Cryolite dust on *Cryptolaemus montrouzieri* (mealy bugs), DDT and rotenone on *Rodolia cardinalis* (cottony cushion scale), sulphur on *Trichogramma* (Oriental fruit moth), DDT and Ryanex on *Macrocentrus ancylivorus* (Oriental fruit moth), DDT and BHC on *Trichogramma japonicum* (rice stem borer, rice green caterpiller), nicotine sulphate, tar distillates, all tar oil preparations, DDT and BHC on *Aphelinus mali* (woolly apple-aphid), DDT on predators (citrus red mite), parathion on parasites (soft scale) DDT on parasites and predators (aphids).

There is little doubt that some insecticidal effects may be expected also in the case of *Anicetus ceroplastis*. In order to illustrate this point it seems necessary to show an example of our schedule for spraying *Citrus* in warmer seasons.

Major pests	Spray	When to apply spray
Phyllocnistis citrella	Nicotine sulphate or pyrethrin plus BHC	From the beginning of June to the end of August. Every other week.
Oxycetonia jucunda	BHC (spray or dust)	May.
Dialeurodes citri	Resin wash	June to August.
Unaspis yanonensis	Lime sulphur plus zinc sulphate or DDT (0.02—0.05%)	May to July.
Pulvinaria aurantii	Resin wash or DDT or BHC (0.05%)	June.
Ceroplastes rubens	Resin wash or DDT (0.02%)	July to August.
Dacus tsuneonis	DDT (0.05%) or BHC (0.04%)	From the end of July to the middle of August. Every other week. Three times.

For the control of *Kakivoria flavofasciata*, a serious pest of persimmon, the use of 2.5% DDT dust (carrier: bentonite or caoline) is said to be very effective.

During the years 1949, 1950 and 1951 studies were conducted with DDT, BHC and some other insecticides against *Anicetus ceroplastis* both in the laboratory and in the field. Of course the object of these experiments was to determine the adverse effect of insecticides to this parasite. The dosage of insecticides tested in the present investigation was adjusted or followed to our schedule for spraying citrus and persimmon trees. Therefore no effort was made to determine the minimum effective dosage for insecticides against adult *Anicetus ceroplastis*.

Table 4. Effect of various dust upon adult *Anicetus ceroplastis* (♂ ♀) exposed continuously (From 20 to 30 0–24 hours old unfed adults were used in each test) (9. vi. 1949, 21°C).

Dust	Test number	Down in 10 min. Per cent	Down in 2 hour Per cent	Kill in 24 hours Per cent
Bentonite	4	0	100	100
Spore of *Penicillium* sp.	3	0	100	100
DDT (5%)	5	100	100	100
BHC (0.5%)	5	100	100	100
Control	5	0	0	0

Table 5. Results from exposing *Anicetus ceroplastis* (♂ ♀) continuously to dry DDT and BHC residues obtained by evaporating spray mixture in which filter paper of 70 mm. in diameter was dipped. All residues were exposed to weathering for one day (From 20 to 30 0—24 hours old unfed adults were used in each test) (1. vi. 1950, 20°C).

	Test number	Down in 10 min. Per cent	Down in 2 hours Per cent	Kill in 24 hours Per cent
BHC water suspension (0.04%)	5	0	80	100
DDT water suspension (0.05%)	4	0	40	100
DDT water emulsion (0.05%)	4	0	68	100
Control	1	0	0	0

Table 6. Results from exposing *Anicetus ceroplastis* (♂ ♀) continuously to dry DDT and BHC residues obtained by evaporating spray mixture in which filter paper of 70 mm. in diameter was dipped. All residues were exposed to weathering for one day (From 20 to 30 0—24 hours old unfed adults were used in each test) (7. vi. 1950, 27°C).

	Test number	Kill in 24 hours Per cent	Kill in 48 hours Per cent
BHC water suspension (0.01%)	2	0	45
DDT water suspension (0.01%)	2	100	100
DDT water emulsion (0.01%)	2	100	100
Control	1	0	0

Table 7. Results from exposing *Anicetus ceroplastis* (♂ ♀) continuously to dry DDT and BHC residues obtained by evaporating spray mixture in which filter paper of 70 mm. in diameter was dipped. All residues were exposed to weathering for one day (From 20 to 30 13 days old adults were used in each test) (5. vii. 1950, 28°C).

