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Biology of the Formosan Subterranean Termite, Coptotermes Formosanus, Shiraki, With Primary Emphasis on Young Colony Development.

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BIOLOGY OF THE FORMOSAN SUBTERRANEAN TERMITE, *COPTOTERMES FORMOSANUS* SHIRAKI, WITH PRIMARY EMPHASIS ON YOUNG COLONY DEVELOPMENT

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ABSTRACT

Young colony development of Coptotermes formosanus Shiraki from paired, virgin, first-form reproductives was studied in the laboratory and under caged conditions in the field. Four oviposition periods were observed in the laboratory during the first 2.5 years of development. The fecundity of the female became greater at each subsequent oviposition period. Up to 4541 individuals were found in one 3.5 year old colony, and no nymphs were observed in colonies up to 3.5 years old.

There was a reduction in size of the male and female first-form reproductives during the first oviposition period, thereafter, the female increased in size.

The developmental rate and fecundity increased with temperature, however, colony survival was reduced at 32°C. The threshold temperature for embryonic development was lower than that for hatching.

Pairing was observed between males and between females. However, parthenogenesis did not occur.

Four larval instars were detected during the first oviposition period and a fifth formed at the beginning of the second oviposition period. Soldiers in the first oviposition period developed from second instar larvae. Soldiers of other oviposition periods developed primarily from later larval instars. Soldiers constituted about 10 percent of the colonies.

No oviposition in field colonies was observed in the winter during the first two years of development. Vertical movement by colony members through galleries from colder areas to warmer areas was observed in the field during the winter.

Soil moisture and temperature in the field cages did not differ greatly from that in adjacent uncaged areas.

In several mature colonies a greater number of males than females was found among alates. Mature colonies headed by second-form reproductives were found as frequently as those headed by first-form reproductives.

INTRODUCTION

The Formosan subterranean termite, Coptotermes formosanus Shiraki, was first discovered on the mainland of the USA in a shipyard in Houston, Texas, in 1965. However, it was believed to have been eradicated after the warehouse was fumigated with methyl bromide. It was again found in Houston in 1966, in the same shipyard, and a short time later in a shipyard in Galveston, Texas. It was discovered in New Orleans and Lake Charles, Louisiana, in 1966. In 1967 it was reported in Charleston, South Carolina, (Spink, 1967). Spink (1968) reported swarming of this termite in Raceland, Louisiana, (Personal Communication). Weesner (1968) reported swarming of this termite in a shipyard in Beaumont, Texas, (Personal Communication).

Species of Coptotermes are widely distributed throughout the tropical and subtropical regions of the world. Gay (1967) considered C. formosanus to be extremely destructive, and Weesner (1966) reported that species of the genus Coptotermes are considered the most economically important of all the termites.

Oshima (1919), Mori, et al. (1964) and Bess (1970) reported on the development of young colonies in the laboratory from paired virgin, first-form reproductives during the first oviposition period. In addition, Bess also sampled colonies at various times over a period of 4 years after establishment of these colonies in the laboratory in Hawaii. However, in none of these studies were the growth stages categorized nor were colony events followed closely. No published information was found on young colony development in the field for C. formosanus.

To obtain a better understanding of young colony development and the general biology of C. formosanus studies were initiated in the laboratory at Louisiana State University, in Baton Rouge in 1967 and in the field in New Orleans, Louisiana, in 1968. These studies were undertaken in order to develop rearing methods for C. formosanus in both the laboratory and field and to elucidate the patterns of individual and colony development. Pairing, the possibility of parthenogenesis, and the effects of various temperatures on young colony development were also studied. In addition, sex ratios of alates and the occurrence or reproductives in mature colonies were noted.

REVIEW OF LITERATURE

According to Abe (1937) the species, C. formosanus was first described from Formosa by Shiraki in 1909.

Snyder (1949) listed 42 species under the genus Coptotermes. Krishna (1966) reported that of those 42 species only C. formosanus extended its range into the warmer parts of the temperate regions. He further stated that it is native to China, Formosa and Japan, and has been introduced into Ceylon, Hawaii and other Pacific Islands and the southern coasts of North America.

Kofoid (1934), Abe (1937), Schimizu (1962) and Weesner (1970) stated that temperature is the main factor limiting dispersal of this termite. Abe (1937) stated that areas in Japan inhabited by C. formosanus had an average annual temperature of 15°C with the temperature of the coldest month in the winter averaging higher than 4°C. He also stated that the monthly average of the minimum day temperature had to be higher than 0°C. Hrdy (1965) reported that Lsai Pang-Hwa and Chen Ning-Sheng found that in China the northern boundary of distribution

for C. formosanus lies in a region where the isotherm totals 4500°C for the year and the annual rainfall totals about 1000 mm. Weesner (1970) stated that the U. S. Dept. of Agriculture Hardiness Map of 1960 showed that most of the gulf coastal area of the Nearctic has an average annual minimum temperature between -6.67 and -1.11°C. She concluded from this and Abe's data that the C. formosanus infestations in Texas, Louisiana and South Carolina appeared to be peripheral ones. Kofoid (1934) stated that the maximum summer temperature means along the California coast may not be high enough for this species to flourish.

There have been several reports that dealt with the biology of termites (Kofoid, et al. 1934; Snyder, 1948; Harris, 1961). These books provide good general information on termites, their social organization and control. More recently a modern, comprehensive review of the biology of termites has been published (Krishna and Weesner, 1969, 1970). Anatomical, physiological, biochemical, behavioral, and laboratory studies treated in these volumes are concerned primarily with taxonomy and general biology of the termites of the different zoogeographical regions.

It is apparent from the nature of the studies reported in this review: (1) That the biology of relatively few

species of termites has been studied; (2) That most of these studies have been conducted in the laboratory; (3) That much extrapolation of data has occurred; and (4) That these laboratory data have been used to make inferences on the biology of other species and to connote biological behavior of species in the field. Miller (1969) states that the intergration of findings upon different species, arrived at by various methods, is both hazardous and useful. Species differences may provide both contradictions and insights.

In all of these reports there appears to be a scarcity of reliable data concerning the genus Coptotermes. Therefore, information on other species related to this problem will be utilized.

Terminology: A number of individuals have advocated terminology based on the different forms found in termite colonies (Weesner, 1960, 1965; Buchli, 1958; Esenther, 1969; and Miller, 1969). Miller (1969) follows the terminology of European investigators and defines the different termite forms as follows: larva--an immature individual without any external signs of wing buds or of soldier morphology; nymph--an individual succeeding the larval stages and showing external wing buds; worker--a permanently sterile form, without visible differentiation toward alate or soldier,

which serves the colony in nutrition and construction; pseudergate--an individual that has regressed from nymphal stages by molts that reduce or eliminate wing buds or a form derived from a larva by undergoing "stationary" nondifferentiating molts; soldier--a form with defensive adaptations, such as enlarged mandibles or stopperlike heads and with the head heavily pigmented and sclerotized; presoldier--an intermediate developmental stage between larva, pseudergate or nymph with a definitive mature soldier form; first-form reproductive--the colony founding type derived from winged adult or alate; second-form reproductive--a functional male or female derived from a nymph and retaining, to some degree, wing buds; third-form reproductive--a functional male or female without evidence of wing buds, usually larval in external form but more or less pigmented. He further states that a replacement reproductive may be a second-or third-form functional reproductive which replaces or, in some species, supplements the first-form reproductives.

Foraging Galleries: Several authors have reported on the gallery systems of various species of the genus Coptotermes. (Ratcliffe and Greaves, 1940; Gay, 1946; Greaves, 1959; and Kalshoven, 1941). Erhorn (1934), Mori, et al. (1965).

King and Spink (1969) have reported on the gallerying and nesting habits of C. formosanus. In each of these reports there is some discussion of the biology of the respective species.

Young Colony Development in the Laboratory: The young colony has been defined by Nutting (1969) as a colony from the time of its establishment until it is capable of producing all castes characteristic of the species and capable of staging flights of winged reproductives. This phase of termite biology is known largely from laboratory observations on the early development of about two dozen species (Nutting, 1969). The following laboratory studies on species other than in the genus Coptotermes were reviewed due to their pertinence to this study: Cryptotermes brevis (Walker), (McMahan, 1962); Zootermopsis angusticollis (Hagen), (Castle, 1934); Reticulitermes lucifugus Rossi, (Buchli, 1950); R. hesperus Banks, (Weesner, 1956); R. hesperus, (Pickens, 1932); R. speratus (Kolbe), (Schimizu, 1963); R. flavipes (Kollar), (Snyder, 1932); R. hesperus, (Light and Weesner, 1955); Tenuirostritermes tenuirostris (Desneux), (Light and Weesner, 1955); and Odontotermes assmuthi (Holmgren), (Sen-Sarma, 1962).

There have been few reports on young colony development in the laboratory in the genus Coptotermes. Gay, et al. (1955) stated that some sort of flight was apparently necessary to trigger the mating and oviposition activities of termites. This was based on the observation that in the laboratory dealates persisted in colonies for variable periods without producing any eggs. Williams (1965) simulated field temperature in the laboratory for C. niger. The temperatures ranged between 24° to 36°C. Egg-laying began in about 7 days and the incubation period was about 27 days. The average number of individuals in 10 colonies after 16 weeks was 48. Oshima (1919) described some of the different forms found in C. formosanus colonies. He found that after mating female swarmers would lay 20 to 25 eggs over a period of five months after which deposition of eggs was discontinued until all the eggs of the first brood had hatched. Approximately 10 percent of the hatched individuals were soldiers. Mori, et al. (1964) reported that in C. formosanus the first deposition of eggs occurred 10 to 20 days after swarming and that egg laying continued until about 20 eggs were deposited. Roonwal (1970) gave information on C. formosanus young colony development, but this was apparently taken from Oshima (1919). Bess (1970) observed

colonies of C. formosanus in the laboratory for four years. He found that about 30 eggs were laid during the first 50 days of colony development and that 40 individuals were present after 1 year, 250 after 2 years, 1250 after 3 years, and over 5000 after 4 years in the more successful colonies. This apparently was based on infrequent sampling where only counts of individuals were made.

Culture Methods: A variety of culture methods have been utilized in the laboratory. No synthetic diet has yet been formulated. All diets for the lower termites consist of some naturally occurring cellulose product. Becker (1969) reviewed the different rearing methods for termites. The following studies were reviewed due to their pertinence to this study. Pickens (1932) in culturing R. hesperus used a rounded glass vessel 2½ in. by 5 to 6 in. as a container. Fungus-browned wood was placed at the bottom and covered with sand. Adobe clay covered the sand and more sand was placed over the clay. Snyder and Popenoe (1932) set up pairs of R. flavipes in tin covered boxes containing moist sand, white pine wood and several disks of specially washed pure cellulose filter paper. Pence (1957) described moisture gradient tubes for the prolonged maintenance of subterranean

termites. Gay, et al. (1955) used ground carton material with water as a substrate with different woods as food. The carton to water ratio differed with the species: 90 ml water: 120 gm dry carton for C. lacteus and C. acinaciformis. (Ratcliffe, et al. (1952) defined carton as material utilized in nest and gallery building consisting of soil and masticated wood that has been cemented together by saliva and excrement of the termites). Williams (1965) reported that C. niger developed best on sapwood of Pinus caribaea Morelet when compared with the heartwood, rotten heartwood and soil medium. For permanent observation of young colonies culturing between glass plates was advocated (Adamson, 1941; Luscher, 1949). The glass plates were separated by glass rods about equal to the height of the termites and sealed with paraffin wax. Cotton wool was used as a moisture reservoir; the moisture reservoir was separated from the sand and wood by glass wool. Oshima (1919) successfully reared young colonies of C. formosanus for 5 months in test tubes, 2 by 16 cm, which had a hole in the bottom covered with cotton. Crushed clay was layered on top of the cotton and wood or cotton was placed on top of the clay for food. The end of the test tube was placed in water thereby maintaining a constant high humidity within the tube. Light and Weesner (1947) reported the use

of an agar and wood mixture in 1 oz. jars for small colonies. Agar at 3 and 4.5 percent was mixed with wood sawdust.

Becker (1969) reported that suitable wood species are essential for successful breeding and testing and that attack of wood by fungi is of value to the termites. Light and Weesner (1947) stated that slight deterioration by fungal action increased the nutritional value. Some fungi such as the white rot fungi were reported as toxic (Becker, 1969). Collembola in a culture were reported as a useful means of control of fungi (Becker, 1969). The addition of antibiotics to the culture media seemed to be of little or no value (Light and Weesner, 1947; Becker, 1969).

Wood Preference: Martin (1968) found the block of southern "yellow" pine (Pinus spp.) one of the more preferred woods of C. formosanus. Strother (1970) showed that blocks of sapwood of Loblolly pine (Pinus taeda L.) were significantly more heavily fed on and the weight of the termite colony was significantly heavier when compared to all other species of timber tested. Smythe and Carter (1970a) showed that blocks of slash pine (Pinus elliotti Engelm. var. elliottii) and Loblolly pine was preferred by C. formosanus while Smythe and Carter (1970b) showed that freshly ground sawdust from

these 2 species was not preferred by C. formosanus. Becker (1969) stated that pinewood can show a repellent effect, which disappears after leaching with water.

Temperature and Moisture: Few studies have been conducted to obtain the optimum temperature and humidity for the different termite species. Becker (1969) reports that, for wood consumption and probably for other activities of larvae and workers, the optimum temperature may be higher than that for a developing young colony or for egg production, and he advised use of a somewhat lower temperature for breeding termites. He further indicated that a high relative humidity was particularly important to young developing colonies since termites produce their own microclimate in the colony nest. Their ability to do this is related to size of the colony. The most favorable temperature for culturing Coptotermes spp. was listed as between 26° and 30°C (Becker, 1965). Gay, et al. (1955) reported for C. lacteus that the best conditions for testing purposes was 26°C and 75 percent relative humidity. Smythe and Carter (1970a) reported that 27°C approximated the optimum for both survival and wood consumption for colony segments of C. formosanus.

Swarming and Postflight Behavior: C. formosanus in Louisiana has been observed to swarm beginning the last of April and extending through the first part of June. It is crepuscular in its flight habits and swarms in the evening (King and Spink, Unpublished Data). Abe (1937) reported that when C. formosanus swarms it needs an atmosphere containing at least 95 percent of moisture.

After swarming the male and female pair and seek out a favorable nesting area where copulation takes place. Stuart (1969) states that pairing takes place only after dealation. Williams (1959) suggested the possibility that a pheromone may be released by the female which promotes dealation. Moore (1969) stated that short range sex attractants appear to be involved in the establishment of tandem pairs between newly dealated imagoes after swarming. The male makes sweeping searching movements while the female raises the tip of the abdomen in an apparent "calling" attitude until contact is made. This "calling" attitude has been observed in R. flavipes and R. lucifugus but not in Zootermopsis (Stuart, 1969). He further states that the male is attracted to the female by the "calling" attitude but thereafter the stimulus was mainly tactile. Stuart (1969) states that the tandem behavior is to ensure that the

sexes pair and the fact that only males follow females has probably evolved for the reason that two females founding a nest would be biologically uneconomical. Stuart further stated that males in absence of the female still form chains. The females, on the other hand, do not form chains. Williams (1965) concluded that in C. niger pairing took place only in the presence of a potential nest site. Oshima (1919) reported that in C. formosanus the male is attracted to the female and "followed her tirelessly and closely."

Instar Determination: Pickens (1932) stated that the head width was the only reliable index for study of instar increase. Since overlapping of instars occurred in a series of several colonies he suggested that the only reliable method was to check each colony with a scale of measurements suitable to the particular form and to measure individual heads daily to check on their growth. Dyar (1890) found that in lepidopterous larvae, the head width size progressed geometrically with increase in instars. Hare (1934) divided individuals of R. arenincola Goellner on the basis of antennal structure, wing pad development and structural measurement. Fuller (1920) stated "that the third antennal segment of termites was the formative zone and segments are

budded from this point." He stated that this segment was a capsule containing a series of variously developed segments which arise by a process of proliferation. Chapman (1969) stated that since there were no muscles in the flagellum of Pterygota insects the use of the term "segment" should be avoided. Buchli (1958) stated that the number of antennal segments and the head width was static within stadia. In the nymphs, the length of antennae, tibia and wing pads were good criteria for determining instars and that head width and thoracic plate size were too variable. He further stated it was better to follow the development in a single colony rather than several colonies. The number of antennal segments is closely correlated with instar development and increases as growth progresses (G. R. Esenther, Personal Communication; R. V. Smythe, Personal Communication). Oshima (1919) described several forms in C. formosanus colonies. Descriptions of the "worker," soldier and adult are also given in Anonymous (1966). Marking of individuals with paint for the purpose of identification has been used (Luscher, 1952a, 1952b; R. V. Smythe, Personal Communication; Weesner, 1956). Buchli (1958) marked termites by a partial amputation of an antenna or leg.

Caste Differentiation: A number of authors have worked on caste differentiation in termites. The following papers pertinent to this study were reviewed: (Hare, 1934; Miller, 1942, 1968, 1969; Luscher, 1960, 1961; Stuart, 1969; Light, 1942, 1944; and Wigglesworth, 1965). Miller (1969) stated that the factors that regulate castes in Kalotermes flavicollis seem to operate at three levels: (1) environmental, acting on the colony as a whole; (2) social (pheromones), acting among individuals; and (3) individual (hormones), acting within the individual. The pheromones according to Luscher act via the endocrine system and inhibit the secretion by the brain neurosecretory cells. In the absence of pheromones, the neurosecretory cells produce a hormone which activates the prothoracic glands which then produce a hormone that induces the insect to molt. The result of this molt depends in part on the existing stage of development and in part on the timing of the molt relative to the secretory cycle of the corpora allata.

Luscher (1961) showed that the production of male and female replacement reproductives is mediated by specific pheromones. It can be concluded from Miller (1969) that most of the species included in the Lower Termites readily produce replacement reproductives when separated from a

pheromone producing reproductive. Light (1944), working with Z. angusticollis, proved that the pheromone for inhibition is produced somewhere in the head or thorax. Shimizu (1963) found that replacement reproductives could develop from larva-workers and nymphs in R. speratus. Hrdy (1961) found that R. clypeatus Lash and R. lucifugus would produce replacement reproductives, however, R. clypeatus had a greater capacity than did R. lucifugus. Miller (1942) reported that in P. simplex, replacement reproductives were produced, but in small experimental colonies many were later eliminated.

There are several reports on the production of replacement reproductives in the genus Coptotermes. Gay, et al. (1955) reported that they were uncommon in C. acinaciformis and C. lacteus in Australia. Williams (1965) concluded that replacement reproductives were not readily produced by C. niger. Becker (1969) reported that the genus Coptotermes seldom or never produce replacement reproductives. Roonwal (1970) reported that replacement reproductives are commonly produced in C. curvignathus (Holmgren). Replacement reproductives production in C. formosanus has been reported by the following authors: Keck, 1954; Lang Chuh and Li Shen, 1960; National Pest Control Association, 1966; Beal,

1967; Bess, 1970; King and Spink, 1969; and Oshima, 1919. Oshima (1919) stated that supplementary reproductives were rarely found in C. formosanus. Keck (1954) reported the finding of 137 replacement reproductives in one carton nest.

Gay, et al. (1955) reported the finding of pigmented nymphs in C. lacteus colonies. He believed that these were incipient replacement reproductives. Gay and Calaby (1970) reported that pigmented nymphs with a superficial resemblance to replacement reproductives were found occasionally in colonies of C. frenchi and C. lacteus (Froggatt). There was no evidence to suggest that they were functional. Snyder (1948) reported that in mature colonies of Reticulitermes large numbers of nymphs with short wing pads were produced each year. The brachypterous forms were more active than the macropterous nymphs. Esenther (1969) stated that the pigmented nymphs represented the replacement line of development rather than the winged line and that these potential replacements may be similar to ant gynes (a nonsocially functional reproductive) as described by Brian (1957). Skaife (1955) reported pigmented nymphs found in Amitermes atlanticus Fuller and stated that if the functional reproductives are removed and an abundance of food is present then these become functional reproductives. Hrdy (1965)

described pigmented nymphs found in mature colonies of C. formosanus and called them nonfunctional reproductives. Chapman (1969) reported that in Gryllus campestris, short wings were the result of a slight predominance of the juvenile hormone in the later stages. Roy-Noel (1967) described 2 different form replacement reproductives which he observed in C. intermedius Silvestri. He stated that they were of fawn coloration and had black eyes which were similar to those of the imagoes. He also presented illustrations of three forms. It appears from his description that these are similar to the pigmented nymphs described in other species.

Luscher (1961) states that in K. flavicollis pre-soldiers can arise from larval stages, pseudergates and nymphal stages. It is apparent that for any given species there is a relatively constant soldier ratio (Luscher, 1961; Light, 1942; Miller, 1942). Luscher (1960) states that in K. flavicollis soldier differentiation is caused by a gonadotropic hormone produced by the corpora allata. He stated that it was possible since soldiers in the field are produced in large numbers when nymphs molt into adults that they had picked up the gonadotropic hormone from the excreta produced by the nymphs. Further the first soldier in a

young colony was the result of gonadotropic hormone in the excreta of the parents. Luscher (1961) states that in K. flavicollis soldier regulation is much slower and very often does not occur in laboratory colonies. Moore (1969) stated that soldier production is likely mediated by pheromones. Gay and Calaby (1970) reported that soldiers make up 2 to 3 percent of the individuals in a colony of C. lacteus. Oshima (1919) reported that soldiers make up about 10 percent of the individuals in a young colony of C. formosanus after about 5 months of growth. Nakajima, et al. (1964) stated that in natural field colonies of C. formosanus the soldiers make up 5 percent of the colony; under cage feeding conditions the percentage was higher, ranging from 20 to 60 percent in the feeding area. Roonwal (1959) reported that soldiers made up 33 percent of one colony of C. heimi (Wasm.).