	Test number	Down in 10 min. Per cent	Down in 1 hour Per cent	Kill in 3 hours Per cent
BHC water suspension (0.04%)	3	0	87	100
DDT water suspension (0.05%)	3	0	30	80
DDT water emulsion (0.05%)	3	0	74	100
Control	1	0	0	0

Table 8. Residual effect of BHC and DDT upon *Anicetus ceroplastis* (♂ ♀) exposed continuously (From 30 to 40 0—24 hours old unfed adults were used in each test. All residues were exposed to weathering for 10 days) (22. vi. 1949, 20.5°C).

	Test number	Down in 10 min. Per cent	Down in 1 hour Per cent	Killed in 3 hours Per cent	Killed in 5 hours Per cent
BHC water suspension (0.04%)	3	0	0	0	0
DDT water suspension (0.05%)	4	0	43	56	100
DDT water emulsion (0.05%)	4	0	75	88	100
Control	1	0	0	0	0

Table 9. Effect of some insecticide sprays upon *Anicetus ceroplastis* (♂ ♀) (From 20 to 30 four days old adults were used in each test) (10. vi. 1949, 22°C and 23. vi. 1951, 23°C).

		Test number	Kill in 6 hours Per cent
Resin wash (alkali 0.40%) Water	1 part 25 parts	2	100
Nicotine sulphate (nicotine 40%) Water	1 part 1000 parts	6	100
Lime sulphur Water	1 part 80 parts	3	100
Lime sulphur Water	1 part 100 parts	3	100
Control (water)		1	0

Parasites sprayed or dusted with DDT usually began to show definite reaction within 5 minutes. Within 6 minutes most of the parasites were down and on their back. Most of the parasites sprayed or dusted with BHC were down and on their back within 20 seconds. In both cases death usually occurred within 2 to 5 hours. On the other hand parasites dusted with bentonite or spore of *Penicillium* sp. crawled about for a long time and struggled to free themselves on their back for more than 10 hours. Death occurred within 24 hours though some lingered as long as 30 hours. Parasites sprayed with resin wash, nicotine sulphate or lime sulphur and exposed to direct wetting for a few second, dried on blotting paper and held in clean cages lives slightly longer but larger numbers were killed within 5 hours. Dried residues of DDT and BHC either on filter paper or on foliage were decidedly toxic to adult *Anicetus ceroplastis* contacting it. Tables 5—8 show the results obtained for residues containing DDT and BHC that had weathered for periods ranging from one to ten days. The residual effect of DDT lasted more than three weeks, while that of BHC lasted only for a few days. This toxicity was noted under field conditions by observing parasites that visited sprayed foliage. Examination shows that most of the lethal effects take place in the first 2 hours and is completed within 24 hours. About ten to twenty minutes exposure to DDT residue represented, in the present tests, on the parasites also a catastrophe. Results obtained from field spraying of resin wash, nicotine sulphate or lime sulphur were not quite the same as in the laboratory conditions since spraying usually disturbed the parasites and some flew away to avoid the spray. So far as my experiments go, foliage or branches which were sprayed with resin wash, nicotine sulphate or lime sulphur and dried had little or no effect on adult *Anicetus ceroplastis* which were exposed to the surface. From the experiments performed it became clear that insecticides have a detrimental effect on the production of *Anicetus ceroplastis* by repelling the host-searching females or by the destruction of the adult parasites and the application of insecticides for the control of other pests should be so timed that parasites of the scales are least affected. As mentioned before, parasites, *Anicetus ceroplastis*, thrive best when the scale is in all stages of development especially in early summer season and anything, for example spraying or dusting, that brings about an even-hatch condition of the scale has adverse effect upon the parasites, since existence of the scales of all stages of development (except for the youngest and full-grown individuals) is needed for the effective oviposition of the parasites. In this connection Dr. Flanders (1942) showed that in the case of *Metaphycus helvolus* (Compere) "insecticides tend to decrease the effectiveness of this parasite indirectly by bringing about an even-hatch condition of the host generations so that there is a lack of food for the parasites."