Wigglesworth (1965) stated that since young termites do not produce winged forms their production may be inhibited by pheromones from the first-form reproductives. Others have stated that this is likely due to nutrition (Luscher, 1960, 1961; Buchli, 1958). Luscher (1960, 1961) reported that in the presence of abundant food, juvenile hormone production is reduced and this leads to alate production in

K. flavicollis. Snyder (1948) stated that at time of swarming the sexes are represented in equal numbers. Buchli (1958) reported an unequal sex ratio among alates of R. lucifugus from a locality in France. Sands (1965) reported a prevalence of females among the alates of five species of Trinervitermes in Nigeria. He ascribed selective value to this occurrence, since the females have a static calling behavior and may thus be more susceptible to predation than the wandering males. Miller (1968) stated that alates do not usually appear except in natural colonies of larger size. This implies an optimum social and nutritive environment. A large colony also introduces the possibility of effective distance of some of the population from inhibiting hormone sources or a dilution below some critical threshold. Bess (1970) stated that alates did not develop in laboratory colonies of C. formosanus 1 to 5 years old or in field collected colonies containing productive queens which were transferred to the laboratory.

Young Colony Development in the Field: There is a scarcity of published information on young colony development in the field for termites in general and no published information on young colony development in the field for C. formosanus

was found. Snyder (1915) observed the development of Leucotermes (Reticulitermes) flavipes. He built a cage which consisted of a large metal box sunk into the ground and covered with wire. He found that mating took place after the construction of a cavity in the soil and that the first brood consisted of about 6 to 12 members which were of smaller size than the normal form. These conclusions were made on a few observations. Pickens (1932) infested wood blocks in the field with R. hesperus but gave little data on their development. Brook (1965) placed pine blocks in the field on the premise that they would later be infested by swarmers of R. flavipes. However, his data on development does not agree with that presented by Snyder and Pickens. It appears that the blocks were infested by nearby mature colonies and were therefore feeding stations and not young developing colonies. Williams (1965) observed that large pieces of litter or stumps were the normal site in which colony foundation took place in C. niger. Gay and Calaby (1970) observed colony development in the field by C. lacteus. Colonies were founded most commonly beneath logs or at the base of stumps. The initial growth rate was slow and colonies three years old seldom contained more than 200 to 300 individuals. It appeared to require 1 to 3 decades

for a colony to reach mature size. Oshima (1919) stated that C. formosanus pairs enter pieces of decaying wood, or holes and crevices in wood or directly into the earth to establish new colonies.

Parthenogenesis: Weesner (1969) stated that parthenogenesis is known to occur readily in a few termite species. Light (1944) obtained female offspring from both virgin, pigmented nymphs and first-form reproductives in Z. angusticollis. Weesner (1956) reported that R. hesperus virgin females could lay eggs. However, few of these eggs hatched. Buchli (1950) reported that "eggs laid by R. lucifugus virgin females degenerated without hatching."

METHODS AND MATERIALS

The terminology advocated by Miller (1969) to define the different termite forms will be used in this study.

Throughout the subsequent discussion the term source colony refers to a mature field colony from which alates were obtained. A designated "series" of colonies includes all cultures established during a given year. A unit of colonies within a given series is distinguished by a separate source colony and/or by different culture conditions.

The alates utilized for establishing the laboratory colonies were obtained in Lake Charles, West Lake and New Orleans, Louisiana. The areas from which alates for the different series and units were obtained are listed in Table I.

Alates were collected from nests after the swarming season had begun. No alates from nests containing callow adults were used in these tests. Wood containing mature alates was cut transversely into blocks about 2 ft in length. The blocks were then carefully split longitudinally and the alates present were shaken into plastic boxes containing

moistened paper toweling by tapping the end of each block. Several methods of transporting adults to the laboratory were used. These, with methods of pairing adults, are described later with individual series and/or units.

Laboratory Studies

All pairs of adults, with the exception of Units B and C in Series Cf-67L, were first established in a modified culture medium similar to that developed by Light and Weesner (1947). The wood ingredient of the medium was sawdust from Pinus spp. dried and heated at a temperature of 105° to 110°C for 48 hours. Wood chunks were removed by sifting through a 16 mesh screen and fine dust by sifting through a 196 mesh screen. Two and eight tenths gm of this sawdust was placed in a 1 oz. jar (3.5 cm in depth and 3.5 cm in diameter). Nine ml. of 3 percent warm agar was added at a temperature low enough to prevent extensive absorption by the particles of wood, yet high enough to allow complete mixing with the sawdust. Once the agar was thoroughly mixed with the sawdust, the mixture was pressed down and leveled. The sawdust-agar mixture was allowed to cool in uncapped jars to prevent condensation. After cooling, 4 to 5 ml. of 4.5 percent agar was added at a

temperature just warm enough to pour in order to form an agar cap over the medium. Following solidification of the agar cap a hole about 1/8 in. in diameter was punched adjacent to the side of the jar, through the agar cap and agar-sawdust mixture. This served as an entrance for the paired first-form reproductives and ensured development of the copularium adjacent to the glass side of the jar for observation. To prevent excessive development of micro-organisms the jars were cleaned and heated at 160°C for 24 hours. Various concentrations of methyl-p-hydroxybenzoate were utilized to further reduce microorganism development in the cultures.

Samples were taken at predetermined intervals in each of the laboratory series and their respective units. Instar determination and caste differentiation were based only on characters that were distinct and easily observed and all data were based on averages for a number of individuals from different colonies. Measurement data for all stages and/or forms, other than eggs and first-form reproductives, were obtained from specimens killed and preserved in 70 percent ethyl alcohol. These data were obtained with the aid of an ocular micrometer and consisted of the following: body lengths and widths of head capsule, pronotum and

Table I. Sources of alates utilized for culture groups.

Series	Unit	Date of Collection	General Location	Substrate[a]
Cf-67L	A	May 18, 1967	Westlake, La.	bald cypress
	B	May 18, 1967	Westlake, La.	bald cypress
	C	June 14, 1967	Lake Charles, La.	bald cypress
Cf-68L	A	May 16, 1968	New Orleans, La.	southern "yellow" pine
Cf-70L	A	May 27, 1970	New Orleans, La.	weeping willow
	B	May 8, 1970	New Orleans, La.	southern "yellow" pine
	C	May 8, 1970	New Orleans, La.	southern "yellow" pine
	D	May 8, 1970	New Orleans, La.	southern "yellow" pine
	E	-		
		Field Studies		
Cf-68F	A	May 16, 1968	New Orleans, La.	southern "yellow" pine
Cf-69F	A	May 31, 1969	New Orleans, La.	southern "yellow" pine
Cf-70F	A	May 8, 1970	New Orleans, La.	southern "yellow" pine
	B	May 8, 1970	New Orleans, La.	southern "yellow" pine

[a] Bald cypress, *Taxodium distichum* (L.) Rich.; southern "yellow" pine, *Pinus* spp.; and weeping willow, *Salix babylonica* L.

mesonotum. In addition, the number of antennal segments possessed by different individuals was recorded by counting all visible annulations. These segments were numbered consecutively from the base of the antenna (1, 2, etc.) with the flagellum labeled as originating on antennal segment 3. Antennal segments that lacked visible hair rings were termed "bare." The length and greatest width were measured on unpreserved eggs at various stages of development. Measurements were obtained on live first-form reproductives by measuring the total length of the body and its width at the fifth sternite.

Series Cf-67L: This series consisted of three units: Units A, B and C. Dr. William T. Spink, H. Gross and D. J. Martin prepared the culture medium, paired the termites and introduced them to the culture jars in Units A and B. Unit C was initiated at a different time and is discussed separately.

Units A and B: Unit A differed from Unit B in the culture medium that was used. The other methods and procedures were the same.

The alates were transported to the laboratory from Lake Charles in plastic boxes on moistened paper toweling.

They were anesthetized with CO_2 and sexed by examining the abdominal sternites with the aid of a stereoscopic microscope. They were paired by introducing a male and female into each 1 oz. jar containing the culture medium with the aid of an aspirator.

Unit A consisted of a modified culture medium similar to that described by Light and Weesner (1947). The agar consisted of 0.225 percent methyl-p-hydroxybenzoate. The culture medium in Unit B consisted of 2.8 gm of sawdust and 8 ml of distilled water per jar. Two-hundred pairs of first-form reproductives were placed in each unit.

The rearing room was maintained at a constant temperature of $26\pm2^{o}C$. No effort was made to control photoperiod or the relative humidity. The glass jars were kept in a steel-lined rearing cabinet.

Four live pairs of termites were inspected at 14 day intervals beginning 23 days after pairing. Total counts were taken on each colony and individuals were classified as to developmental stage, i.e., egg, larva, presoldier, soldier and first-form reproductive. Additional information was obtained on some of the larval instars and their activity during the development of the colony. This schedule was followed for 245 days after pairing. From 259 days to 319

days after pairing, colonies that had been examined and then re-established in pint Mason jars containing sawdust with 2 parts water during the first 177 days after pairing, were checked at 14 day intervals. The caps were removed from the remaining jars and these were placed in 1 gallon jars containing sawdust with 2 parts water (See Plate I). Some of the colonies were sampled after 3 years development and others were taken to the field and placed in cages on April 18, 1970. These colonies are being continued in the field and laboratory in an attempt to obtain information on alate production.

Unit C: This unit was established to determine the optimum moisture content of the sawdust for survival and reproduction. Ten pairs were established at each of the following moisture contents: 0.66, 1.33, 2.00 and 2.66 parts water to 1 part sawdust (parts equal grams). The termites were allowed to dealate and pair in a pan. The pairs were picked up with an aspirator and introduced into the jars. All colonies were checked 90 days after pairing and the number of colonies surviving and the number of individuals per live colony was recorded. The moisture level in which survival and reproduction was greatest was utilized in subsequent tests where sawdust-water was used as a medium.

Plate I. Containers with media, which were utilized in rearing young colonies of C. formosanus in the laboratory. (Photographed by author)

Series Cf-68L: One unit was established in this series. The culture medium was similar to that described by Light and Weesner (1947). The agar consisted of 0.09 percent methyl-p-hydroxybenzoate. Colonies were maintained in environmental cabinets kept at a constant temperature of $26 \pm .5^{\circ}C$, about 80 percent relative humidity and continuous darkness. The relative humidity was maintained by keeping open pans of water in the cabinets.

Alates used in this series were collected from timbers in a building in New Orleans. They were transported to Baton Rouge in plastic boxes containing moistened paper toweling. They were kept in a room maintained at $15.6^{\circ}C$ until after they were sexed. The males and females were mechanically dealated by clipping their wings with scissors or breaking the wings at the basal suture, and placed in separate trays.

A male and female was introduced into each of 1297 1 oz. jars by picking it up on a small piece of cardboard and then shaking it off into the jar.

Four jars containing live colonies were removed at random and inspected at 14 day intervals beginning 28 days after pairing. The sampling intervals were extended to 30 days, 438 days after pairing and the sample number was

reduced to 2 colonies 687 days after pairing. In March, 1969 (about 270 days after pairing) the lids to the 1 oz. jars containing live colonies were removed and these jars were buried in sawdust in pint Mason jars (See Plate I).

After the colonies were transferred to pint jars it became increasingly difficult to remove them from the medium. This difficulty was decreased by placing them in a refrigerator maintained at about 7.5°C for several hours prior to sampling. This caused most of the termites to congregate in the nursery area where they could be easily removed.

The colonies were observed several times daily during the first few weeks to determine the time at which copulation occurred, when oviposition began, and other general behavior patterns. When the colonies were examined the termites were removed and placed in 70 percent ethyl alcohol. The different individuals were examined and classified to the following stages of development: egg, first through sixth instar larva, presoldier, soldier, and male or female first-form reproductive. Measurements were taken on the first-form reproductives at each sampling date and compared to measurements taken on virgin first-form reproductives to determine changes in size.

Series Cf-70L: Unit A: Twenty-five colonies were established at each of 4 temperature regimes: 16°C, 21.5°C, 26°C and 32°C. The termites were paired by using the same procedures discussed for Series Cf-68L, except that they were deactivated by placing the pan containing the termites into another pan containing ice water and methyl-p-hydroxybenzoate was not used in the culture medium.

The following criteria were used to determine their response to the 4 temperature regimes: length of preoviposition period; incubation period; developmental stages; total number of individuals found in the colonies 90 days after pairing; and number of colonies found surviving. Various other observations were taken on the colonies.

Pairing: Pairing was observed between virgin first-form reproductives in the laboratory. Male and female reproductives were confined together and separately in petri dishes. In some cases they were mechanically dealated and in others the wings were left intact.

Parthenogenesis: The possibility of parthenogenesis was evaluated by placing virgin females in 1 oz. jars containing the culture medium. The medium and method of handling of the termites were as in Unit A of Series Cf-70L.

A single female was introduced into each of 25 culture jars and two females were introduced into each of 25 other jars. The termites were observed to determine survival, egg laying, egg development and general behavior patterns.

Unit C: Twenty-five pairs were established at each of 2 concentrations of methyl-p-hydroxybenzoate treated agar: 0.09 and 0.225 percent. A third series of 25 pairs was placed in untreated agar. The objective was to determine if methyl-p-hydroxybenzoate at these rates could affect colony development and/or survival. The methods and materials were the same as in Unit A.

Observations were taken on the colonies to determine the length of the preoviposition period and the incubation time. In addition, 5 live colonies were removed at random from each treatment at 65, 86 and 96 days after pairing. Individuals present in each colony were classified as to developmental stage and the over-all survival of the colonies was determined. An analysis of variance using a randomized block design was run on the total number of termites present in the colonies at each sampling date. Also, an analysis of variance using a completely randomized design was run on days after pairing before oviposition began and the number

of termites in the third instar or a later developmental stage 96 days after pairing. These stages of development in the latter test were used as an index to developmental rate.

Unit D: A culture method described by Luscher (1949) was used in an attempt to better observe young colony development. The objective was to establish stadium lengths and confirm the different instars.

Glass tubing, 2 mm in diameter, was glued to the perimeters of a 9 by 12 cm washed photographic plate. Another piece of glass tubing was laid across one end of the plate so that 2 chambers were constructed; a large chamber, 8 cm by 9 cm, served as the nest chamber and a small chamber, 8 cm by 2 cm served as a moisture source. The nest chamber was filled about 1/3 full with sand and the moisture chamber was filled with cellu-cotton. A small break was made in the tubing separating the two chambers and this hole was filled with glass wool. Once water was added to the cellu-cotton it was drawn by capillarity through the glass wool into the sand of the nest chamber. Two pieces of aged southern "yellow" pine wood were stuck into the sand to serve as a food source. Moisture was added when needed as indicated by the drying of the sand.

Both the nest chamber and moisture chamber were covered with 4-76 by 26 mm microscope slides after the introduction of the male and female first-form reproductives. The slides were fixed to the glass tubing and to each other with paraffin wax. The colonies were kept in environmental cabinets maintained at $26\pm0.5^{\circ}C$. Daily observations were made on these colonies throughout the test period.

Unit E: Young colonies were placed in petri dishes on moistened circular discs of paper toweling. These colonies had been maintained in 1 oz. jars on the sawdust-agar culture medium for about 60 days after pairing prior to the introduction into the petri dishes. The paper toweling served as a substrate, food source and moisture reservoir. The petri dishes with termites were kept in desiccators partially filled with water. The colonies were maintained at $26\pm0.5^{\circ}C$.

When the termites were removed from the 1 oz. jars and transferred to the petri dishes, all developmental stages were classified. The different developmental stages were marked with different colors of Testors® paint by placing a small drop on the head and/or abdomen. When the termites molted and lost the spot they could be identified from the other termites that had paint marks. In this way, stadium lengths were determined and instars confirmed.

In addition to termites from the 1 oz. jars, termites were removed from older colonies and their development was also traced.

Young Colony Development in the Field

Series Cf-68F: Young colonies were reared in cages. Each cage consisted of a 20 gallon galvanized metal garbage can (See Plate II). Aluminum screen[a] with 30 squares per linear inch was attached to the cage with epoxy glue[b] over a 1/2 sq ft hole, which had been sawed in the bottom of the cage. Nylon screen with 32 squares per linear inch was used to cover the top of the cage. The can lid, with a circular hole 1 ft in diameter cut in it, was used to hold the nylon screen in place.

The screen served to confine the termites within the cage and to prevent entry of similar sized and larger animals. It also permitted entry of precipitation and movement of moisture in the soil within the cage. The inside surface of the cage was painted with epoxy paint and the outside surface was painted with DeRusto paint.[c]

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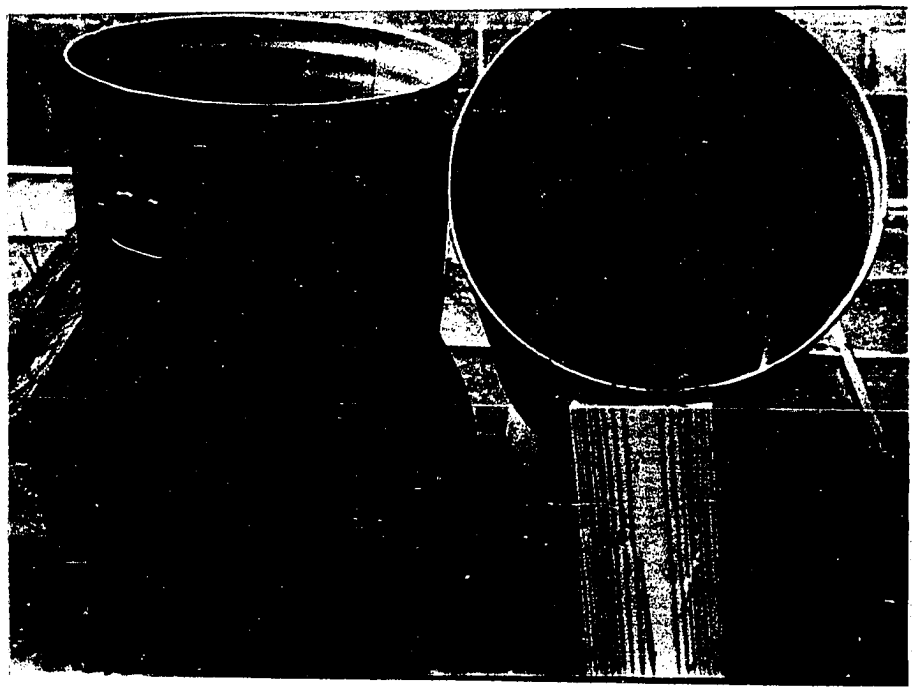
[a]Ludlow-Saylor Wire Cloth Division

[b]Products Research and Chemical Corp.

[c]Master Bronze Powder Co., Inc.

Plate II. (a) Cage utilized in rearing young colonies of C. formosanus in the field (b) Study area in New Orleans, Louisiana, in which cages were inbedded. Note white stakes that mark cage positions. (Photographed by W. T. Spink)



a

b

These cages were imbedded in the ground with the tops positioned at the soil surface level and then filled with soil. Two to 3 in. of soil, which had been sifted to remove the shale, was placed in the bottom of the hole before the cage was imbedded. Each cage was placed in the hole and twisted until soil could be seen coming through the screen. Two to 3 in. of sifted soil was placed in the bottom of the cage to assure soil contact between the inside and the outside of the cage. Soil that had been removed prior to the placement of the cage was used to fill in and around the cage. The top soil that had been removed was replaced in the original position.

The study area was on the Louisiana State University campus near the east bank of Lake Ponchartrain in New Orleans (See Plate II). The soil consisted primarily of sand and some shale and was relatively the same throughout the area. Pockets of clay were found throughout the area. The soil on the east part of the plot contained more shale than that on the west part of the plot. The soil in this area was basic with a pH of 8.2. The water table was about 3 feet. It had earlier been sampled and analyzed for chlorinated hydrocarbon residue and was found to contain 0.01 ppm p-p' DDT.

In the summer and fall the predominant vegetation consisted of bermuda grass, Cynodon dactylon (L.) Persoon; broom sedge, Andropogon virginicus L.; fennel, Foeniculum vulgare Miller; and Aster sp. In late winter and spring it was covered with bedstraw, Galium aparine L. and cranesbill, Geranium carolinianum L.

A large population of imported fire ants, Solenopsis saevissima richteri Forel, was located in the study area. To remove the possibility of the termites being preyed on by these ants the perimeter of the study area and the surrounding area were treated with Mirex. Wilson and Oliver (1969) have shown that termites, when they are present, constitute an important part of the imported fire ant diet.

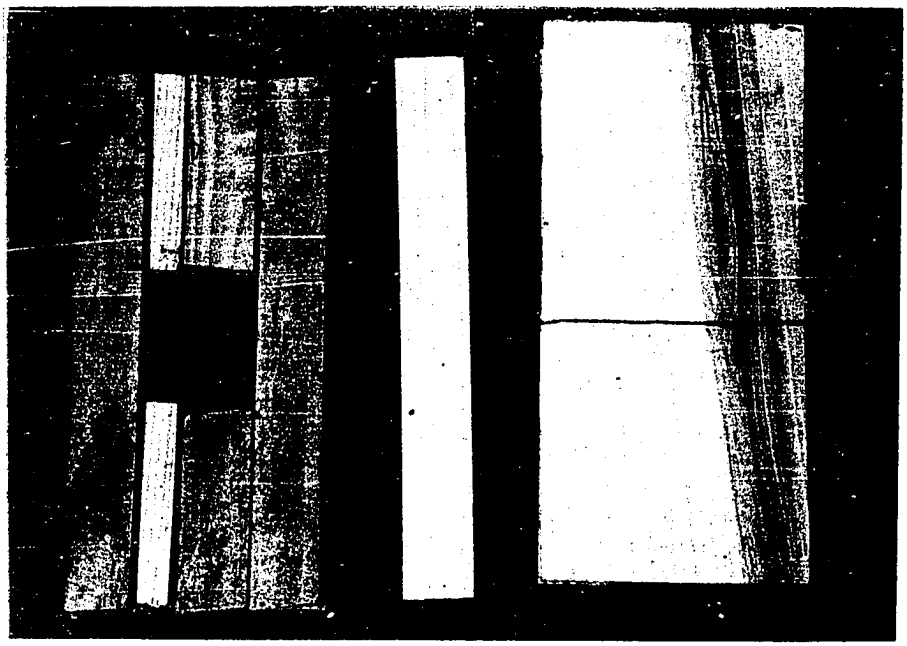
Colonies which had been established May 17, 1968, in 1 oz. jars were used to infest the cages. The jars with the lids removed were placed in a cavity in a wood block filled with sawdust containing 2 parts moisture (see Plate III). The wood in this block was southern "yellow" pine and consisted of 2-2 by 6 in. boards 12 in. long, 2-2 by 4 in. boards 4.5 in. long and 2-1 by 4 in. boards 4.5 in. long. These boards were constructed so that when placed together they formed a cavity in the center, which was filled with sawdust. Once the jar was placed in the cavity the wood was wired together forming a block.

One wood block containing a live colony was placed in each of 120 cages so that the colony was about 10 in. below the soil surface. The termites were placed in the cages October 12, 1968. Each colony at this time contained 20 to 40 individuals consisting of eggs, first through fourth instar larvae and 1 to 3 presoldiers and soldiers. Beginning Nov. 12, 1968, two live colonies were removed from the cages every 30 days. The developmental stages of the young termites were categorized and their activity and behavior were noted.

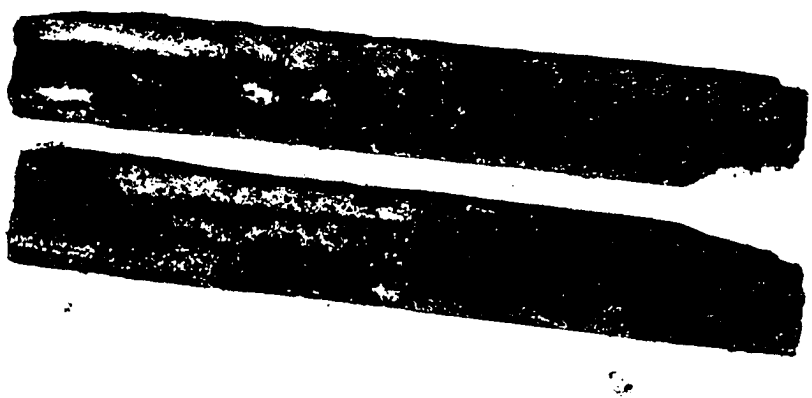
For 2 years, soil temperature and percent of moisture in the soil were obtained at depths of 5 in., 15 in. and 20 in. within and outside of each cage sampled at about 30 day intervals. Soil temperature was taken with a Weksler® soil thermometer and soil moisture percent was determined by the following formula: water lost divided by oven dry soil weight x 100 equalled percent moisture. These data were analyzed to determine if a difference in these two factors existed between the inside and the outside of the cages.

Series Cf-69F: Due to the partial failure of Series Cf-68F this series was established in 1969. A hole 1/2 in. in diameter was bored through the center of 400 southern "yellow" pine stakes (2 in. by 2 in. by 12 in.). In addition, 1 in.

Plate III. (a) Wood block in which young colonies of C. formosanus were reared in Series Cf-68F. (Photographed by W. T. Spink) (b) Stake utilized in rearing young colonies of C. formosanus in Series Cf-70F, Unit A. Note galleries depicted in white on stake. (Photographed by author)



a



b

from the top of the stake another hole, 1/2 in. in diameter, was bored into the middle of the stake from the side. The stakes were driven into the ground at 3 ft. intervals in an area adjacent to the Series Cf-68F study area. Sawdust with 2 parts moisture was used to fill the hole through the center of the stake. It was then plugged with a cork.

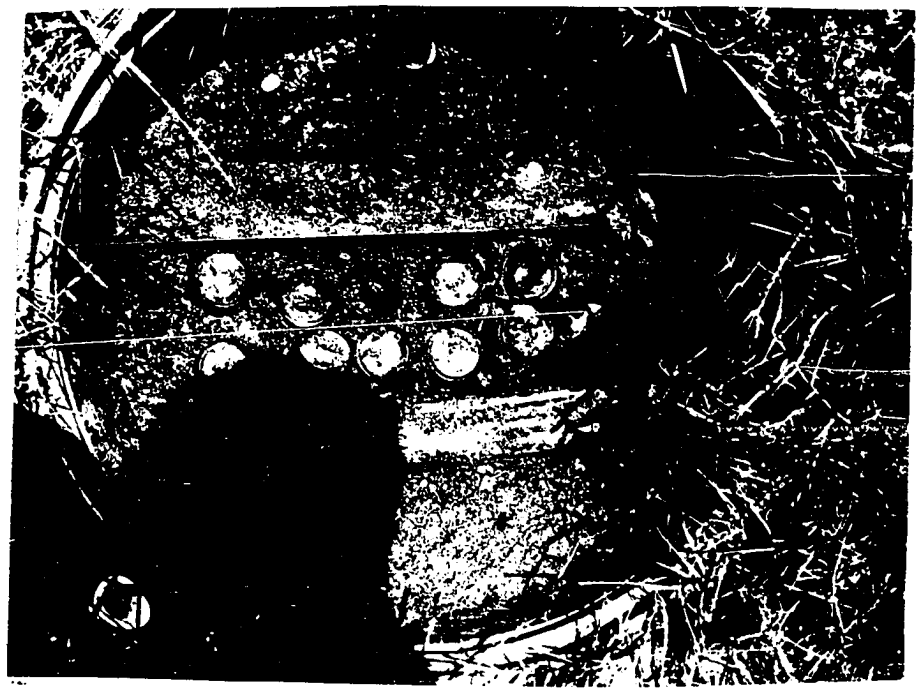
Alates were removed from a building in New Orleans and treated the same as in Series Cf-68L. As they were sexed and dealated a male and female were placed in a plastic jelly cup. The plastic cups with the pairs were kept in a styrofoam chest between layers of moistened paper toweling until infestation of the stakes.

The stakes were infested between 6:00 and 10:00 p.m. on June 3, 1969. Because of dryness the cork was removed from the stake and 3 to 5 ml of water was added to the sawdust in each stake. A male and female first-form reproductive were introduced into the hole in the top of each stake. The hole was then replugged with a cork. Since the hole in the side of the stake remained open the termites were not restricted to the stake. Two stakes, each containing a live colony, were to be sampled at 14 day intervals. Colony survival, total number of individuals found in each colony and their developmental stages were scheduled to be recorded.

Series Cf-70F: Two units were set in this series. One unit consisted of southern "yellow" pine stakes in the cages and the other consisted of the 1 oz. jars in the cages. The method for setting up the jars and the stakes was different than in Cf-68F and Cf-69F. An attempt was made to compare the two methods to determine the best procedure.

Unit A: Unit A consisted of 10 stakes (2 in. by 2 in. by 12 in.) that were placed in each of 5 cages. These cages were those described in Series Cf-68F. The stakes were those that had been used in Series Cf-69F. The stakes had been removed from the soil on April 18, 1970, and taken to Baton Rouge. They were brushed to remove the soil and termites (R. flavipes) that had infested them in the field. They were split longitudinally down the middle resulting in a groove 1/2 in. in diameter (See Plate III). On May 2, 1970, the stakes were imbedded 2 to 3 in. below the soil surface within the cages. The groove down the center of the stakes was filled with sawdust with 2 parts moisture and the two halves were then wired together and the hole in the top was plugged with a cork (See Plate IV). On May 8, 1970, the alates were collected from a building in New Orleans. They were immobilized by placing the container in ice water. They were sexed and their wings were broken or clipped at

Plate IV. (a) 1 oz. jars and (b) stakes after introduction of first-form reproductives of C. formosanus in cages in New Orleans, Louisiana. (Photographed by author)



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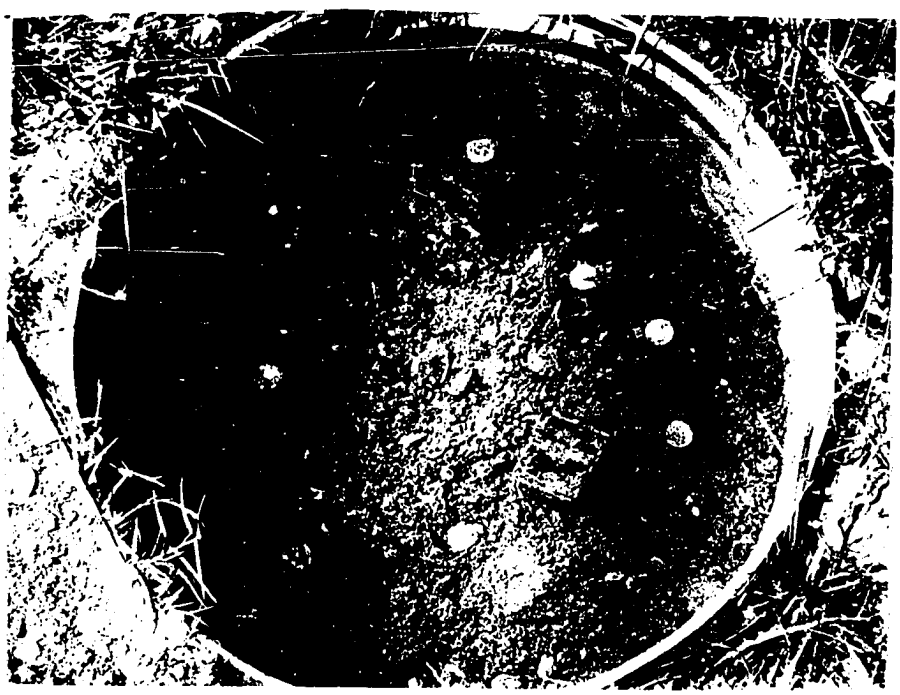


b

the basal suture. A male and female was placed in each of 50 plastic jelly cups, which were placed in a portable styrofoam chest between moistened paper toweling. The stakes were infested the following morning by removing the cork and introducing a male and female into the top of each stake. The stake was then replugged and the soil that had been removed above the stake was replaced.

Two stakes, each containing a live colony, were removed at about 14 day intervals until egg laying had ceased. Sampling intervals, thereafter, were extended to 30 days. The number of individuals found in each colony and their stage of development were recorded. The position and depth of the copularium and nursery and the extent of gallerying were noted for each stake. In addition, the soil temperature and percent of moisture in the soil was obtained at the copularium and nursery depth.

Unit B: Unit B was established at the same time as Unit A. The methods and materials for collection and dealation were the same as in Unit A. A male and female were placed in each of 50, 1 oz. jars containing the sawdust-agar mixture. The following morning 10 jars were placed in each of 5 cages. The jars were placed in a wooden block the same as in Cf-68F with the jar opening pointing down

(See Plate IV). The remaining space in the jar and the cavity in the wood block surrounding the jar was filled with soil. The cage was filled with soil to the ground surface level. The sampling procedure was as in Unit A.

Observations on Mature Field Colonies

Sex Ratio: A count was kept on the number of males and females examined for each series and unit. In addition, samples were taken from light trap collections and males and females were counted. A Chi Square test for significance was run on each sample count.

Reproductives: As nests were examined in the field a record was kept on the different types of reproductives found in each nest. Some notes were kept on the different types of individuals found in each of these nests.

RESULTS

Laboratory Studies

Series Cf-67L: Units A and B: Thirty-eight of the 200 pairs placed in the sawdust-agar medium, and 31 of the 200 pairs placed in the sawdust-water medium survived for further testing. Most of the termites died prior to the beginning of the first oviposition period. Due to the presence of the bacterium, Serratia marcescens Bizio, a large number of the dead termites exhibited a red discoloration. In the field, alates from the same source colony also exhibited the red discoloration the day after they were collected. Many of the termites, which had not dealated prior to placement in the 1 oz. jars, stuck to the media and sides of the jar and died. This sticking was particularly evident in the sawdust-water medium.

When the colonies were surveyed within the first 20 days after pairing, it appeared that mortality was greater in Unit B than in Unit A. Therefore, 3 colonies of Unit A and 1 colony of Unit B were inspected on each sampling day for the first 177 days after pairing. However, during this

period additional mortality occurred in Unit A and most colonies sampled after 177 days after pairing were from Unit B.

No difference was found in total number of termites produced in Units A and B (see Table II). Therefore, the results were combined and the average number of individuals recovered per colony, per sampling day, is presented in Table III.

The number of larval instars present and the number of individuals in each instar were not determined for samples on each sampling date. However, specimens were preserved and the occurrence of some of the larval instars was later determined.

Eggs were first detected in samples 23 days after pairing and oviposition continued until about 120 days after pairing, with most of the eggs being laid during the first 50 days. No eggs were found in the colonies from 177 to 217 days after pairing. Since the incubation period had been observed to be between 40 to 50 days, oviposition had ceased by about 120 days after pairing. Eggs were again found in the colonies 259 days after pairing. Most of the females resumed oviposition at about the same time and were laying eggs at a more rapid rate than in the first oviposition period.

Table II. Average number of individuals of C. formosanus developed in laboratory colonies from paired virgin, first-form reproductives, during the first 177 days after pairing in Units A and B, Series Cf-67L, Baton Rouge, La. 1967-1968.

Days after pairing	Average number individuals per colony[a]	
	Unit A[b]	Unit B[c]
23	8.00	10.00
27	9.33	13.00
51	17.67	2.00
65	19.00	34.00
79	21.33	29.00
93	24.67	2.00
107	41.67	39.00
121	46.33	42.00
135	27.00	49.00
149	41.67	2.00
163	41.67	32.00
177	34.00	28.00
	ns	

[a] These averages are based on data presented in Appendix Table I. Averages for Unit A based on 3 colonies per sampling day and for Unit B based on 1 colony per sampling day.

[b] Culture media consisted of agar plus sawdust with the agar containing 0.225 percent methyl-p-hydroxybenzoate.

[c] Culture media consisted of water plus sawdust.

Table III. Average number of individuals of C. formosanus developed in laboratory colonies from paired virgin, first-form reproductives, Baton Rouge, La. 1967-1968.[a]

Days after pairing	Average number of individuals[b]				Average Total[c]
	Eggs	Larvae	Presoldiers	Soldiers	
23	6.50	0.00	0.00	0.00	8.50
37	8.25	0.00	0.00	0.00	10.25
51	11.75	0.00	0.00	0.00	13.75
65	15.00	0.75	0.00	0.00	22.75
79	18.25	3.00	0.00	0.00	23.25
93	13.50	3.50	0.00	0.00	19.00
107	21.00	16.75	1.00	0.25	41.00
121	22.50	19.25	0.25	1.25	45.25
135	6.00	24.50	0.25	1.00	32.50
149	1.75	26.00	0.00	1.75	31.75
163	5.50	29.50	0.00	2.25	39.25
177	1.25	26.50	0.00	2.75	32.50
191	0.00	34.25	0.00	3.25	39.50
202	0.00	32.00	0.00	3.25	37.25
217	0.00	28.25	0.00	2.50	32.75
231	0.50	27.25	0.00	2.75	32.50
245	0.00	25.00	0.00	2.25	29.25
259	3.75	29.25	0.00	2.50	37.50
273	2.25	21.50	0.00	2.00	27.75
289	17.50	25.00	0.00	2.75	45.75
303	45.75	21.50	0.25	2.50	72.00
319	32.75	28.75	0.00	4.00	67.70

[a] Unit A and Unit B, Series Cf-67L.

[b] Average number derived from 4 colonies of C. formosanus per sampling date.

[c] Average total includes categories listed plus first-form reproductives.

Larvae were observed in samples 65 days after pairing and they accumulated thereafter. Presoldiers and soldiers were observed in samples 107 days after pairing. Soldiers were present in all colonies sampled after 163 days after pairing. The colonies sampled during the period of 191 through 245 days after pairing averaged 34.25 individuals per colony and consisted of 8.18 percent soldiers. More pre-soldiers and soldiers were produced after the second oviposition period began. Prior to the beginning of the second oviposition period the larvae had advanced to the fourth instar. Fifth instar larvae were found in the colonies 319 days after pairing during the second oviposition period.

The cavity at first was a small enclosed area excavated in the media prior to mating and was considered a "copularium." The copularium was usually found alongside the glass or at the bottom of the jar. The entrance hole that had been punched in the agar was plugged by the termites with masticated material. If this entrance hole was not plugged it was indicative of some unfavorable condition which usually resulted in the death of the termites. Frequently, the male and/or female were found dead in the copularium or the entrance hole to the copularium.

Twenty-three days after pairing this cavity contained eggs and was lined with masticated material isolating the termites from the media. At this point the cavity was considered the nursery area (see Plate V). Ninety-three days after pairing the nursery area averaged about 8 by 11 by 6 mm and 107 days after pairing gallerying was observed from the nursery. Young larvae and eggs were frequently found in the gallery extensions near the original cavity. By 121 days after pairing, extensive gallerying by the termites had occurred and the original cavity was progressively expanded until it covered the bottom of the jar. The area in which the termites were active remained isolated from the rest of the media and was lined with carton. In Unit A six months after pairing galleries had been extended throughout the sawdust-agar medium and into the agar cap.

In order to save some colonies for long-term growth studies sampling was terminated 319 days after pairing. They were then transferred to pint Mason jars and later transferred to gallon jars, both containing southern "yellow" pine sawdust with 2 parts water.

Two colonies were examined 1126 days after pairing, one contained 546 individuals and the other contained 1972 individuals with 6.6 and 11 percent soldiers, respectively.

Plate V. Nursery area of C. formosanus in 1 oz. jar containing sawdust-agar media. Note eggs and first-form reproductives. (Photographed by author)

Eggs were not found in either colony and most of the termites were larvae in the third, fourth and fifth instars. A colony sampled 1188 days after pairing contained 1766 individuals consisting of 1151 eggs and 615 termites. Most of the termites were recently hatched individuals with 255 being in a fourth or later instar. Soldiers constituted 8.6 percent of the termites. The last colony sampled in this series, 1349 days after pairing, contained 4541 individuals including 80 eggs. About 50 percent of these termites were in the first, second and third larval instars. Soldiers and pre-soldiers constituted 6 percent of the termites. The female first-form reproductive was 8.97 mm long and her abdomen at the fifth sternite was 1.71 mm in width. The male first-form reproductive was 6.51 mm long and his abdomen was 1.71 mm in width.

Unit C: Highest survival of pairs occurred in 2 parts water. There was no difference in the number of individuals produced between 2.00 and 2.66 parts water (see Table IV). At 2.66 parts water first-form reproductives were observed to stick to condensation on the glass. However, once the copularium was formed development proceeded as in those colonies in 2.00 parts water. Two parts water to 1 part sawdust (2 gm water to 1 gm sawdust) was subsequently

Table IV. Response of young colonies of C. formosanus established by paired virgin, first-form reproductives to sawdust containing various parts water. Baton Rouge, La. 1967.[a]

Parts water	Survival (no./10 colonies[b])	Average number individuals per viable colony[c]
0.66	0	0.00
1.33	2	16.00
2.00	7	23.00
2.66	4	25.75

[a] Unit C, Series Cf-67L. Parts equal grams.

[b] Each moisture group replicated 10 times.

[c] Colonies checked 90 days after pairing.

utilized in all sawdust-water combinations in the laboratory and in the field.

Series Cf-68L: Seventy-three percent of the 1297 colonies were surviving 3 months after pairing. However, only 25 percent of the colonies were actually utilized for test purposes.

During the summer of 1968 an Acarid mite, Tyrophagus putrescentiae, was found contaminating the culture jar. This particular mite feeds on mold and is a common pest of laboratory cultures. (H. B. Boudreaux, Personal Communication). Due to the excretion by this mite an excessive amount of microorganism growth developed on the culture medium. The mites were eliminated within 60 days by removing the pans of water which had been used to maintain a high relative humidity in the cabinets. As a result, considerable moisture was lost from those jars near the back of the cabinet which were exposed to constant ventilation. This was evinced by shrinkage of the agar cap over the sawdust-agar medium. Therefore, all jars in which the agar cap showed extensive shrinkage were discarded since it was believed that they would not reflect actual colony development. The lids to the remaining 1 oz. jars containing live colonies were removed and these jars were buried in pint Mason jars containing sawdust.

Although the first samples were not taken until 28 days after pairing the colonies were observed daily during this period. Most of the termite pairs had entered the entrance hole in the agar cap, plugged it, and had constructed the copularium within 24 hours after pairing. Copulation was observed to take place within 72 hours after pairing. Two to 4 of the terminal antennal segments were missing on the male and female in all pairs examined within 96 hours after pairing. The incubation period was closely observed in 12 colonies and averaged 45.17 days (see Table VI).

Egg laying was gradual with 0 to 3 eggs being laid per day, beginning about 7 to 12 days after pairing. Although egg hatch was not observed in the samples until 71 days after pairing it was observed in some of the other colonies within 52 days after pairing. Most of the eggs of the first oviposition period were laid during the first 60 days after pairing. A maximum of 40 eggs was observed in the colonies.