Next it is worthy of consideration that the elimination of one major pest by some insecticides has sometimes left the trees open to attack by another that may have been controlled by it. Dr. Ullyett (1947) discussed the problem on the increase of the associated pests by the elimination of major pests and wrote as follows:—"In many instances, the use of insecticides for the control of one insect pest of a crop has resulted in another pest, which may be normally of little importance, assuming epidemic proportions. Scale-control problems become more difficult each year in California and that a similar tendency is apparent in other countries." Such problems have been treated by the following authors—Gardner (1934), Gilliatt (1935), Driggers and Pepper (1936), Boyce (1936, '50), Osburn and Spencer (1938), Schoene (1938), Steiner (1938), Ingram and al. (1947), DeBach (1947), Ewart and DeBach (1947), Carter (1949), etc. For example Boyce (1950) wrote:—"Almost from the beginning of the use of DDT on agricultural crops, in 1944, 'side problems' resulting from an upset in the balance of certain parasite-host or predator-host relationships have been apparent. This generally striking effect has greatly stimulated interest in this question. Upsets in the natural balance which have been observed on Citrus in California from the use of DDT involve the following pests: cottony-cushion scale, citrus red mite, citrus mealybug and other mealybugs, California red scale, yellow scale, orange Tortrix, and several species of aphids; from use of sulphur: black scale and the citrus mealybug; and from the use of parathion: soft (brown) scale." Further the following example exhibited by Dr. Carter (1949) is of extreme interest:—"Dr. Carter exhibited a mango leaf heavily infested by this wax scale (*Ceroplastes rubens*). The tree had been given heavy applications of DDT about a year ago in an effort to combat *Dacus dorsalis*. The scale infestation on this particular tree is in striking contrast to untreated trees nearby which are relatively free from the scale." In Hawaii, *Ceroplastes rubens* has been known as a minor pest and this fact is apparently responsible to the activity of three Hymenopterous parasites, viz. *Aneristus ceroplastae* Howard, *Microterys kotinskyi* (Fullaway) and *Tomocera californica* Howard. In Japan the following close relationships exist among insect pests of major importance and their natural enemies in citrus orchard.

Major pests	Natural enemies
Unaspis yanonensis (Kawana)	*Chilocorus kuwanae* Silvestri
Aonidiella aurantii Maskell	*Comperiella bifasciata* Howard
Pulvinaria aurantii Cockerell	*Chilocorus kuwanae* Silvestri *Chilocorus rubidus* Hope
Ceroplastes rubens Maskell	*Anicetus ceroplastis* Ishii
Icerya purchasi Maskell	*Rodolia cardinalis* Mulsant
Aleurocanthus spiniferus Quaintance	*Prospaltella smithii* Silvestri

In Tsukumi District spraying of DDT or BHC has been recommended in recent years to control *Dacus tsuneonis* Miyake, a local major pest, or to prevent the oviposition of this fly in citrus orchard. The spraying is applied three times (every other week) from the end of July to the middle of August. Thus the residual effect of DDT may last until the beginning or middle of September, and not only a number of natural enemies listed above will be killed during this period but also many of the scales of major importance will increase prominently. Therefore the application of insecticides, especially those having residual effect, on trees infested with scales would be undesirable or must be so timed as to save the natural enemies until the parasites and predators establish themselves and natural control can become effective in citrus or some other orchards.

SOME PRACTICAL SUGGESTIONS ON THE LIBERATION OR COLONIZATION OF THE KEY PARASITE

Until we establish a method of successful mass production of both *Ceroplastes rubens* and *Anicetus ceroplastis*, it is desirable to collect twigs of various plants, such as *Fortunella* sp., *Citrus Unshu*, *Laurus nobilis*, *Ilex Oldhami*, *Ilex integra*, *Ilex latifolia*, *Eurya japonica montana*, etc., which are infested with *Ceroplastes rubens* in Kyushu, so as to emerge as many adult *Anicetus ceroplastis* as possible and then release only the parasites to any desired places in Honshu, Shikoku and Kyushu where this scale insect has been a serious pest for the past forty to fifty years. In this connection the liberation or colonization of a large number of parasites is of course the first essential. As mentioned before the scales harbour full-grown larvae and pupae of the parasite in