During this period the adults were observed to groom each other frequently. When the female laid an egg the male would take it from her abdomen tip and place it with the other eggs. The male and female were often observed turning the eggs over in their mouthparts and moving them from one

Table V. Average number of individuals of C. formosanus developed in laboratory from paired virgin, first-form reproductives. Baton Rouge, La. 1968-1970.[a/] [b/]

Days after pairing	Egg	Larval Instars[c/] 1st	2nd	3rd	4th	5th	Pre-soldier	Soldier	Average total[d/]	Range
28	16.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.25	15-22
45	21.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23.25	14-31
57	16.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.25	4-31
71	20.75	4.00	0.00	0.00	0.00	0.00	0.00	0.00	26.75	8-49
84	30.75	2.00	3.50	2.50	0.00	0.00	0.25	0.00	40.50	34-43
99	21.25	6.00	6.00	10.50	0.00	0.00	0.75	0.00	46.50	20-69
112	14.00	4.00	4.25	11.00	0.50	0.00	0.75	1.00	37.50	4-61
129	7.00	2.50	3.00	7.50	1.25	0.00	0.50	1.50	25.25	8-50
142	7.00	5.00	4.50	11.00	3.25	0.00	0.25	1.25	34.25	13-48
158	1.25	2.00	2.50	11.50	6.25	0.00	0.25	1.50	27.25	18-40
171	0.25	0.25	1.00	15.50	3.75	0.00	0.25	1.00	25.75	5-43
183	0.00	0.00	0.00	7.00	7.00	0.00	0.00	0.75	16.50	3-23
197	0.25	0.25	0.00	2.50	4.75	0.00	0.00	1.50	11.50	5-27
211	0.00	0.00	0.00	6.50	4.75	0.00	0.00	2.00	15.25	8-27
226	1.75	0.00	0.00	3.75	10.50	0.25	0.00	2.00	19.25	10-35
242	0.00	0.00	0.00	0.50	5.75	1.00	0.00	2.00	11.25	6-18
256	2.75	0.00	0.00	3.25	19.00	3.25	0.00	3.00	33.25	7-56
264	15.50	0.00	0.00	0.00	12.75	3.50	0.00	2.25	36.00	8-65
288	12.00	2.50	1.50	0.00	12.25	0.50	0.00	2.75	33.25	7-104
302	6.75	0.75	0.00	0.00	11.75	2.00	0.00	2.50	25.25	6-63
317	29.75	12.25	4.75	2.75	16.50	10.00	0.00	4.00	82.00	31-136
330	6.50	3.25	1.50	1.50	7.00	9.50	0.00	3.00	34.25	7-72
344	8.00	8.00	1.50	1.75	5.00	7.00	0.00	1.50	34.75	16-57

Table V. (continued)

Days after pairing	Egg	Larval Instars[c] 1st	2nd	3rd	4th	5th	Pre-soldier	Soldier	Average total[d]	Range
360	0.50	0.75	6.00	4.00	3.50	5.75	0.00	2.25	24.75	4-49
376	0.00	0.00	2.25	0.00	3.25	4.75	0.00	2.00	14.25	4-26
392	9.00	2.25	0.00	1.00	7.00	11.50	0.00	4.75	37.50	8-80
408	2.00	0.50	1.00	6.25	3.50	6.75	0.00	4.25	24.25	8-70
438	0.00	0.00	1.25	3.50	12.75	11.00	0.00	3.75	34.25	8-63
468	0.00	0.00	0.00	7.50	18.25	17.50	0.00	8.25	53.50	29-91
499	0.00	0.00	0.00	1.00	8.25	9.25	0.00	3.00	22.50	8-62
532	0.75	0.00	0.00	0.00	9.50	16.25	0.00	4.50	32.25	15-57
563	111.75	6.50	0.00	1.00	11.00	22.50	0.50	6.75	162.00	8-347
596	27.25	1.00	0.25	0.25	3.50	21.00	0.25	3.75	59.25	25-134
627	60.00	48.50	17.25	12.75	0.00	28.75	0.00	8.25	177.50	4-359
656	0.00	0.00	0.00	0.00	0.00	15.75	0.00	3.75	21.50	2-54
687	25.00	16.00	24.50	87.00	0.00	33.50	0.50	10.00	198.50	7-390
710	4.00	3.50	3.50	29.50	37.50	6.50	0.00	4.50	91.00	5-177
743	1.00	0.00	0.00	2.00	110.50	46.50	0.00	17.50	179.50	53-306
773	0.00	0.00	0.00	15.00	204.00	64.00	0.00	27.50	312.50	296-329
800	101.50	0.00	0.00	1.50	223.00	117.00	1.00	33.00	479.00	398-560
820	139.00	22.50	0.50	0.00	0.00	120.50	0.50	22.50	305.50	174-441
849	88.50	40.00	32.00	36.00	73.50	120.00	2.00	32.00	426.00	390-462
880	20.00	20.00	23.50	58.00	54.00	103.00	0.00	31.00	311.50	258-365

Table V. (continued)

Days after pairing	Egg	Larval Instars[c] 1st	2nd	3rd	4th	5th	Pre-soldier	Soldier	Average total[d]	Range
911	90.00	53.00	64.00	178.50	124.00	89.00	5.50	38.50	644.50	617-672
942	80.50	41.00	49.00	308.00	130.00	137.00	6.50	61.50	815.50	674-957

[a]Unit A, Series Cf-68L.

[b]Colonies maintained at 26±0.5°C, 24 hour dark photoperiod and 80 percent relative humidity.

[c]Fifth instar larva category also includes a few individuals which were probably sixth instar larvae.

[d]Average total includes the categories listed plus the first-form reproductives.

Table VI. Incubation period for eggs of C. formosanus during first oviposition period. Baton Rouge, La. 1968[a]

Jar Number	Incubation Period[b]
1199	42
1262	46
1257	46
1167	49
1234	46
1162	45
1189	47
1242	44
1256	47
1220	43
1100	47
1150	46
1265	46
1165	46
Average±S.D.	45.71±1.77

[a] Eggs incubated at 26±.5°C, 80 percent relative humidity and continuous darkness.

[b] Incubation period given in days.

section of the nursery to another. Eggs that did not receive this care rapidly deteriorated. When the eggs hatched and the young larvae molted the adults were observed assisting in the removal of the egg chorion and the exuvia from the larvae. The chorion and exuvia were then eaten by the termites.

The first and second instar larvae were not observed to feed on wood. Both forms were relatively inactive with the second instar larva being more active than the first instar larva. They were cared for and fed by the first-form reproductives during initial colony development. Participation in colony activities by larvae was not observed until they reached the third instar, about 84 days after pairing. This individual then cared for the other young larvae and was observed to feed other individuals stomodeal and proctodeal food. It was at this point that gallerying from the nursery area was observed and it was initiated by the third instar larva. Fourth instar larvae were first observed 112 days after pairing and no difference in behavior was observed between them and the third instar larva.

Presoldiers, that later developed into soldiers, were found in the colonies at about the same time as the third instar larvae. This would indicate that they were also derived from second instar larvae. The presoldiers

were not aggressive in the defense of the colony as were the soldiers and were generally not found in the galleries. The soldiers were found in the galleries and actively defended the colony when it was examined. They were not observed to feed on wood, but received their food from the other termites.

Most of the soldiers in oviposition periods, other than the first oviposition period, were larger and possessed one more antennal segment than the soldiers produced during the first oviposition period. The soldiers constituted a relatively constant percent in the colonies. Colonies sampled during the intervals between the first and second, second and third and third and fourth oviposition periods consisted of 7.88, 13.34 and 8.13 percent soldiers, respectively.

A termite form which was larger and possessed more antennal segment than the fifth instar larva was found at the beginning of the third oviposition period. This individual was categorized as a sixth instar larva. However, since these individuals were found in only 9 colonies with a maximum of 3 in any 1 colony they were included in the fifth instar larva category.

The termites lived at least one year as can be deduced from Table V and Appendix Table 2. The fifth instar larvae and most of the soldiers had developed during the

first oviposition period and therefore continued in the colonies for over a year. However, once the termites derived from the second oviposition period developed to the fourth and fifth instar, their age could no longer be determined.

During the first oviposition period the first and second stadium combined was about 30 days in length and the fourth instar larva did not molt to the fifth instar until 226 days after pairing, which was at about the same time as the beginning of the second oviposition period. This made the fourth stadium about 100 days in length.

The 20 colonies sampled between the first and second oviposition period from 142 to 242 days after pairing averaged 20.22 individuals. Colonies sampled in this series prior to this period averaged up to 46.50 individuals per sampling date. Apparently there was a considerable reduction in the number of individuals in colonies sampled near the end of the first oviposition period.

There were four periods of egg laying, separated by periods in which relatively few eggs were laid: first oviposition period, 7 to 136 days after pairing; second oviposition period, 256 to 393 days after pairing; third oviposition period, 563 to 665 days after pairing; and

fourth oviposition period, 800 days after pairing to present. The beginning of an oviposition period was based on the day egg laying began in relatively large numbers. The end of a period was determined by subtracting 45 days, which was about the incubation period, from the last day in which a relatively large number of eggs were found. During the first two oviposition periods, development in most of the colonies coincided. However, development was not synchronized in the different colonies during the third and fourth oviposition periods.

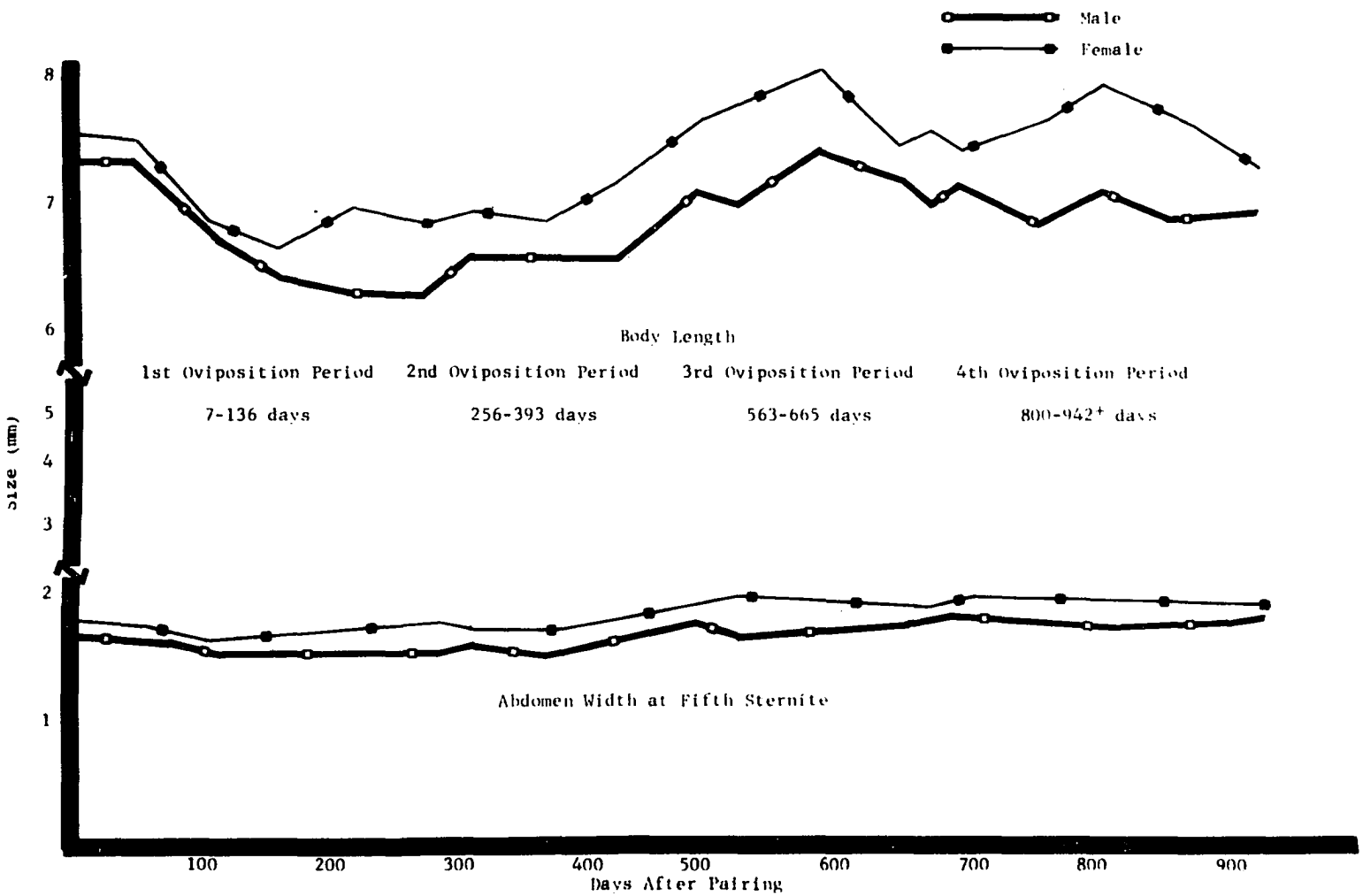
The number of individuals per colony was variable throughout the test period. The average number of individuals generally was lower than was expected and the maximum number probably better reflected what actually occurred during colony development. However, a definite trend can be seen in colony development from Tables V and 2. Eggs were not deposited continuously. Between each oviposition period there was a period in which relatively few eggs were produced. During the first oviposition period as many as 69 eggs were deposited with an average of about 30. During the second oviposition as many as 96 eggs were laid, when the number of young larvae was also considered, with an average of about 50. During the third oviposition period a maximum of 288

eggs were produced with an average of about 150 in the stronger colonies. During the fourth oviposition period a maximum of 629 eggs had apparently been deposited with an average of about 300. This shows a trend of a gradual increase of egg laying capacity by the female first-form reproductive during each egg laying period. Also, due to the longevity of the colony members, the size of the colony was increased from year to year. The increase in number of eggs laid was particularly evident in the third and fourth oviposition periods.

Throughout the test period eggs, larvae and soldiers of two different sizes were found. To date no nymphs have been found. In order to determine the time of nymphal development this series is being continued in the laboratory.

The size of the female and male first-form reproductives averaged at about 60 day intervals are presented in Fig. 1. There was an average increase of about 0.4 mm in total length and 0.2 to 0.3 mm in abdomen width at the fifth sternite in the female during the third and fourth oviposition periods. Although the male first-form reproductive also increased in length and width after the first oviposition period, it was essentially no larger at the fourth oviposition period than at the time of pairing. Both the male and female decreased

Fig. I. Graph showing length and width of male and female first-form reproductives of C. formosanus from laboratory colonies averaged at about 60 day intervals after pairing.



in size during the first oviposition period and between each of the other oviposition periods. The female was at her maximum size just prior to and during each oviposition period.

Series Cf-70L: Unit A: Temperature had a marked affect on the development of the young colony of C. formosanus. The termites were observed to pair at all four temperature regimes studied.

Eggs were laid at 21.5°C, 26°C and 32°C but not at 16°C. In 10 of the colonies held at 16°C at least 1 member of the pair was alive 35 days after pairing, however, the copularium was undefined and the entrance hole was not plugged in 7 of these pairs. Throughout this period the termites held at 16°C were inactive. The 3 colonies that survived during the 35 day period after pairing were transferred to a 26°C regime. They began laying within 2 to 3 days and produced 20 to 30 individuals in each colony. At the other 3 temperature regimes as temperature was increased, the preoviposition period was shortened (see Table VII). Averages of 13.43, 7.60 and 4.07 days after pairing were obtained at 21.5°, 26° and 32°C, respectively.

Table VII. Length of the preoviposition period in laboratory colonies of C. formosanus initiated by paired virgin, first-form reproductives when maintained under various temperature regimes. Baton Rouge, La. 1970.[a/] [b/]

Temperature Regimes			
16°C[c/]	21.5°C	26°C	32°C
--	5	6	4
	12	10	3
	13	8	4
	12	6	4
	12	8	8
	13	6	4
	27	7	6
		8	3
		9	6
		10	3
		6	3
		8	2
		8	4
		9	3
		6	
		6	
		6	
		6	
		9	
		10	
Average±S.D. --	13.43±6.60	7.60±1.54	4.07±1.59

[a/] Unit A, Series Cf-70L.

[b/] Figures given in days. Observations taken on culture jars in which nest could be observed.

[c/] No oviposition observed at 16°C.

Egg hatching was observed at 26° and 32°C with an incubation period of 45.70 and 28.77 days, respectively (see Table VIII). As the temperature was increased the incubation period was shortened. Eggs were not observed to hatch through a 103 day period at 21.5°C. Up to 21 eggs were produced in each of the colonies maintained at 21.5°C. Fertilization of these eggs occurred as evinced by the development of the embryo. The young termite was observed through the chorion and appeared to be externally, completely developed in 3 of the eggs. Many of the eggs in colonies held at 21.5°C developed amorphous white inclusions which could be seen through the chorion. These inclusions were not observed at 26° and 32°C. When colonies held at 21.5°C were transferred to cabinets maintained at 26°C, hatching was observed. However, it was not determined if the eggs present at the time of transfer hatched or if additional eggs had been laid and hatched.

As temperature was increased the fecundity and developmental rate also increased (see Table IX). At 26° and 32°C an average of 25.24 and 53.57 individuals were found in each colony, respectively. A maximum number of 47 and 89 individuals was found in colonies maintained at 26° and 32°C, respectively. That the developmental rate was

Table VIII. Incubation period of eggs in laboratory colonies of C. formosanus initiated by paired virgin, first-form reproductives when maintained under various temperature regimes. Baton Rouge, La. 1970.[a/] [b/]

Temperature Regimes			
16°C[c/]	21.5°C[d/]	26°C	32°C
		49	30
		47	28
		45	28
		46	30
		46	29
		43	27
		46	29
		46	29
		46	30
		43	29
			28
			30
			27
Average±S.D.		45.70±1.77	28.77±1.09

[a/] Unit A, Series Cf-70L.

[b/] Figures given in days. Observations taken on culture jars in which nest could be observed.

[c/] No oviposition observed at 16°C.

[d/] No egg hatch observed through 103 days after pairing.

Table IX. Average number of individuals of C. formosanus developed in laboratory colonies from virgin, first-form reproductives during the first 90 days after pairing when held at 26±0.5° and 32±0.5°C. Baton Rouge, La. 1970.[a]

Temperature	Eggs	First Instar	Second Instar	Third Instar	Fourth Instar	Pre-soldier	Soldier	Average total[b]	Range
26°C	10.67	2.81	3.29	6.10	0.00	0.43	0.05	25.24	2-47
32°C	9.00	8.71	5.71	17.43	7.14	0.14	3.43	53.57	5-89

[a] Unit A of Series Cf-70L.

[b] Average total includes all categories listed plus 2 first-form reproductives per colony.

higher at 32°C was evinced by the relatively larger number of fourth instar larvae, presoldiers and soldiers found in colonies maintained at this temperature than in colonies held at 26°C.

Survival of the colonies after 90 days varied considerably between the different temperatures. The results were as follows: 0 percent survived at 16°C; 36 percent survived at 21.5°C; 84 percent survived at 26°C; and 28 percent survived at 32°C.

Pairing: When alates were combined with larvae and soldiers in the nest material, no pairing was observed. Moreover, if the alates were placed in large numbers in containers and were not disturbed they would bunch together with the wing tips projecting outward. When these alates were disturbed the former reaction was reversed and pairing would be initiated. Most of the pairing termites had shed their wings; however, pairing was observed between individuals that had not shed their wings. The "calling" attitude, where the female elevates abdomen tip upward until joined by a male, was not observed to take place in C. formosanus.

Males and females isolated in separate containers were observed to form pairs, i.e., males would follow males and females would follow females. Tandems were observed

consisting of 4 to 5 males and up to 3 females in the respective containers. Although pairing was observed between females and between males there was a stronger attraction between the pair consisting of a male following a female as evinced by the relatively longer period in which the pair stayed together.

Parthenogenesis: Unit B: There was a marked difference in behavior between 2 virgin females and 1 virgin female in the 1 oz. jars. The single female galleried extensively through the culture medium and did not plug the entrance hole, while the paired females quickly formed a "copularium" and plugged the entrance hole. Some time after pairing 4 to 5 of the terminal antennal segments were amputated from each of the paired females during this developmental period.

Both the paired and unpaired females laid eggs; however, the paired females laid more eggs and the preoviposition period was shorter. In the jars containing 2 females, I did not determine if both were laying eggs. Up to 10 eggs were observed in cavities containing 2 females 9 days after pairing and this accumulated to a maximum observed number of 33 eggs. Eggs were not observed in jars containing 1 female until 16 days after pairing, at which time a maximum of 9 eggs was observed.

Survival was greater in those jars containing 2 females than in those containing 1 female. Sixty-two days after introduction to the jars all unpaired females were dead. Sixty percent of the paired females were still alive and eight of the 25 pairs were still surviving 327 days after pairing.

Eggs were observed in the jars containing a single female from 16 to 60 days after pairing and in the paired female jars from 9 to 327 days after pairing. No embryonic development was observed in any of these eggs and the chorion remained clear. The eggs did increase in size and this was apparently due to absorption of water. The paired females constantly brooded over their eggs while the single female did not and her eggs rapidly deteriorated. In no case was egg hatch observed.

Fourteen females 327 days after pairing averaged 7.29 mm in length and 1.82 mm in abdomen width at the fifth sternite. Therefore, they were about the same size at this point as they were at the time of removal from the nest.

Unit C: No difference was found in the total number of individuals present in C. formosanus colonies reared in sawdust-agar media containing 0.00, 0.09 and 0.225 percent methyl-p-hydroxybenzoate (see Table X). Since there was

Table X. Response of young colonies of C. formosanus established by paired virgin, first-form reproductives, to sawdust-agar media containing various concentrations of methyl-p-hydroxybenzoate. Baton Rouge, La. 1970.[a]

	Concentrations			Mean
	A 0.00%	B 0.09%	C 0.225%	Comparisons
Days after pairing	(Ave. no. of individuals/colony)[b]			
65	23.80	32.80	29.00	
86	27.00	31.80	27.00	ns
96	31.80	33.40	24.80	
Preoviposition period[c]	(No. of days)			
	8.58	8.83	9.38	A vs BC*
				A vs B ns
	(Ave. no. of 3rd and 4th instar individuals/colony 96 days after pairing)[d]			
	11.00	8.20	5.80	ns

[a] Unit C, Series Cf-70L.

[b] Figures are averages of 5 colonies. Based on data shown in Appendix Tables 7, 8 and 9. Analysis of variance given in Appendix Table 11.

[c] Based on data shown in Appendix Table 10. Analysis of variance given in Appendix Table 12.

[d] Larvae and presoldiers in third instar and soldiers in fourth instar. Figures are averages of 5 colonies. Based on data shown in Appendix Table 9. Analysis of variance given in Appendix Table 13.

no difference between dates this was indicative that most of the eggs had been laid by 65 days after pairing.

There was a difference in length of the preoviposition period between the colonies reared in 0.00 and 0.09 percent and 0.225 percent methyl-p-hydroxybenzoate (See Table X). The preoviposition period in colonies at 0.225 percent methyl-p-hydroxybenzoate averaged about 1 day longer than that at the other 2 concentrations.

No difference was found in the number of third instar larvae, presoldiers and soldiers present in colonies at each concentration 96 days after pairing (see Table X). This indicated that methyl-p-hydroxybenzoate at these concentrations had not affected the larval developmental rate.

There apparently was no difference in incubation time for the eggs at the different concentrations. An average of 47.63, 48.44 and 47.00 days was required in 0.00, 0.09 and 0.225 percent methyl-p-hydroxybenzoate, respectively.

Unit D: For 50 pairs the preoviposition period averaged 11 days in length. Once oviposition was initiated 5 to 6 eggs were laid on the first day and accumulated to a maximum of 27 eggs. These eggs hatched, but in all colonies except 1 when the first instar molted to the second instar it was cannibalized by one of the adult first-form reproductives.

In many of the containers no defined copularium was formed. Some of the eggs were untended and deteriorated. This test was discontinued after 60 days.

Unit E: Cannibalism also occurred in this unit, however, it was not as extensive as in Unit D. It usually occurred at the time of molting and this was determined by counting the antennal segments of the remaining head after the body was cannibalized. Termites that died in the dishes were frequently buried by the other termites under a mass of masticated paper.

In addition to cannibalization, during the grooming process, the paint spots were frequently removed. Therefore, even if an individual lacked a paint spot it was not always indicative of a molt. Further, molts could not be determined by total counts alone since cannibalization may have occurred or eggs may have hatched. Eggs often were reduced in number without a corresponding increase in first instar larvae and were apparently cannibalized.

An attempt was made to maintain all the individuals taken from a colony with their respective first-form reproductives to reduce a possible effect caused by the removal of individuals. Further, a certain number of termites was apparently required in each colony for the mutual feeding

process to function efficiently, since colonies of 4 to 5 individuals died. There was an indication that larger colonies could control the mold growth on the paper better than colonies with 7 to 8 individuals. Since termites were active only in that portion of the paper lacking mold growth they were frequently restricted to a small portion of the total surface area. When this occurred the termites were transferred to another dish containing paper free of mold growth.

Measurements of the first through the sixth larval instar, first presoldier and the first and second soldier are presented in Table XI. Measurements of the fifth and sixth larval instars and the second soldier were obtained from preserved specimens from Series Cf-68L since these growth stages could not be obtained in the required time. The fifth instar larvae were removed from colonies that had begun the second oviposition period and were therefore derived from the first oviposition period. The sixth instar larvae were removed from colonies beginning the third oviposition period. The second soldier was removed from colonies preserved a year after the first oviposition period. The other growth stages were obtained from colonies in the first oviposition during the summer of 1970.

Table XI Measurements (mm) and antennal segment number of young produced by virgin first-form reproductives of C. formosanus in the laboratory at 26±0.5°C. Baton Rouge, La. 1970.[a/] [b/]

Young[c/]	No. measured	Head widths	Pronotum widths	Mesonotum widths	Body lengths	Antennal segment number[d/] mode	range
First instar larvae	24	0.490±0.016	0.300±.007	-	1.710±0.274	9/11	8/11-9/12
Second instar larvae	24	0.654±0.022	0.342±0.016	0.387±0.015	2.608±0.330	10/11	9/11-11/11
Third instar larvae	24	0.824±0.031	0.435±0.019	0.482±0.014	3.186±0.325	11/12	11/11-11/12
Fourth instar larvae	17	0.875±0.031	0.484±0.024	0.534±0.028	3.424±0.260	12/13	12/12-12/13
Fifth instar larvae	15	0.945±0.014	0.551±0.032	0.582±0.045	3.575±0.409	13/13	12/13-13/14
Sixth instar larvae	12	1.106±0.032	0.699±0.033	0.714±0.044	5.074±0.364	14/14	14/14-14/14
First pre-soldier	10	0.773±0.028	0.464±0.021	-	3.823±0.324	11/12	11/11-11/12
First soldier	13	0.933±0.048	0.596±0.023	-	4.221±0.434	12/12	11/11-12/12
Second soldier	12	1.013±0.057	0.680±0.031	-	5.005±0.554	13/13	13/13-13/13

[a/] Unit E of Series Cf-1970L.

[b/] Measurements are averages ± the standard deviation of individuals preserved in 70 percent alcohol.

[c/] The first 5 larval instars, first presoldier and first soldier developed from eggs laid during the first egg laying period.

[d/] Antennal segment number is the number of segments with setae over the total number of segments.

The first five larval instars, first presoldier and soldier and the second soldier were confirmed by marking experiments. The sixth instar larva was based on size differences and antennal segment number. The first presoldier, which developed during the first oviposition period, developed from a second instar larva. It then molted to produce the first soldier. The second soldier developed from a third instar larva and, based on two observations, from the fourth instar larva, too.

There was no overlap in sclerotized structure between the first three larval instars. However, there was an overlap in sclerotized structure size between the third and fourth and the fourth and fifth instar larvae. Since as termites molt the exuvium is eaten, instars could be definitely identified only by marking and antennal segment number. There was no overlap in sclerotized structure size between the fifth instar larva derived from the first oviposition period and the sixth instar larva.

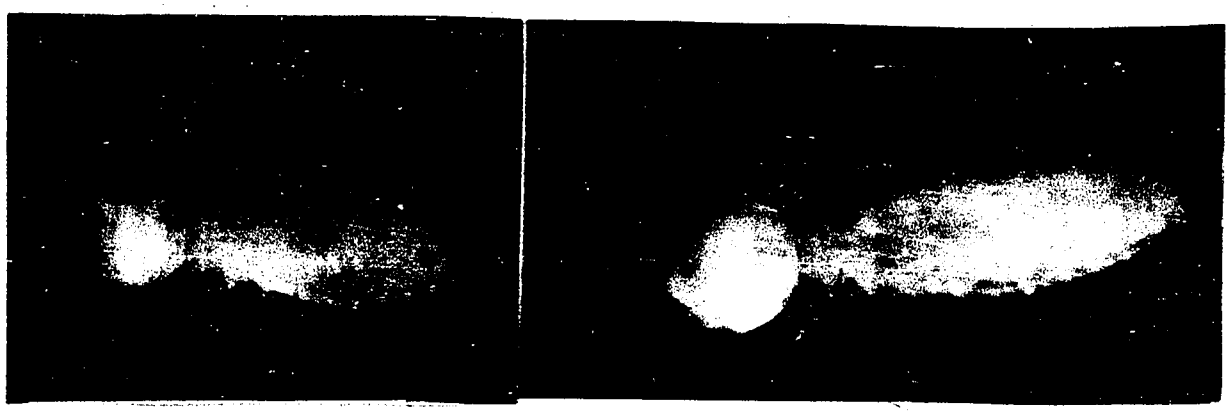
One antennal segment possessing setae was usually added at each larval molt. Overlap was observed between the fourth and fifth larval instar where some individuals of both instars had 12/13 antennal segments. The first presoldier, first soldier and second soldier usually had

11/12, 12/12 and 13/13 antennal segments, respectively. Although not shown in Table XI several second presoldiers had 12/13 antennal segments. Antennal segments were added by division of the third antennal segment. Where antennal segments lacked setae they began at the third antennal segment and they could be identified by external annualtions. Pictures of the growth stages derived from the first oviposition period are shown in Plates VI to VIII.

The stadium lengths of the first four larval instars and the first presoldier are presented in Table XII. The stadium lengths of the first three larval instars and the first presoldier were determined from individuals in the first oviposition period. The fourth instar larval stadium was determined from individuals taken from older colonies. The first and second larval stadiums averaged 17.57 and 18.33 days, respectively. The length of the third and fourth larval stadiums were longer than the first and second larval stadiums averaging 48.57 and 48.50 days, respectively. The stadium length of the first presoldier was consistently about 14 days in length.

There was considerable variation in the stadium lengths of the various larval instars and very little variation in the first presoldier stadium. Counts taken on

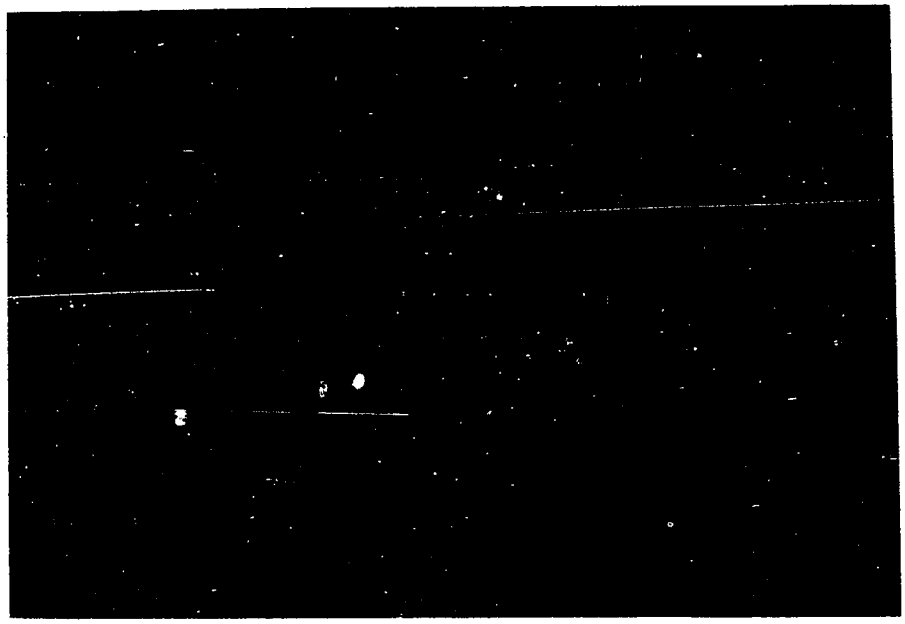
Plate VI. Larval stages of C. formosanus developed during the first oviposition period: (a) first instar; (b) second instar; (c) third instar; (d) fourth instar. (Photographed by author)



a b

c d

Plate VII. (a) Presoldier and (b) soldier that developed during the first oviposition period. (Photographed by author)



a

b

Plate VIII. (a) Fifth instar larva of C. formosanus that developed just prior to or during second oviposition period; (b) Eggs of C. formosanus. Upper egg immediately after laying and lower egg just before hatching. Note difference in size and coloration. (Photographed by author)

a

b

Table XII. Stadium lengths of various growth stages of C. formosanus in laboratory colonies from paired virgin, first-form reproductives held at 26±0.5°C. Baton Rouge, La. 1970.[a/] [b/]

First instar larvae		Second instar larvae	Third instar larvae	Fourth instar larvae	First Pre-soldier
15	18	17	42	40	14
19	16	18	42	47	14
19	16	17	48	43	13
17	15	18	52	48	14
18	15	18	48	56	14
19	19	18	52	50	14
20	18	19	54	49	14
18	17	19	52	53	14
20		20	48		14
18		19	48		14
17		17	49		
18		18	49		
18		16	45		
17		20	51		
17		21			
Average±S.D.	17.565±1.472	18.333±1.345	48.571±3.631	48.50±4.870	13.9±0.316

[a/]All individuals were marked and development traced.

[b/]Fourth instar larvae were not from first oviposition period and were isolated by themselves.

first and second instar larvae from older colonies indicated that their stadium lengths could be more than 30 days. However, presoldier stadiums of other than the third instar were consistently 14 days in duration. This would indicate that the colony composition with other factors constant affected larval stadium lengths. However, regardless of the colony composition, once the presoldier is formed, it continues development toward the soldier form.

Immediately after deposition, the eggs are reniform shaped, more or less transparent, and contain an abundance of yolk that can be seen through the chorion. During development they become opaque and whitish in color. Before hatching, they become oblong in shape and body segments of the developing embryo are easily seen through the chorion (see Plate VIII).

Measurements of the eggs on the day deposited and immediately prior to their hatching are presented in Table XIII. An attempt was made to take measurements on the same egg in the different colonies, therefore, these measurements are paired. The eggs averaged 0.789 mm in length and 0.367 mm in width at the midpoint on the day of deposition and 0.878 mm in length and 0.493 mm in width at the midpoint just prior to hatching. Although it was not

Table XIII. Paired measurements (mm) of eggs of C. formosanus from first oviposition period. Eggs from laboratory colonies established with paired virgin, first-form reproductives held at 26±0.5°C. Baton Rouge, La. 1970.[a]

Day Deposited		Immediately prior to hatching		Increase in size	
Length	Width	Length	Width	Length	Width
0.815	0.379	0.910	0.493	0.095	0.114
0.778	0.379	0.872	0.512	0.094	0.133
0.797	0.379	0.872	0.455	0.075	0.076
0.797	0.379	0.891	0.493	0.094	0.114
0.797	0.379	0.853	0.474	0.056	0.095
0.759	0.341	0.891	0.493	0.132	0.152
0.815	0.341	0.853	0.512	0.038	0.171
0.797	0.341	0.910	0.493	0.113	0.152
0.759	0.379	0.853	0.493	0.094	0.114
0.778	0.379	0.872	0.512	0.094	0.133
Average±S.D. 0.789±0.01	0.367±0.02	0.878±0.01	0.493±0.01	0.089±0.01	0.125±0.01

[a] Measurements made on same egg for each observation.

determined when the eggs began increasing in size they attained maximum size in about 31 days.

Young Colony Development in the Field

Series Cf-68F: From November, 1968 through May, 1969, 16 of 18 cages sampled contained live colonies. These colonies consisted of about 30 individuals each. These individuals developed from the first oviposition period. Several individuals in cage 69 displayed the red coloration characteristic of those infested by Serratia marcescens and this bacterium was probably responsible for the low number of individuals in this colony (see Table XIV).

Beginning in July, 1969, it was necessary to sample more cages to obtain 2 live colonies. On July 2 and 3, 5 cages were sampled to obtain 2 live colonies. However, on July 31 only two cages were required. On the next 3 sampling dates, 25 cages were sampled to obtain 6 live colonies. In March, 1970, this series was terminated due to failure of the colonies.

That the mortality of these colonies occurred prior to July, 1969, was evinced, during these sampling dates, by the finding of exoskeletons of dead termites and the lack of exoskeletons at later sampling dates. After the death of

Table XIV. Number of individuals of C. formosanus developed in field colonies from paired virgin, first-form reproductives held in cages in wood blocks. New Orleans, La. 1968-1970.[a/] [b/]

Cage number	Days after pairing	Eggs	Larval Instars					Pre-soldier	Soldier	Total[e/]	Average total[d/]
			1st	2nd	3rd	4th	5th				
1	167	0	0	2	14	8	0	0	3	29	
18	167	0	0	0	17	8	0	0	3	30	29.50
120	198	0	0	0	18	5	0	0	2	27	
61	198	1	0	1	10	7	0	0	2	23	25.00
16	221	0	0	3	13	6	0	2	2	28	
42	221	0	0	0	18	10	0	0	3	33	30.50
15	256	0	0	0	10	9	0	0	3	24	
77	256	0	0	0	7	10	0	0	2	21	22.50
54	286	0	0	0	18	9	0	0	2	31	
8	286	0	0	0	16	15	0	0	3	36	33.50
95	320	0	0	0	2	1	0	0	0	5	
69	320	0	0	0	2	2	0	0	3	9	7.00
4	331	0	0	0	24	10	0	0	3	39	
75	331	0	0	0	2	1	0	0	3	8	23.50
97	365	44	0	0	11	16	1	1	3	78	
53	365	17	0	0	5	18	0	0	3	45	61.50
56	402	0	0	0	6	1	0	0	0	10	
21	402	9	8	8	9	19	1	0	5	61	35.50
60	429	0	1	0	16	11	12	0	7	49	
72	429	0	0	0	3	3	2	0	1	11	30.00
36	465	0	0	0	0	4	19	0	0	25	
58	465	1	0	0	3	7	4	0	3	20	22.50

Table XIV. (continued)

Cage number	Days after pairing	Eggs	Larval Instars 1st	2nd	3rd	4th	5th	Pre-soldier	Soldier	Total[e]	Average total[d]
79	500	0	0	0	8	23	9	0	8	50	
84	500	0	0	0	2	20	11	0	5	40	45.00
99	532	0	0	0	19	5	0	0	7	33	
34	532	0	0	0	6	17	3	1	6	35	34.00
91	566	0	0	0	31	31	6	0	11	81	
76	566	0	0	0	1	2	0	0	2	7	44.00
39	605	0	0	0	0	0	36	0	7	45	
27	605	0	0	0	0	0	6	0	3	9	27.00
33	626	0	0	0	0	0	1	0	1	4	
86	626	0	0	0	0	41	1	0	5	49	26.50

[a] Series Cf-68F, Unit A.

[b] Colonies maintained in the laboratory at $26 \pm 0.5^{\circ}C$ for the first 139 days after pairing.

[c] Total equals categories listed plus 2 first-form reproductives.

[d] Totals for each sampling date were averaged.

the termites their remains deteriorated with time and exoskeletons were only occasionally found.

On July 2 and 3, 1969, soil temperatures ranged from 31.67°C at the 20 in. depth to 41.11°C at the 5 in. depth. At the 15 in. depth, which closely approximated the temperature in the cavity in the wood block, temperatures ranged from 32.22° to 33.33°C inside the cage. The temperature of the sawdust surrounding the 1 oz. jars containing the colonies ranged from 31.11° to 34.44°C during these 2 days. These temperatures were probably all maximums since they were obtained in the middle of the day.

The percent of moisture in the soil was low during this sampling period, ranging from 0.74 percent at the 5 in. depth to 5.56 percent at the 20 in. depth inside the cages. However, the level of moisture in the sawdust in the wood block ranged from 1.53 to 1.92 parts water. In addition, the agar cap of the sawdust-agar medium did not shrink as it would have if it had dessicated.

The following information was obtained from Local Climatological Data as determined at the New Orleans, La., International Airport. From June 20 to July 9, 1969, the ambient air temperature was consistently 1.67° to 3.33°C above normal. On July 2 and 3, 1969, the day ambient air

temperature averaged above 32.22°C and ranged up to 36.67°C. At the time these high temperatures were occurring, there was very little rainfall. From June 20 to July 9, 0.15 in. of rainfall was recorded and for 5 days prior to this series of days 0.01 in. of rainfall was recorded.

The combination of high ambient air temperature and low rainfall apparently was, in part, the cause of the high soil temperatures and low percent moisture in the soil. In addition, the sandy soil allowed rapid drainage of any water, therefore, leaving little to evaporate and cool the soil. Further, there was little ground cover since the study area had been mowed regularly. After the establishment of the experimental plot, vegetation growth was not restricted.

Since only 2 colonies were removed per sampling date, the actual number of individuals found in each colony and the total average number are presented in Table XIV. All individuals found in the colonies were categorized as to developmental stage.

No eggs were found in these colonies until 365 days after pairing (May 29, 1969). Therefore, all individuals found in these colonies up to this date developed from the first oviposition period. Fifth instar larvae were found in these colonies at the beginning of the second oviposition

period. That the eggs had been recently laid was evinced by the lack of embryonic development in any of the eggs and the absence of first instar larvae.

A third oviposition period was not observed during 1969 and the test was terminated in the Spring of 1970. One colony that had been overlooked was discovered 823 days after pairing (August 28, 1970). It contained 2846 individuals of which 547 were in older stadiums and the remainder were first and second instar larvae and eggs. Several galleries were found leading from the food source into the soil. Apparently a large number of eggs was laid during the third year of development. Oviposition was not observed in the winter of 1968-1969 and 1969-1970.

The soil temperature inside the cage averaged less than $0.3^{o}C$ higher than the soil temperature outside the cages and this difference was statistically significant (see Table XV). There was no interaction between the cages and days sampled, depths sampled or depths and days sampled.

There was no difference between over-all percent of soil moisture within and outside the cages (see Table XVI). However, as indicated by the significant interaction between depth and treatment, the cages apparently affected the percent of moisture in the soil at the depths sampled.

Table XV. Analysis of variance of soil temperature at three depths inside and outside of C. formosanus cages in New Orleans, La. 1968-1970.[a]

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F
Total	215	11943.7603	55.5524	
Days	17	11038.4592	649.3211	252.1635**
Error A	18	46.3505	2.5750	
Treatment	1	5.5713	5.5713	5.0332*
Days X Treatment	17	21.5750	1.2691	1.1465^{ns}
Error B	18	19.9249	1.1069	
Depth	2	294.6878	147.3439	148.3676**
Depth X Treatment	2	1.5685	0.7842	0.7896^{ns}
Depth X Days	34	394.7144	11.6092	11.6898**
Depth X Treatment X Days	34	49.4073	1.4532	1.4632^{ns}
Error C	72	71.5016	0.9931	

[a] Based on data shown in Appendix Table 23.

Table XVI. Analysis of variance of percent of moisture in soil at three depths inside and outside of C. formosanus cages in New Orleans, La. 1968-1970.[a]

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F
Total	215	6619.9160	30.7930	
Days	17	3880.9482	228.2911	19.8272**
Error A	18	207.2512	11.5140	
Treatment	1	2.6379	2.6379	0.2400^{ns}
Days X Treatment	17	102.8842	6.0520	0.5508^{ns}
Error B	18	197.7636	10.9869	
Depth	2	268.1770	134.0885	17.4655**
Depth X Treatment	2	64.8320	32.4160	4.223*
Depth X Days	34	1006.9485	29.6161	3.8576**
Depth X Treatment X Days	34	335.7064	9.8737	1.2860^{ns}
Error C	72	552.7670	7.6773	

[a]Based on data shown in Appendix Table 24.

The cages had no effect on percent of moisture in the soil on different days.

Series Cf-69F: None of the pairs of C. formosanus survived in this test. The same high temperatures and low percent of moisture in the soil during June and July, 1969, prevailed as in Series Cf-68F. Later it was observed that most of these stakes, which were not in the cages, became infested with R. flavipes.

Series Cf-70F: Units A and B: Development in the colonies during the first 52 days after pairing was comparable in Units A and B (see Table XVII and Fig. II). However, as time progressed it was evident that colony survival and number of termites in each live colony was greater in the stakes than in the 1 oz. jars. In addition, the number of termites present in the jars was more variable than in the stakes.

The stakes remained relatively moist throughout the test period, however, they were never observed to contain free water. The material in the jars dried and became very moist during dry and wet conditions, respectively.

Fig. II. Young colony development of C. formosanus in the field in New Orleans, La. 1970-1971.