April or May. Therefore we may be able to expect almost 100 per cent emergence of the parasites from the scales collected in the middle or later part of the spring season. If we collect the twigs infested with scales in August or September, some parasite progeny may fail to complete the larval life and cannot reach the adult stage, since the parasites within the scales are in all stages of development in August or September. Consequently we shall run a risk of destroying some progeny of the parasite if we collect the twigs in Kyushu in the early part of the autumn. Next it is important to select the twigs infested with scales of comparatively small size (average length of the longitudinal axis of the wax covering being 2.5 mm. or less). The reason is that the scales parasitized by parasites in the autumn season cannot make normal growth as in sound scales. Thus scarcely any parasite may emerge from the scales of much larger size in the spring season.

As indicated before, orchard parasitization may be depressed following regular and thorough application of insecticides. Therefore, it must be emphasized that the orchard or the plants where parasites are liberated must be left unfumigated or unsprayed for a period of at least two or more years, irrespective of the existing scale populations, or the growers wishing to enjoy the advantage of natural control must actually encourage a certain degree of scale infestation over a period sufficient to enable the parasites to establish populations which take a position to control the pest in the future. On the other hand establishments of the parasites could best be done by liberating the parasites in non-commercial orchards or on some non-commercial plants near or surrounding the commercial orchards. Heavy infestation of plants by *Ceroplastes rubens* growing in other places than orchards may be responsible for the production of a large number of parasites. The parasites would thus become plentiful after parasitizing the scales and be ready to attack the scales of the commercial orchards. This method would well correspond with the principle of the so-called strip farming or croping. In addition to the above suggestion I am firmly convinced that in most, if not all, of the places where *Ceroplastes rubens* is making severe damage, the climatic condition is also favourable to *Anicetus ceroplastis*.

REVISED LIST OF THE HYMENOPTEROUS PARASITES OF *Ceroplastes rubens* MASKELL

Parasites	Localities	References
Anabrolepis bifasciata Ishii	Japan	Yasumatsu et Tachikawa (1949)
Anabrolepis extranea Timberlake	Japan	Yasumatsu et Tachikawa (1949)
Aneristus ceroplastae Howard	Hawaii	Timberlake (1918), Fullaway (1919)
	Fijii	Simmonds (1936)
Anicetus ceroplastis Ishii	Japan	Yasumatsu et Tachikawa (1949), Yasumatsu (corrected in this report)
Aphytis sp.	Japan	Yasumatsu et Tachikawa (1949)
Casca sp.	Japan	Yasumatsu et Tachikawa (1949)
Cerapteroceroides japonicus Ashmead	Japan	Ishii (1940)
Cheiloneurus ceroplastis Ishii	Japan	Ishii (1923, 1928, 1932, 1940), Kaburaki (1934)
Coccophagus hawaiiensis Timberlake	Japan	Ishii (1923, 1932, 1940), Kaburaki (1940), Yasumatsu et Tachikawa (1949)
Eupelmus sp.	Japan	Ishii (1932)
Eusemion sp.	China	Silvestri (1929)
Marietta sp.	Japan	Ishii (1940)
Metacerapterocerus fortunatus (Ishii)	Japan	Original record*
Microterys kotinskyi (Howard)	Hawaii	Fullaway (1918)
Microterys okitsuensis Compere	Japan	Yasumatsu et Tachikawa (1949)
Microterys speciosus Ishii	Japan	Ishii (1923, 1928, 1932, 1940), Kaburaki (1934), Yasumatsu et Tachikawa (1949)
Physcus atrithorax Girault	Australia	Girault (1939)
Quaylea whitieri (Girault)	Hawaii	Ishii (1940)
Tomocera californica Howard	Hawaii	Fullaway (1919), Smith et Compere (1928)
Tomocera ceroplastis Perkins	Hawaii	Fullaway (1919)

* 1♀, Kochi, Shikôku, 8. vi, 1950, reared by Mr. T. Yoshii, ex *Ceroplastes rubens.*

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