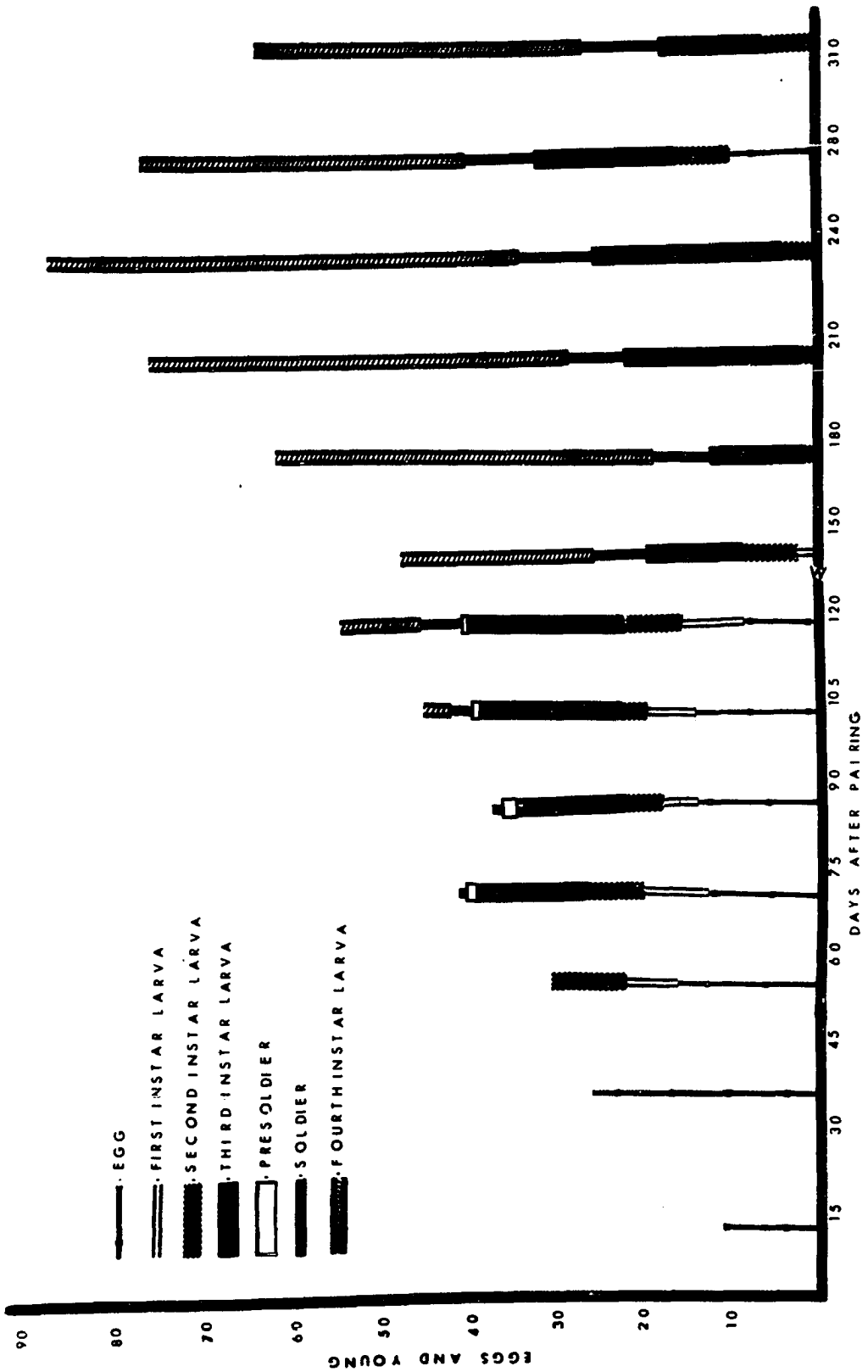


Table XVII. Number of individuals of C. formosanus developed in field colonies from paired virgin, first-form reproductives in 1 oz. jars in wood blocks. New Orleans, La. 1970.[a]

Days after pairing	Eggs	Larval Instars 1st	2nd	3rd	4th	5th	Pre-soldier	Soldier	Total[b]	Average total[c]
13	12	0	0	0	0	0	0	0	14	
	12	0	0	0	0	0	0	0	14	14.00
35	21	0	0	0	0	0	0	0	23	
	32	0	0	0	0	0	0	0	34	28.50
52	26	13	5	0	0	0	0	0	46	
	15	3	0	0	0	0	0	0	20	33.00
67	24	0	3	4	0	0	0	0	33	
	1	4	3	3	0	0	1	0	14	23.50
82	4	0	1	3	0	0	0	0	10	
	21	10	5	12	0	0	1	3	54	32.00
95	13	5	3	25	3	0	1	0	52	
	7	3	2	14	2	0	0	0	30	41.00
109	3	1	3	16	0	0	0	4	29	
	0	0	0	2	0	0	0	1	5	17.00
138	0	0	3	2	20	0	0	3	30	
	0	0	2	5	30	0	0	4	43	36.50
175	0	0	0	3	56	0	0	9	70	
	2	0	1	12	13	0	0	3	30	50.00

[a]/Unit B, Series Cf-70L.
[b]/Total equals categories listed plus 2 first-form reproductives.
[c]/Totals for each sampling date were averaged.

There was no difference in developmental rate of the termites between Units A and B as evinced by the fact that the different instars occurred at the same times. Third instar larvae, presoldiers and soldiers were first observed in Units A and B 67 days after pairing. Fourth instar larvae were found in the colonies 95 days after pairing.

Eighteen of 50 colonies were sampled in Unit B. No colonies were recovered after 175 days after pairing. Twenty-six of 46 colonies sampled in Unit A have been recovered to date. This test is being continued. Most of the colony mortality in Unit B did not occur until after pairing as evinced by larval exoskeletons. However, in Unit A most of the colony mortality occurred at the time of pairing as shown by the lack of development in the stakes.

The following results were obtained from Unit A (see Fig. II). Up to 11 eggs were found in the colonies 14 days after pairing. With the exception of 1 colony, 52 to 90 eggs were laid over a period of about 100 days. In this 1 colony, 138 individuals, including 18 eggs, were found 278 days after pairing. Many of the eggs found 278 days after pairing contained amorphous white inclusions which could be seen through the chorion. Little embryonic development was observed.

The occurrence of first and second instar larvae 52 days after pairing indicated that the incubation period was about 30 days. The combined duration of the first and second larval stadium was about 20 days. The third larval stadium was about 20 days in length and thereafter fourth instar larvae accumulated in the colonies. To date, no larvae with fifth instar characters have been found. Presoldiers and soldiers developed in the field colonies at the same time as third instar larvae which was 67 days after pairing.

The mean number of individuals observed in the last 12 colonies sampled was 70.58 with a maximum of 138. Soldiers constituted 10.74 percent of these colonies.

The first oviposition period ended about 100 days after pairing. A second oviposition period has not yet been observed 313 days after pairing.

For the first 52 days after pairing there were no galleries extended from the original copularium, which had been formed in the sawdust. Sixty-seven days after pairing gallery extension was observed and it was correlated with the development of the third instar larva.

By 175 days after pairing galleries had been constructed that extended 20 to 22.5 cm down the stake. Some galleries were found ramifying through the solid wood,

however, none were found extending into the soil. Based on these data there is not more than 23 to 30 cm of gallerying from the nursery area during the first year of development and once the copularium is formed there is no further gallerying until third instar larvae are formed.

During the first 175 days of development the nursery was always found in the sawdust in the center of the stake. After this the nursery was frequently found in a cavity in the solid wood of the stake.

The original copularium was consistently 5 to 7.5 cm below the stake top making it 12.5 to 15 cm below the soil surface. The nursery was at about this same depth during the first 175 days of development (see Table XVIII). From 207 to 278 days after pairing the nursery was found from 18 to 38 cm below the soil surface. These sampling dates spanned the months of November, December, January and February, which are the months with the coldest average temperature. Although the soil temperature at the 3 in. depth was slightly warmer than at the nursery depth, this temperature was a maximum since it was taken at midday. During this period the termites were found congregating in the nursery area and not in the galleries. The termites were found near the top of the stakes 313 days after pairing

Table XVIII. Average depth (cm) of the nursery of C. formosanus and average soil temperature (°C) and moisture percent in cages on various sampling dates. New Orleans, La. 1970-1971.[a/] [b/]

Sampling date	Days after pairing	Nursery depth[c/]	Soil Temperature		Percent moisture in soil at nursery depth
			At nursery	3 in.	
May 22, 1970	13	18.00	25.28	28.06	8.02
June 12	35	14.25	28.33	28.06	16.59
June 29	52	16.25	29.72	29.58	11.09
July 14	67	19.00	26.67	26.39	10.12
July 29	82	15.00	29.73	30.84	6.92
Aug. 11	95	13.75	28.88	29.44	10.42
Aug. 25	109	14.50	28.06	27.78	13.28
Sept. 23	138	14.00	27.22	26.95	11.05
Oct. 30	175	13.50	22.78	23.06	13.46
Dec. 2	207	22.50	19.44	17.78	10.92
Jan. 3, 1971	239	38.00	14.44	15.28	12.68
Feb. 11	278	28.00	13.88	15.84	10.10
Mar. 8	313	8.89	15.70	19.17	12.14

[a/] Series Cf-70F, Unit A.

[b/] Colonies established in stakes in cages from paired virgin, first-form reproductives.

[c/] Stake (12 in. in length) imbedded vertically 3 in. below soil surface.

and the soil temperature at this depth was 18.89°C. Cavities were found in both stakes 22 cm below the soil surface in which the termites had been active and the soil temperature at this depth was 15.70°C. Apparently the termites had moved from this area to the area near the top of the stake in response to the warmer temperature.

If there was a response to rainfall in vertical movement I was unable to detect it in this test. No movement was observed 95 and 109 days after pairing, although at each sampling date about 2 in. of rainfall had been recorded within two days prior to sampling. However, 138 days after pairing the termite nursery was 11.25 cm below the soil surface and 0.74 in. of rainfall had been recorded. The soil moisture percent apparently was favorable for the stake colonies throughout the test as indicated by the high percentage of colony survival and the number of individuals per colony.

About 6 colonies have been recovered in each of 4 cages, however, only 2 were recovered in 1 cage. One colony had been removed from this cage 13 days after pairing and the second was removed 82 days after pairing. The remaining 8 stakes 82 days after pairing were infested with R. flavipes. R. flavipes was probably in the stakes when placed in the

cages since no galleries entering the cage were observed. No R. flavipes were found in the stake containing the C. formosanus colony.

Observations on Mature Field Colonies

Sex Ratio: A significantly higher number of males was found in all samples of alates, which had been removed from a nest, with one exception (see Table XIX). The exception was a colony sampled May 8, 1970. There was no significant difference between number of male and female alates taken from light trap samples.

On April 18, 1969, a group of nymphs, just prior to molting to the adult stage, were sampled and found to contain 117 males and 11 females. A pigmented nymph was found frequently occurring in mature colonies. These pigmented nymphs have been observed to emerge from nests in laboratory colonies which were obtained from mature field colonies, and attempt to swarm. On one occasion, a male and a female of the pigmented nymphs were observed to pair. In two collections of these pigmented nymphs, 9 males and 0 females were found in one collection; and 10 males and 2 females were found in the second collection.

Table XIX. Number of males and females of C. formosanus found in various samples from mature colonies and light traps.

Date of Collection	General Location	Substrate[a/]	No. Males	No. Females	X^2 Value
		Adults removed from nests			
May 9, 1968	New Orleans, La.	Southern "yellow" pine	398	44	283.52 **
May 20, 1968	New Orleans, La.	Southern "yellow" pine	1372	1080	37.77 **
April 18, 1969	New Orleans, La.	Southern "yellow" pine	117	11[b/]	87.78 **
May 30, 1969	New Orleans, La.	Southern "yellow" pine	998	400	255.80 **
May 8, 1969	New Orleans, La.	Southern "yellow" pine	318	313	0.04^{ns}
		Adults removed from light traps[c/]			
May 4, 1970	New Orleans, La.	--	56	44	1.44^{ns}
May 15, 1970	New Orleans, La.	--	49	57	0.04^{ns}
May 26, 1970	New Orleans, La.	--	58	42	2.56^{ns}
June 4, 1970	New Orleans, La.	--	55	45	1.00^{ns}

[a/] Substrate given only for those adults removed from nest.

[b/] Count made on nymphal stage.

[c/] Counts determined from a sample of 100 adults from each light trap collection date. The first 3 samples were from the same location.

Reproductives: Nests headed by second-form reproductives have been found at about the same frequency as nests headed by first-form reproductives (see Table XX). Only one of a male and/or female first-form reproductive was found in any nest. Nests containing female second-form reproductives were found to contain as many as 138 females. No male second-form reproductives were found. However, in one nest containing 7 second-form female reproductives, a male first-form reproductive was found. No third-form reproductives were found in any of the colonies.

No difference in colony members was observed between colonies headed by first and second-form reproductives. Nymphs, soldiers, pigmented nymphs and various larval instars were found in all mature colonies. No attempt was made to determine if any of the individuals were pseudergates.

Female first-form reproductives measured up to 21 mm in length and 5.0 mm in width at the fifth sternite. Male first-form reproductives were generally about the same size as they were at swarming. The male first-form reproductive found with the 7 female second-form reproductives was 8.1 mm in length and his abdomen was 1.75 mm in width at the fifth sternite.

Table XX. The occurrence of the various reproductive forms in field colonies of C. formosanus.

Date of Collection	General Location	Substrate	Type Reproductives		Number Reproductives	
			Male	Female	Male	Female
February 16, 1967	Westlake, La.	-	-	second-form	-	6
May 13, 1967	Westlake, La.	Southern "yellow" pine	first-form	first-form	1	1
June 29, 1967	New Orleans, La.	Southern "yellow" pine	-	second-form	-	19
June 29, 1967	New Orleans, La.	Southern "yellow" pine	-	second-form	-	2
November 5, 1969	New Orleans, La.	Southern "yellow" pine	first-form	second-form	1	7
April 18, 1969	New Orleans, La.	Southern "yellow" pine	-	first-form	-	1
August 7, 1970	Westlake, La.	Bald cypress	-	first-form	-	1
June 13, 1967	Westlake, La.	Bald cypress	-	first-form	-	1
May 18, 1967	Lake Charles, La.	Bald cypress	first-form	first-form	1	1
May 7, 1970	New Orleans, La.	Southern "yellow" pine	-	second-form	-	138

DISCUSSION

The bacterium, Serratia marcescens, apparently was the cause of the high initial mortality among adults in Series Cf-67L, Units A and B. Symptoms of infection by this bacterium were also recognized among alates of the same source colony in the field. On several occasions segments of field colonies brought into the laboratory have exhibited the red discoloration that is indicative of the presence of this bacterium (King and Spink, Unpublished Data). Lund (1965) reported that this bacterium was pathogenic to several species of Reticulitermes and usually the red strain is most toxic. One colony in Series Cf-68F contained S. marcescens and was probably responsible for the relatively small size of the colony.

In Series Cf-67L, Units A and B, the adults had not been dealated prior to installation in the culture jars. As a result their wings frequently stuck to the media and to the condensation on the glass and they eventually died. In the remaining series, the wings were mechanically removed prior to pairing. Schimizu (1963) earlier reported this practice for R. speratus.

Extensive microorganism development in the culture media, most of which appeared to be due to the presence of the mites, was probably detrimental to the termites. Becker (1969) stated that a large number of mold fungi, white rot fungi and bacteria can produce toxic substances. This was probably the cause for mortality and reduction in colony size in Series Cf-68L. In Unit E, Series Cf-70L, the termites appeared to be restricted to areas on the paper toweling which lacked mold development. Collembola were found in both laboratory and field colonies and Becker (1969) reported that their presence was useful in the control of fungi.

Although 2 parts water to 1 part sawdust appeared to be adequate for rearing the termites it probably was not the optimum level. Esenther (1969) reported feeding by R. flavipes on sawdust containing up to "600 percent moisture." Based on this report, a higher level could probably have been used in my study. However, in this study, at high moisture levels, the paired virgin, first-form reproductives stuck to water condensation on the glass and died while attempting to construct the copularium.

In Series Cf-68F and Cf-70F, Unit B, the 1 oz. jars appeared to collect moisture and this was probably a mortality factor in both cases. However, dessication also occurred in

Series Cf-70F, Unit B. Moisture content in these jars apparently fluctuated with the soil moisture percent since they were placed directly in the soil. In Series Cf-70F, Unit A, the stakes apparently allowed good drainage and maintained an optimum moisture percent as indicated by survival and development.

Temperature proved to have a marked effect on colony survival and development. Poor survival of colonies was obtained at 16°, 21.5° and 32°C. However, in those colonies that did survive at 32°C a higher fecundity and developmental rate was recorded. Williams (1965) stated that at 40°C the protozoans in the gut of C. niger died and subsequently the termites died. Based on this article and the low colony survival after high temperatures were recorded and results obtained in the laboratory at 32°C, it was concluded that high temperatures recorded in the field from June 20 to July 9, 1969, were responsible, in part, for the high mortality in Series Cf-68F. At low temperatures (7.5° to 16°C) the termites became quiescent and mortality was probably due, in part, to depletion of nutritional reserves and subsequent starvation. Survival was obtained in colonies refrigerated at 7.5°C after about 14 days and among adults maintained at 16°C for 35 days. Apparently adequate feeding took place at 21.5°C but was greatly reduced at 16° and 7.5°C.

In the laboratory as temperature was increased the fecundity and developmental rate also increased. However, fecundity appeared to be greater in the field in Series Cf-70F, Unit A, even though the temperature was lower than the highest laboratory temperature. At 26° and 32°C and in Series Cf-70F, Unit A, about 20 to 30, 54 and 71 individuals were produced in the first oviposition period, respectively. The number of individuals obtained at 26°C in Series Cf-67L, Cf-68L, and Series Cf-70L, Unit A, is in agreement with results obtained by other authors on C. formosanus. However, in none of the papers were conditions cited. The results I obtained at 32°C and in Series Cf-70F, Unit A, are considerably different than those obtained by other authors. Oshima (1919), Mori, et al. (1964) and Bess (1970) reported that in C. formosanus 20 to 25 eggs, about 20 eggs and about 30 eggs, respectively, are deposited by C. formosanus in the first oviposition period. These differences may merely reflect different culture temperatures. However, Oshima (1919) reported the incubation period to be 24 to 32 days; therefore, the culture temperature had to be near 32°C and this difference in number may be due to culture methods.

Smythe and Carter (1970a) reported that 27°C approximated the optimum for both good survival and wood consumption for colony segments of C. formosanus. Based on this finding and results obtained in Unit A, Series Cf-70L, 26°C may have been slightly low for optimum colony survival and development. However, Becker (1969) did state that the optimum temperature for the development of the young colony and egg production may be somewhat lower than that for wood consumption and probably for other activities of larvae and workers.

Chapman (1969) gave two possible reasons for failure of eggs to hatch at low temperatures: the larvae may be inactive at the lower temperatures and/or the temperature may not be sufficiently high for the enzyme digesting the serosal cuticle to function efficiently. Since C. formosanus is less active at 21.5°C, the first reason appears to be a credible explanation for the failure of eggs to hatch at 21.5°C. Since virtually complete embryonic development was observed in some eggs in colonies maintained at 21.5°C it appears that the threshold temperature for embryonic development is lower than that for hatching.

The difference in time between oviposition periods in laboratory and in field colonies was probably due to lower

temperatures in the field. No references have been found relating these oviposition periods to light as a direct stimulus. However, Nutting (1969) stated that in termites found in temperate climates oviposition ceases during the colder months. Harris (1970) reported that activity within colonies of R. flavicollis is governed by the succession of summer and winter. During cold weather oviposition, feeding and molting stops. Eggs laid during the last 2 weeks of October overwintered and resumed development toward the end of May. C. formosanus behaved, in part, in this same manner in Series Cf-68F and Series Cf-70F, Unit A. No eggs were laid during the winter in either series and if molting occurred it was at a low rate as evinced by the length of the fourth larval stadium in both series and the presence of second instar larvae in Series Cf-70F, Unit A. Eggs were found in 1 colony in Series Cf-70F, Unit A, however, these eggs were thought to be from the first oviposition period for the following reasons: (1) adults in this series were not laying at the time of collection nor were they ovipositing 1 month later; (2) fifth instar larvae, which were found to occur at the beginning of the second oviposition period, were not found in this colony; (3) egg laying did not begin until May, 1969 in Series Cf-68F; and (4) some of these eggs

contained amorphous white inclusions similar to those eggs found in colonies maintained at 21.5°C. Young larvae, apparently newly hatched from eggs, have been found in mature field colonies during February (King and Spink, Unpublished Data). Apparently the temperature in the nursery was high enough for embryonic development to proceed and for eggs to hatch. Greaves (1964) has shown that large termite colonies can modify the ambient air temperature by as much as 20°C.

An activity pattern which also appeared to be related to temperature was recognized in Series Cf-70F, Unit A, (see Table XVIII). The nursery area was found near the soil surface during the summer and early fall, but was found deeper in the soil during the winter months. In addition, 313 days after pairing the nursery area was again found near the soil surface and this was probably due to warmer soil surface temperatures. These data indicate that daily fluctuations in location of these termites does occur in response to temperature. This is in agreement with findings in Wisconsin by Esenther (1969) on R. flavipes. Since the termites were apparently restricted during the first winter to the 1 oz. jars in Series Cf-68F and were constantly under a low temperature, this could also have been a mortality factor in this series.

Buckman and Brady (1960) stated that the temperature of the surface layers of soil vary more or less with the air temperature and the subsoil is characterized more by seasonal changes. This was borne out in tests in New Orleans. In addition, they stated that the subsoil is warmer in the winter than the surface layers. This was generally true from 207 to 278 days after pairing in Unit A, Series Cf-70F and it was reflected in the nursery depth.

The termite activity was sluggish when soil temperatures were below 21°C. At lower temperatures (about 16°C) they were found bunched together which was probably a response to modify the temperature. This behavior pattern has frequently been observed during the winter in mature colonies of C. formosanus (King and Spink, Unpublished Data).

It is interesting to note that the temperature Weesner (1956) used in rearing young colonies of R. hesperus was 21.11°C and Pickens (1932) stated that "laboratory experiments show 18° to 22°C as the most favorable temperatures for reproductive activities and growth of the young" in Reticulitermes. This points out a distinct species difference between C. formosanus and the above 2 species and lends some credibility to the statement by Weesner (1970) that the current C. formosanus infestations on the mainland U. S.

appeared to be peripheral ones. Temperature will apparently restrict future northward dispersal. It would probably be a more effective deterrent against colonies initiated by virgin first-form reproductives than colony segments which could form replacement reproductives. This would be true due to the apparent inability of these young colonies to greatly modify the ambient temperatures. Reproduction through replacement reproductives was found to be the normal means of reproduction in R. flavipes in Wisconsin (Esenther, 1969) and may also be true for C. formosanus should it disperse northward.

Smythe and Carter (1970b) have shown that freshly ground sawdust of slash pine and loblolly pine was not preferred by C. formosanus. However, most of the termites maintained in our laboratory were reared on southern "yellow" pine sawdust. Becker (1969) stated that pinewood can show a repellent effect, which disappears after leaching with water. The fact that the sawdust utilized in the rearing of C. formosanus had been leached by water and was partially rotted probably contributed to survival. In addition, C. formosanus was active in this sawdust in the field.

Moore (1969) stated that controlled cannibalism was a factor in the nitrogen economy of most termites and in times of nutritional hardship extensive cannibalism may take place. Buchli (1956) stated that decrease in size of the first egg hatch was due to cannibalization of the eggs and young larvae. He stated that 2 to 4 of the larvae developing in the first oviposition period in each young colony of R. lucifugus were cannibalized. The above factors could, in part, explain the reduction in size of colonies of Series Cf-68L between the first and second oviposition period and the failure of first instar larvae to reach the second instar in Unit D, Series Cf-70L.

The use of stakes in the field in Unit A, Series Cf-70F apparently provided nearly optimum conditions for colony survival and development. More individuals were recorded per colony and colony survival was higher than in any other group reared in the laboratory or in the field. The fact that they could move vertically in the stakes probably allowed them to stay within a favorable environment. However, it did appear that once the copularium was built little or no movement from this area occurred until the formation of the third instar larvae. Becker (1969) stated that termites produce their own microclimate in their nests

and galleries and the utilization of stakes in the field probably enhanced this ability.

The cages effectively prevented invasion by other termites in all cases except one and in this case R. flavipes was probably in the stakes when they were buried in the cages. R. flavipes probably inhibited development of some of the young colonies in these stakes. This incident proved the need for a cage in the field. Pickens (1934) reported the placement of potential colonies of R. hesperus in cages, but native workers in the same territory explored the surface of the cage beneath the ground and destroyed most of the colonies.

Pairing between female, virgin first-form reproductives was observed in the laboratory. This observation was contrary to Stuart (1969) where he stated that females would not form chains and the fact that females did not exhibit the following response had probably evolved for the reason that two females founding a nest would be biologically uneconomical. Both Weesner (1956, 1965) and Buchli (1950) obtained results similar to the findings in our laboratory. Williams (1965) concluded that in C. niger pairing took place only in the presence of a potential nest site. This apparently was not true in C. formosanus since they were pairing in open petri dishes. In addition, pairing was observed in the plastic jelly cups in Series Cf-69F and Series Cf-70F, Unit A.

In general, the sequence of events in C. formosanus colonies was similar to those in other species as reported by different authors (Harvey, 1934; Pickens, 1934; Weesner, 1965; etc.). Most other papers deal with the first oviposition period only and in many the developmental stages are not categorized. A number of species differences have been found and differences have been found between laboratory and field data.

In C. formosanus the following developmental pattern appeared to be followed. In Louisiana swarming by alates from the nests occurs from the last of April to the first of June (King and Spink, Unpublished Data). In the laboratory once the adults were paired a copularium was formed within 24 hours. Mating was observed to occur at 26°C within 72 hours after pairing. Removal of 2 to 4 of the terminal segments occurred within 96 hours after pairing. Buchli (1950) and Williams (1959; 1965) have observed amputation of the antennal segments in other termite species. Williams (1959) concluded that this was a manifestation of cannibalism. Removal of several of the terminal antennal segments also occurred in females that had been paired together in Series Cf-70L. The preoviposition period varied with temperature and was 3 to 4 days at 32°C and up to 27 days at 21.5°C.

Oviposition was gradual during the first oviposition period with 0 to 3 eggs being laid per day during the first 40 to 60 days after pairing. However, some eggs were laid after this in laboratory and field colonies. A period then followed in which no eggs were laid. The length of this period differed between the laboratory and field; about 120 days in the laboratory at 26°C and about 220 days in the field. Most authors studying this phase of colony development in different termite species recognize 2 distinct oviposition periods. However, Nutting (1969) reported that Buchli stated that at higher laboratory temperatures oviposition is more nearly continuous. The ceasing of oviposition in the laboratory may be due to a depletion in sperm supply since Weesner (1956) stated that there was a marked reduction in number of sperms by 130 days after pairing in R. hesperus. She further stated that copulation is apparently repeated before the resumption of egg laying.

Four larval instars were recognized in the first oviposition period. The first and second instar larvae were at first cared for by the young adults. When the young reached the third stadium of development they assumed an active role in the colony. They assisted the adults in caring for the eggs and the young, groomed and fed other individuals, and

initiated gallerying from the copularium. Functionally speaking, larvae of the third instar and thereafter could be considered workers. The larvae remained in the third stadium 30 to 40 days and then molted to the fourth instar. Fourth instar larvae appeared in the colony until the beginning of the second oviposition period when they began molting to the fifth instar. These results are in agreement with Williams (1965) on C. niger 16 weeks after pairing, but appear to be somewhat different than those presented by Oshima (1919) on C. formosanus. Oshima apparently failed to detect the second instar larva and consequently combined these two stadiums calling them "newly hatched undifferentiated larvae." Therefore, the "worker larva" he described with 12 antennal segments and 0.91 to 0.94 mm head width are believed to be third instar larva and not the second instar. Neither Mori, et al. (1964) nor Bess (1970) reported the developmental stages of the young in C. formosanus. Buchli (1950, R. lucifugus) and Light and Weesner (1955, R. hesperus) reported that there was a break between the first and second oviposition periods and that the second oviposition period begins after the first larvae molt to the fourth instar. However, Weesner (1956, R. hesperus) reported some colonies depositing two distinct groups of eggs during the first six months after

pairing and in these cases the third larval stadium was relatively short.

In both the laboratory and field fifth instar larvae were produced at about the beginning of the second oviposition period. The stadium lengths of the fourth instar larvae, which developed during the first oviposition period in laboratory colonies maintained at 26°C and in the field were about 100 and 200 days in length, respectively. This difference was believed to have been due to lower temperatures in the field. The stadium length of fourth instar larvae from later oviposition periods averaged 48.5 days at 26°C. Apparently there is also some interaction between the development of fifth instar larvae and the beginning of the second oviposition period. Larval development in the second, third and fourth oviposition periods in the laboratory differed from the first oviposition period in that larval development proceeded through the fifth instar and did not stop at the fourth instar. Based on measurements at the beginning of the third oviposition period a different growth stage occurred and it was classified as a sixth instar larva. This growth stage occurred in only a few colonies and at a frequency of 1 to 3 per colony.

There is a possibility that the fifth instar larvae in the third and fourth oviposition periods could have been pseudergates. Miller (1969) defined a pseudergate as an individual that has regressed from nymphal stages by molts that reduce or eliminate wing buds or as an individual derived from a larva by undergoing "stationary," nondifferentiating molts. To be a pseudergate they would have had to fit the second definition. However, in this study it was not determined if these later stages were actually undergoing nondifferentiating molts. The first five larval stages that were reported in Series Cf-70L, Unit E, were not pseudergates and were collected in the sequence in which they occurred in the colonies.

Colonies sampled between the first and second oviposition period in Series Cf-67L, Cf-68L, Cf-68F and Cf-70F, Unit A, averaged 8.18, 7.88, 10.20 and 10.74 percent soldiers, respectively. In Series Cf-67L, colonies sampled 1126, 1188 and 1349 days after pairing averaged 6.1, 8.6 and 6 percent soldiers, respectively. In Series Cf-68L, the percent soldiers averaged 13.34 and 8.13 percent in colonies sampled between the second and third and third and fourth oviposition periods, respectively. Most of the termites were removed from an auxillary nest of C. formosanus after

the alates had swarmed. This nest contained over 60,000 termites, including 13.22 percent soldiers (King and Spink, Unpublished Data). It has been reported that for any given species there is a relatively constant soldier ratio (Luscher, 1961; Light, 1942; Miller, 1942). Apparently this is true in C. formosanus, the ratio being about 1 soldier to 10 termites. Oshima (1919) reported that after 5 months of colony growth soldiers make up about 10 percent of the individuals in a young colony of C. formosanus. Nakajima, et al. (1964) stated that in natural field colonies of C. formosanus the soldiers made up 5 percent of the colony, however, in caged feeding stations they ranged from 20 to 60 percent. The latter figure appears to be too high and it was probably as King and Spink (1969) pointed out that the soldiers were conspicuous because of their defensive function and the "workers" had retreated. Of 17 termite species reported by Bouillon (1970) only Trinervitermes had a greater percentage of soldiers than C. formosanus. Roonwal (1959) reported that soldiers made up 33 percent of one colony of C. heimi (Wasm), however, Roonwal (1970) reported that they usually make up about 10 percent of the colony. Gay and Calaby (1970) reported that soldiers make up 2 to 3 percent of the individuals in a colony of C. lacteus.

The soldier develops from a presoldier which Weesner (1965) states always molts to produce a soldier. Presoldiers of C. formosanus in the first oviposition period developed from second instar larvae, however, in the second to fourth oviposition period they developed from second, third and probably fourth instar larvae. King and Spink (Unpublished Data) found that soldiers derived from mature colonies were frequently larger and had more antennal segments than those formed during the first four oviposition periods. Soldiers with wing pads were found in 1 colony segment from a mature colony that was being maintained in the laboratory (King and Spink, Unpublished Data). Apparently the larger soldiers were derived from later instar larvae than those observed during the first four oviposition periods in the laboratory and the soldiers with wing pads were derived from nymphal instars.

Oshima (1919) reported that soldiers in the first oviposition period arose from the "newly hatched larvae." This apparent discrepancy was due to his failure to separate the first and second instar larvae.

Weesner (1965) stated that the earliest stadium in which the presoldier is known to appear in the young colony is the fourth. In the lower and middle termites, which

includes C. formosanus, the presoldier is usually a fourth instar individual. This statement contradicts the finding that in C. formosanus presoldiers can arise from second instar larvae and is therefore a third instar individual. In addition, Williams (1965) working with C. niger indicated in his data tabulations and Roy-Noel (1968) working with C. intermedius indicated in his summary that presoldiers could arise from second instar larvae in these species.

Presoldiers and a corresponding increase in soldier number occurred only during marked periods of egg laying in field and laboratory colonies. However, in Series Cf-70L, Unit E, presoldier production in the larvae could be stimulated by removing the existing soldiers in the colony. Apparently, the occurrence of soldier production is related to a constant soldier ratio and as the individuals increase in a colony, soldier numbers increase. C. formosanus apparently responded differently than did K. flavicollis in laboratory colonies where Luscher (1961) states that soldier regulation is slower and very often does not occur. Since no nymphs were present through the first four oviposition periods in Series Cf-68L and in colonies from Series Cf-67L, it would appear that the mechanism for soldier production in C. formosanus is different than that reported by Luscher

(1960) in K. flavicollis. He proposed the following: (1) soldier differentiation is caused by a gonadotropic hormone produced by the corpora alata; (2) it was possible since soldiers in the field are produced in large numbers when nymphs molt into adults they were picking up the gonadotropic hormone from the excreta; and (3) the first soldier in a young colony was the result of gonadotropic hormone in the excreta of the parents. However, in C. formosanus soldiers are readily formed in colony fragments in which the soldiers are removed and which lack nymphs and adults. This was found in Series Cf-70L, Unit E, and also in other tests (G. R. Strother, Personal Communication). Soldiers are produced in large numbers when nymphs molt into adults in C. formosanus (King and Spink, Unpublished Data), however, this also corresponds with a period when eggs are found in large numbers.

During the first oviposition period the first-form reproductive abdomen decreased in size in Series Cf-68L. This probably reflected their role in caring for the young during this period of development. Based on measurements of first-form reproductives in Series Cf-67L and in Series Cf-70F, Unit B, the same thing occurred and it was after the eggs began hatching that a decrease in size was observed.

Buchli (1950, R. lucifugus) reported that during the larval stages of the first oviposition period the first-form reproductives lose weight and become more slender. The reproductives did not regain their original size and show actual growth until the third oviposition period in C. formosanus. The increase in size of the female was apparently due to the maturation of more and more ovarioles as reflected in her greater fecundity. It appears from Fig. I that after the first oviposition period the female decreases in size between oviposition periods and this is probably due to the lack of eggs in her abdomen. Probably a greater size by the female is attained in the field than is recorded here as indicated by the greater fecundity and number of individuals developed in Series Cf-70F and in the one colony in Series Cf-68F found 823 days after pairing.

Bess (1970) reported that in the laboratory the following number of individuals were found in the more successful colonies: first year 40; second year 250; third year 1250; and fourth year 5000 plus. The maximum number of individuals in laboratory colonies maintained at 26°C during the first 3.5 years closely agree with his results. However, at 32°C in the laboratory and in the field a greater number of individuals was obtained. Therefore, the numbers cited in

Bess (1970) and our results from the laboratory are probably lower than the actual numbers that are attained in the field. It is apparent that colony size was increased by increased fecundity of the female and by the retention in the colony of young produced during preceding years. Ths termites, with the exception of the first-form reproductives which can live considerably longer, lived for over one year as can be deduced from the results. Individuals in colony segments have been maintained in the laboratory for up to 2.5 years before they were discarded (King and Spink, Unpublished Data) and Van Zwaluwenburg (1934) reported C. formosanus workers and soldiers live up to 3 years. Although C. formosanus first-form reproductives have been observed to live in the laboratory for 3.5 years they apparently live much longer as evinced by large colonies containing first-form reproductives in the field. Snyder (1948) reported first-form reproductive females living for 25 years.

Bess (1970) reported that no alates developed in laboratory colonies which were 1 to 5 years old. Nymphs were not observed in any of our colonies which were up to 3.5 years old. This could be due to a pheromone produced by the first-form reproductives (Wigglesworth, 1965) and/or due to nutrition (Luscher, 1960, 1961; Buchli, 1958). Buchli (1958) reported

that nymphs developed in colonies of R. lucifugus santonensis containing 200 workers 18 months after colony foundation and in R. lucifugus colonies with 1000 workers a minimum of 4 years developmental time was required.

No pigmented nymphs or second-form reproductives were found in any of the young colonies. However, both were found in mature colonies. A number of authors (Gay, et al., 1955, C.lacteus; Snyder, 1948, Reticulitermes; Esenther, 1969, R. flavipes; Hrdy, 1965, C. formosanus; Skaife, 1955, Amitermes atlanticus) believe that pigmented nymphs are potential replacement reproductives. Since they do possess wing pads, indicating that they are related to nymphs, the reasons for failure to find nymphs in the young colony could be the same as the failure to find pigmented nymphs and subsequently second-form reproductives.

It does appear that an unequal sex ratio among adults did occur in some colonies. However, these data could reflect a nonrandom distribution of males and females in the nest, although it would not explain the constant observation of more males than females. Buchli (1958) and Sands (1965) reported unequal numbers of male to female in R. lucifugus and five species of Trinervitermes, respectively.

Several authors have reported that replacement reproductives rarely occurred in Coptotermes spp. (Gay, et al., 1955, C. acinaciformis and C. lacteus; Williams, 1965, C. niger; Becker, 1969, Coptotermes spp.). However, Roonwal (1970) reported that replacement reproductives are commonly produced in C. curvignathus. Based on our findings, replacement reproductives are frequently found in the field in C. formosanus colonies. The following authors have reported replacement reproductives in C. formosanus: Oshima, 1919; Keck, 1954; Tang Chuh and Li Shen, 1960; National Pest Control Association, 1966; Beal, 1967; King and Spink, 1969; and Bess, 1970. However, Oshima (1919) stated that replacement reproductives were rarely found in C. formosanus.

Male first-form reproductives frequently were not found in the colonies. They apparently escaped notice due to their greater mobility. No male second-form reproductives were found, however, this form has been reported by other authors (Tang Chuh and Li Shen, 1960; and Beal, 1967).

Although a number of authors have shown that different species in the lower and middle termites will readily produce replacement reproductives when separated from the functional reproductives this has not proven true for C. formosanus in the laboratory (D. J. Martin, Personal Communication;

G. R. Strother, Personal Communication). It appears that they are produced only under certain environmental conditions. However, this condition must occur in the field as evinced by their frequent occurrence.

Pigmented nymphs were found only in mature field colonies. They were found in colonies headed by first and/or second-form reproductives. Hrdy (1965) described this form for C. formosanus and speculated that it was a nonfunctional reproductive which became functional when the functional reproductive was lost. His attempts to verify this hypothesis failed. One pair of pigmented nymphs set up in our laboratory also failed to survive.

CONCLUSIONS

1. Egg-laying is not continuous but consists of a series of oviposition periods.
2. The colony increases in size due to, in part, an increase in egg-laying capacity of the female reproductive and to the longevity of the colony members.
3. Pairing may occur between termites of the same sex. However, there is a stronger attraction between male following female.
4. Parthenogenesis was not observed in these studies.
5. Copulation occurs after the copularium is constructed and during this time several terminal segments are apparently removed from the antennae of the male and the female.
6. Fecundity and developmental rate increases with temperature.
7. The threshold temperature is lower for embryonic development than it is for hatching.
8. Four larval instars are formed during the first oviposition period.

9. The first and second larval instars, the presoldier and the soldier are fed by other colony members.
10. Soldiers in the first oviposition period are fourth instar individuals.
11. Soldiers constitute about 10 percent of the colony during at least the first 3.5 years of development.
12. The development of the first fifth instar larvae is closely associated with the beginning of the second oviposition period.
13. No oviposition occurs in young colonies during the winter in the field for at least the first two years of development.
14. In part, vertical movement in soil by C. formosanus is governed by temperature.
15. Once the copularium is completed there is no further gallerying until third instar larvae are formed. There is not more than 20 to 30 cm of gallerying from the original nursery area during the first year of development.
16. There is a reduction in size of the first-form reproductives during the first oviposition period.
17. There is an interaction between colony constituents and larval stadium lengths.

18. There are more males than females in some mature colonies of C. formosanus.
19. Female second-form reproductives occur frequently among mature field colonies.
20. Field conditions modified colony activity patterns as shown in the laboratory, thus emphasizing the need for further studies of the biology of termites in the field.

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APPENDIX

Table 1. Number of individuals of C. formosanus developed in laboratory colonies from paired virgin, first-form reproductives, Baton Rouge, La. 1967-1968.[a/] [b/]

Days after pairing	Jar Number	Eggs	Larvae[c/]	Pre-soldiers	Soldiers	Total[d/]
23	13-A	5	0	0	0	7
	14-A	6	0	0	0	8
	15-A	7	0	0	0	9
	89-B	8	0	0	0	10
37	68-A	12	0	0	0	14
	66-A	10	0	0	0	12
	65-A	0	0	0	0	2
	112-B	11	0	0	0	13
51	71-A	24	0	0	0	26
	70-A	15	0	0	0	17
	69-A	8	0	0	0	10
	113-B	0	0	0	0	2
65	74-A	23	0	0	0	25
	73-A	7	0	0	0	9
	72-A	21	0	0	0	23
	114-B	29	3	0	0	34
79	75-A	27	0	0	0	29
	76-A	21	6	0	0	29
	77-A	1	3	0	0	6
	115-B	24	3	0	0	29
93	78-A	24	7	0	0	33
	79-A	29	7	0	0	38
	80-A	1	0	0	0	3
	116-B	0	0	0	0	2
107	81-A	28	12	0	0	42
	82-A	17	15	0	0	34
	83-A	28	16	3	0	49
	117-B	11	24	1	1	39
121	86-A	17	27	0	3	49
	85-A	17	20	0	0	39
	84-A	49	0	0	0	51
	118-B	7	30	1	2	42
135	89-A	13	20	0	0	35
	88-A	2	4	0	0	8
	87-A	1	33	1	1	38
	119-B	8	41	0	3	49

Table 1. (continued)

Days after pairing	Jar Number	Eggs	Larvae[c]	Pre-soldiers	Soldiers	Total[d]
149	90-A	1	30	0	2	35
	91-A	0	35	0	3	40
	92-A	6	39	0	3	50
	120-B	0	0	0	0	2
163	97-A	9	31	0	2	44
	94-A	3	35	0	3	43
	93-A	10	25	0	1	38
	121-B	0	27	0	3	32
177	98-A	2	27	0	3	34
	99-A	3	30	0	3	38
	101-A	0	26	0	2	30
	122-B	0	23	0	3	28
191	104-A	0	35	0	3	40
	124-B	0	37	0	3	42
	125-B	0	39	0	2	33
	126-B	0	36	0	5	43
202	105-A	0	34	0	3	39
	127-B	0	29	0	3	34
	128-B	0	35	0	5	42
	129-B	0	30	0	2	34
217	130-B	0	26	0	3	31
	131-B	0	27	0	2	31
	132-B	0	30	0	3	35
	133-B	0	30	0	2	34
231	137-B	0	29	0	3	34
	136-B	0	29	0	3	34
	135-B	0	26	0	2	30
	134-B	2	25	0	3	32
245	138-B	0	29	0	2	33
	139-B	0	26	0	3	31
	140-B	0	25	0	2	29
	141-B	0	20	0	2	24
259	14-A2	8	31	0	2	43
	67-A2	1	34	0	3	40
	113-B2	0	24	0	2	28
	142-B	6	28	0	3	39

Table 1. (continued)

Days after pairing	Jar Number	Eggs	Larvae[c]	Pre-soldiers	Soldiers	Total[d]
273	75-A2	0	14	0	1	17
	76-A2	9	24	0	3	38
	78-A2	0	28	0	2	32
	115-B2	0	20	0	2	24
289	83-A2	0	24	0	1	26
	72-A2	27	24	0	3	56
	117-B2	19	32	0	5	53
	79-A2	24	20	0	2	48
303	85-A2	83	22	0	2	109
	87-A2	33	22	1	2	60
	86-A2	34	23	0	4	63
	118-B2	33	19	0	2	56
319	89-A2	0	8	0	2	12
	119-B2	91	41	0	6	140
	141-B2	7	26	0	3	38
	91-A2	33	40	0	5	80

[a] Colonies cultured at room temperature of about 26°C. Relative humidity and photoperiod were not controlled.

[b] Unit A and B of Series Cf-67L.

[c] Larvae category includes first through fifth instar larvae.

[d] Total includes the categories listed plus first-form reproductives.

Table 2. Number of individuals of C. formosanus produced in laboratory colonies from paired virgin, first-form reproductives. Baton Rouge, La. 1968-1970.[a/] [b/]

Days after pairing	Eggs	Larval Instars[c/] 1st	2nd	3rd	4th	5th	Pre-soldier	Soldiers	Total[d/]
28	20	0	0	0	0	0	0	0	22
	15	0	0	0	0	0	0	0	17
	17	0	0	0	0	0	0	0	19
	13	0	0	0	0	0	0	0	15
45	18	0	0	0	0	0	0	0	20
	29	0	0	0	0	0	0	0	31
	26	0	0	0	0	0	0	0	28
	12	0	0	0	0	0	0	0	14
57	2	0	0	0	0	0	0	0	4
	29	0	0	0	0	0	0	0	31
	21	0	0	0	0	0	0	0	23
	13	0	0	0	0	0	0	0	15
71	6	0	0	0	0	0	0	0	8
	5	1	0	0	0	0	0	0	8
	40	7	0	0	0	0	0	0	49
	32	8	0	0	0	0	0	0	42
84	38	1	1	0	0	0	0	0	42
	37	2	0	0	0	0	0	0	41
	24	3	7	6	0	0	1	0	43
	24	2	6	0	0	0	0	0	34

Table 2. (continued)

Days after pairing	Eggs	Larval Instars[c] 1st	2nd	3rd	4th	5th	Pre-soldier	Soldiers	Total[d]
99	25	4	5	10	0	0	2	0	48
	20	9	5	13	0	0	0	0	49
	36	11	9	10	0	0	1	0	69
	4	0	5	9	0	0	0	0	20
112	10	5	6	15	2	0	1	15	42
	21	1	1	15	0	0	1	15	43
	25	10	10	12	0	0	1	12	61
	0	0	0	2	0	0	0	2	4
129	0	3	1	16	0	0	1	2	25
	16	4	7	17	1	0	1	2	50
	10	1	2	7	4	0	0	2	28
	2	2	2	0	0	0	0	0	8
142	4	4	2	18	5	0	0	2	37
	3	2	6	17	7	0	0	2	39
	10	1	0	0	0	0	0	0	13
	11	13	10	9	1	0	1	1	48
158	1	0	3	13	10	0	1	2	32
	3	5	5	14	8	0	0	3	40
	1	1	1	10	3	0	0	1	19
	0	2	1	9	4	0	0	0	18

Table 2. (continued)

Days after pairing	Eggs	Larval Instars[c]					Pre-soldier	Soldiers	Total[d]
		1st	2nd	3rd	4th	5th			
171	0	1	1	13	4	0	0	1	22
	0	0	0	3	0	0	0	0	5
	0	0	2	26	3	0	0	2	33
	1	0	1	20	8	0	1	1	43
183	0	0	0	9	8	0	0	1	21
	0	0	0	7	11	0	0	1	19
	0	0	0	11	9	0	0	1	23
	0	0	0	1	0	0	0	0	3
197	0	1	0	2	0	0	0	0	5
	0	0	0	6	16	0	0	3	27
	0	0	0	2	3	0	0	3	10
	1	0	0	0	0	0	0	0	3
211	0	0	0	7	14	0	0	4	27
	0	0	0	7	1	0	0	1	11
	0	0	0	10	2	0	0	1	15
	0	0	0	2	2	0	0	2	8
226	7	0	0	5	18	1	0	2	35
	0	0	0	2	5	0	0	1	10
	0	0	0	0	6	0	0	2	10
	0	0	0	8	13	0	0	3	26

Table 2. (continued)

Days after pairing	Eggs	Larval Instars[c] 1st	2nd	3rd	4th	5th	Pre-soldier	Soldiers	Total[d]
242	0	0	0	0	5	1	0	3	11
	0	0	0	1	11	2	0	2	18
	0	0	0	1	4	1	0	2	10
	0	0	0	0	3	0	0	1	6
256	4	0	0	4	8	7	0	2	27
	0	0	0	1	2	0	0	2	7
	3	0	0	7	27	1	0	3	43
	4	0	0	1	39	5	0	5	56
264	25	0	0	0	25	8	0	3	63
	0	0	0	0	3	1	0	2	8
	4	0	0	0	1	0	0	1	8
	33	0	0	0	22	5	0	3	65
288	10	0	0	0	3	0	0	2	17
	38	10	6	0	41	1	0	6	104
	0	0	0	0	2	0	0	2	6
	0	0	0	0	3	1	0	1	7
302	6	1	0	0	8	1	0	2	20
	1	0	0	0	8	1	0	2	14
	0	0	0	0	2	0	0	2	6
	20	2	0	0	29	6	0	4	63

Table 2. (continued)

Days after pairing	Eggs	Larval Instars[c] 1st	2nd	3rd	4th	5th	Pre-soldier	Soldiers	Total[d]
317	62	18	9	7	26	9	0	5	136
	11	0	0	0	12	3	0	3	31
	35	20	5	0	23	5	0	3	93
	11	11	5	4	5	23	0	5	65
330	24	6	0	1	10	25	0	4	72
	0	2	0	0	1	0	0	2	7
	2	3	6	5	14	11	0	4	47
	0	2	0	0	3	2	0	2	11
344	0	0	0	0	4	8	0	2	16
	21	13	0	0	1	2	0	1	47
	10	16	6	0	9	8	0	1	57
	1	1	0	7	6	10	0	2	33
360	2	2	0	4	4	5	0	3	25
	0	0	9	0	1	3	0	1	7
	0	0	11	0	1	0	0	1	4
	0	1	4	12	9	15	0	4	49
376	0	0	3	0	3	2	0	3	10
	0	0	0	0	1	3	0	0	6
	0	0	0	0	0	0	0	2	4
	0	0	6	0	9	14	0	3	26

Table 2. (continued)

Days after pairing	Eggs	Larval Instars[c] 1st	2nd	3rd	4th	5th	Pre-soldier	Soldiers	Total[d]
392	1	0	0	2	25	18	0	9	57
	0	0	0	0	2	2	0	2	9
	0	0	0	0	1	3	0	2	8
	35	9	0	2	0	23	0	6	80
393	0	0	0	0	1	5	0	2	8
	1	1	1	0	3	3	0	0	10
	7	1	0	25	10	14	0	5	70
	0	0	3	0	0	5	0	2	9
438	0	0	0	7	7	13	0	4	33
	0	0	0	0	11	13	0	4	26
	0	0	5	0	2	2	0	2	8
	0	0	0	7	31	16	0	7	63
468	0	0	0	6	25	14	0	9	56
	0	0	0	13	33	30	0	13	91
	0	0	0	11	7	13	0	5	38
	0	0	0	0	8	13	0	6	29
499	0	0	0	0	1	6	0	3	12
	0	0	0	4	27	23	0	6	62
	0	0	0	0	1	4	0	1	8
	0	0	0	0	4	4	0	2	12

Table 2. (continued)

Days after pairing	Eggs	Larval Instars[c] 1st	2nd	3rd	4th	5th	Pre-soldier	Soldiers	Total[d]
532	0	0	0	0	3	13	0	6	24
	3	0	0	0	13	14	0	4	36
	0	0	0	0	22	27	0	6	57
	0	0	0	0	0	11	0	2	15
563	205	8	0	1	15	39	0	9	279
	0	0	0	0	0	3	0	3	8
	241	18	0	0	26	47	2	11	347
	1	0	0	0	3	1	0	4	11
596	4	0	0	1	0	24	0	3	34
	81	0	0	0	1	41	1	8	134
	25	4	1	0	7	5	0	1	45
	0	0	0	0	6	14	0	3	25
627	1	3	2	0	0	0	0	4	12
	0	0	0	0	0	1	0	1	4
	129	101	27	31	0	54	0	15	359
	110	90	40	20	0	60	0	13	320
656	0	0	0	0	0	16	0	2	20
	0	0	0	0	0	0	0	0	2
	0	0	0	0	0	6	0	2	10
	0	0	0	0	0	41	0	11	54

Table 2. (continued)

Days after pairing	Eggs	Larval Instars[c] 1st	2nd	3rd	4th	5th	Pre-soldier	Soldiers	Total[d]
687	50	32	49	174	0	63	1	19	390
	0	0	0	0	0	4	0	1	7
710	8	7	7	59	75	10	0	9	177
	0	0	0	0	0	3	0	0	5
743	0	0	0	0	0	41	0	10	53
	2	0	0	4	221	52	0	25	306
773	0	0	0	27	208	63	0	29	329
	0	0	0	3	200	65	0	26	296
800	203	0	0	0	41	131	0	21	398
	0	0	0	3	405	103	2	45	560
820	262	45	0	0	0	105	1	26	441
	16	0	1	0	0	136	0	19	174
849	101	33	27	25	46	127	2	27	390
	76	47	37	47	101	113	2	37	462
880	40	40	47	10	0	185	0	41	365
	0	0	0	106	108	21	0	21	258

Table 2. (continued)

Days after pairing	Eggs	Larval Instars[c] 1st	2nd	3rd	4th	5th	Pre-soldier	Soldiers	Total[d]
911	101	67	77	156	131	97	5	36	672
	79	39	51	201	117	81	6	41	617
942	93	53	50	137	122	159	8	50	674
	68	29	48	479	138	115	5	73	957

[a] Unit A, Series Cf-1968L.

[b] Colonies maintained at 26±0.5°C, 24 hour dark photoperiod and 80 percent relative humidity.

[c] Fifth instar larval category also includes a few individuals which were probably sixth instar larvae.

[d] Total includes the categories listed plus the first-form reproductives.

Table 3. Measurements (mm) of virgin first-form reproductives of C. formosanus before pairing and introduction to culture jars, Baton Rouge, La. 1968.[a/] [b/]

Male first-form reproductive			Female first-form reproductive		
Body Length	Abdomen width	Antennal segment no.	Body length	Abdomen width	Antennal segment no.
7.66	1.66	20/20	7.37	1.77	20/20
7.77	1.71	20/20	7.77	1.83	21/21
7.60	1.71	20/20	7.43	1.71	20/20
7.31	1.60	20/20	7.77	1.71	20/20
7.20	1.71	20/20	7.66	1.83	20/20
7.20	1.60	20/20	7.43	1.77	20/20
7.20	1.71	20/20	7.77	1.71	20/20
7.20	1.71	20/20	7.77	1.71	20/20
7.09	1.60	20/20	7.77	1.83	20/20
7.43	1.60	20/20	7.66	1.71	20/20
7.43	1.60	20/20	7.77	1.83	20/20
6.97	1.60	20/20	6.86	1.83	20/20

[a/] Body length equal head plus thorax plus abdomen; abdomen width taken from ventral surface at the fifth sternite; and antennal segment number equals the number of segments with setae over the total number of segments.

[b/] Series Cf-68L, Unit A.

Table 4. Size of first-form reproductives of C. formosanus at each sampling date after pairing. Baton Rouge, La. 1968-1970.[a/] [b/]

Days after pairing	Male		Female		Days after pairing	Male		Female	
	Length	Width	Length	Width		Length	Width	Length	Width
28	7.66	1.66	7.43	1.71	99	6.00	1.50	6.50	1.70
	7.31	1.60	7.77	1.71		6.60	1.70	6.80	1.60
	7.79	1.71	7.66	1.83		7.40	1.50	7.20	1.50
	7.43	1.60	7.37	1.77		6.60	1.40	6.90	1.50
45	7.43	1.60	7.54	1.71					
	7.54	1.66	7.66	1.77	112	6.00	1.50	6.20	1.60
	7.79	1.71	7.60	1.83		5.80	1.40	6.40	1.60
	7.31	1.60	7.66	1.83		6.50	1.60	6.20	1.50
57	7.30	1.50	7.70	1.80		7.50	1.70	6.20	1.50
	7.0	1.40	7.60	1.70					
	7.1	1.45	7.50	1.60	129	6.30	1.50	6.50	1.60
	6.95	1.55	7.55	1.65		6.60	1.60	7.20	1.60
						6.50	1.40	6.60	1.60
71	7.30	1.60	7.00	1.55		7.30	1.50	7.10	1.60
	7.20	1.60	7.10	1.75					
	7.20	1.80	7.50	1.70	142	5.90	1.50	6.50	1.70
	7.50	1.60	7.50	1.70		6.00	1.50	6.10	1.70
						6.90	1.60	7.20	1.80
84	7.90	1.40	7.30	1.70		6.60	1.60	6.70	1.80
	7.80	1.50	7.50	1.70					
	6.70	1.40	6.70	1.70	158	6.00	1.60	6.50	1.60
	6.90	1.40	7.10	1.80		6.50	1.40	6.70	1.70
						6.60	1.50	6.50	1.70
						6.00	1.50	6.80	1.80

Table 4. (continued)

Days after pairing	Male		Female		Days after pairing	Male		Female	
	Length	Width	Length	Width		Length	Width	Length	Width
171	6.50	1.60	6.60	1.70	242	6.20	1.50	6.90	1.60
	6.60	1.50	6.50	1.50		6.00	1.40	6.80	1.60
	6.20	1.50	6.50	1.70		6.00	1.40	6.70	1.60
	6.20	1.60	6.00	1.60		6.30	1.40	6.50	1.50
183	6.10	1.50	6.90	1.60	256	6.70	1.50	7.00	1.60
	6.60	1.60	6.90	1.70		6.20	1.50	6.20	1.60
	6.60	1.50	6.80	1.60		6.40	1.50	6.90	1.70
	6.30	1.40	6.80	1.50		7.40	1.50	7.00	1.75
197	7.00	1.50	7.20	1.60	264	6.40	1.50	7.10	1.60
	6.60	1.60	7.00	1.65		6.20	1.50	7.00	1.60
	5.90	1.55	7.10	1.70		6.20	1.50	7.20	1.60
	6.40	1.60	7.30	1.40		6.50	1.50	6.90	1.70
211	6.30	1.50	6.90	1.60	288	6.40	1.50	6.90	1.60
	6.10	1.60	6.70	1.60		6.20	1.50	6.70	1.60
	6.30	1.40	6.60	1.50		6.30	1.45	6.40	1.70
	6.10	1.40	6.80	1.60		6.70	1.50	7.10	1.60
226	6.60	1.40	7.50	1.60	302	6.70	1.60	7.20	1.60
	6.30	1.40	6.80	1.70		6.60	1.50	7.10	1.70
	6.00	1.40	6.90	1.60		6.40	1.50	7.10	1.80
	6.20	1.50	7.00	1.60		6.60	1.50	7.10	1.70
317	6.40	1.60	6.60	1.60	392	6.30	1.50	7.00	1.70
	6.50	1.50	7.00	1.60		6.30	1.60	6.80	1.70
	6.80	1.60	6.40	1.60		6.00	1.50	7.00	1.60
	6.60	1.50	7.00	1.80		6.20	1.50	6.85	1.60

Table 4. (continued)

Days after pairing	Male		Female		Days after pairing	Male		Female	
	Length	Width	Length	Width		Length	Width	Length	Width
330	6.70	1.50	7.00	1.70	407	6.86	1.66	6.86	1.82
	6.60	1.40	6.30	1.60		6.74	1.60	7.20	1.77
	6.20	1.50	6.70	1.60		5.71	1.71	6.96	1.89
	6.90	1.80	7.00	1.70		6.62	1.60	7.66	1.82
344	6.70	1.50	7.40	1.60	438	7.20	1.60	7.66	1.82
	7.10	1.50	6.70	1.60		6.74	1.77	7.31	1.82
	7.00	1.45	6.80	1.60		7.09	1.71	7.54	1.82
	6.10	1.40	6.80	1.60		6.86	1.66	7.37	1.82
360	6.50	1.40	6.90	1.70	468	7.66	1.71	7.89	2.06
	6.10	1.40	7.00	1.70		7.54	1.71	7.54	1.82
	6.00	1.50	6.40	1.60		7.20	1.71	7.43	1.82
	6.30	1.50	6.60	1.70		6.97	1.71	7.54	1.82
376	6.80	1.50	7.40	1.70	499	7.20	1.71	7.43	1.82
	6.70	1.40	6.80	1.60		6.97	1.71	7.71	1.82
	6.50	1.40	6.80	1.80		6.86	1.66	7.54	1.89
	6.90	1.50	7.10	1.70		7.31	1.66	8.17	1.82
532	6.97	1.60	7.89	1.89	687	6.63	1.83	7.66	1.83
	6.97	1.71	7.66	1.94		7.20	1.71	7.43	1.83
	7.09	1.60	7.54	1.94					
	6.91	1.60	8.00	1.94	710	7.09	1.77	7.43	2.00
563	8.11	1.71	9.03	1.82		7.20	1.71	7.43	1.83
	7.09	1.71	7.66	1.82	743	6.86	1.60	7.54	1.83
	7.89	1.71	8.69	1.82		6.63	1.71	7.77	1.94
					773	7.20	1.71	7.43	2.0
						6.63	1.66	7.66	1.83

Table 4. (continued)

Days after pairing	Male		Female		Days after pairing	Male		Female	
	Length	Width	Length	Width		Length	Width	Length	Width
596	7.09	1.60	8.23	1.94					
	7.42	1.71	8.23	1.94					
	6.97	1.60	7.20	1.89	800	7.20	1.71	7.66	1.71
	7.31	1.71	7.54	1.82		7.09	1.71	7.66	2.06
627	7.20	1.60	7.77	1.89	820	6.63	1.66	7.83	1.83
	6.74	1.71	6.74	1.83		7.43	1.71	8.57	1.94
	7.20	1.71	6.97	1.83					
	7.20	1.71	7.54	1.83	849	6.97	1.71	7.94	1.89
						6.86	1.66	8.00	1.94
656	7.49	1.71	7.77	1.83					
	7.31	1.71	7.89	1.77	880	6.63	1.60	7.77	1.94
	7.31	1.71	7.43	1.89		6.97	1.66	7.09	1.71
	7.20	1.71	7.43	1.83					
911	7.03	1.71	7.3	1.65					
	6.97	1.77	7.5	1.80					
942	6.82	1.71	7.5	1.90					
	7.14	1.77	6.7	1.70					

[a]/Series Cf-68L.

[b]/Body length equals head plus thorax plus abdomen; abdomen width taken from ventral surface at the fifth sternite.

Table 5. Number of individuals of C. formosanus developed in laboratory from paired virgin, first-form reproductives held at 26±0.5°C. Baton Rouge, La. 1970.[a]

Eggs	Larval Instars 1st	2nd	3rd	Pre-soldier	Soldier	Total[b]
12	4	4	14	1	1	38
19	5	3	5	0	0	34
19	4	4	6	0	0	35
15	1	2	6	0	0	26
18	8	6	12	1	0	47
12	4	6	10	3	0	37
0	1	0	0	0	0	3
5	1	1	9	0	0	18
13	3	5	12	1	0	34
9	6	5	5	0	0	27
13	0	3	5	0	0	23
21	4	5	10	2	0	44
16	9	5	13	0	0	45
4	0	5	9	0	0	20
19	3	2	6	1	0	33
1	0	0	0	0	0	3
12	0	1	0	0	0	15
0	0	0	0	0	0	2
12	4	4	6	0	0	28
3	1	6	0	0	0	12
1	1	2	0	0	0	6

[a] Unit A, Series Cf-70L.

[b] Total includes all categories listed plus 2 first-form reproductives.

Table 6. Number of individuals of C. formosanus developed in laboratory colonies from paired virgin, first-form reproductives held at 32±0.5°C. Baton Rouge, La. 1970.[a]

	Larval Instars				Pre-		
Eggs	1st	2nd	3rd	4th	soldier	Soldier	Total[b]
3	15	12	20	12	0	5	69
9	16	10	29	17	0	6	89
24	9	5	14	9	0	4	67
13	5	5	17	5	0	3	50
10	6	5	21	4	1	2	51
0	0	0	2	0	0	1	5
4	10	3	19	3	0	3	44

[a] Unit A, Series Cf-70L.

[b] Total includes all categories listed plus 2 first-form reproductives.

Table 7. Number of individuals of C. formosanus developed in laboratory colonies from paired virgin, first-form reproductives in 0.00 percent methyl-p-hydroxybenzoate at 3 sampling dates after pairing when held at 26±0.5°C. Baton Rouge, La. 1970.[a/]

Individuals in 5 colonies per sampling date						
	Larval Instars			Pre-		Total[b/]
Egg	1st	2nd	3rd	soldier	Soldier	number
			65 days after pairing			
21	16	0	0	0	0	39
8	0	0	0	0	0	10
10	10	0	0	0	0	22
13	9	0	0	0	0	21
11	14	0	0	0	0	27
			86 days after pairing			
4	3	0	0	0	0	9
22	5	8	2	0	0	39
12	9	16	2	0	0	41
4	0	0	0	0	0	6
20	7	9	2	0	0	40
			96 days after pairing			
12	4	4	14	1	1	38
15	1	2	6	0	0	26
12	4	6	10	3	0	37
5	1	1	9	0	0	18
17	5	5	10	0	1	40

[a/] Unit C, Series Cf-70L.

[b/] Total includes categories listed plus 2 first-form reproductives.

Table 8. Number of individuals of C. formosanus developed in laboratory colonies from paired virgin, first-form reproductives in 0.09 percent methyl-p-hydroxybenzoate at 3 sampling dates after pairing when held at 26±0.5°C. Baton Rouge, La. 1970.[a/]

Individuals in 5 colonies per sampling date						
	Larval Instars			Pre-		Total[b/]
Eggs	1st	2nd	3rd	soldier	Soldier	number
			65 days after pairing			
20	9	0	0	0	0	31
26	7	0	0	0	0	35
13	6	0	0	0	0	21
27	12	0	0	0	0	41
24	10	0	0	0	0	36
			86 days after pairing			
7	2	0	0	0	0	11
8	1	7	0	0	0	18
27	4	4	0	0	0	37
22	12	11	5	1	0	53
18	6	4	10	0	0	40
			96 days after pairing			
19	5	3	5	0	0	24
18	8	6	12	1	0	51
5	3	0	0	0	0	10
18	6	5	12	1	0	44
15	6	5	9	1	0	38

[a/]Unit C, Series Cf-70L.

[b/]Total includes categories listed plus 2 first-form reproductives.

Table 9. Number of individuals of C. formosanus developed in laboratory colonies from paired virgin, first-form reproductives in 0.225 percent methyl-p-hydroxybenzoate at 3 sampling dates after pairing when held at 26±0.5°C. Baton Rouge, La. 1970[a/]

Individuals in 5 colonies per sampling date						
	Larval Instars			Pre-		Total[b/]
Eggs	1st	2nd	3rd	soldier	Soldier	number
			65 days after pairing			
17	12	0	0	0	0	31
20	8	0	0	0	0	30
22	5	0	0	0	0	29
12	5	0	0	0	0	19
24	10	0	0	0	0	36
			86 days after pairing			
17	9	5	0	0	0	33
1	4	0	0	0	0	7
28	6	1	0	0	0	37
9	4	0	0	0	0	15
18	8	9	6	0	0	43
			96 days after pairing			
19	4	4	6	0	0	35
0	1	0	0	0	0	3
13	3	5	12	1	0	36
9	6	5	5	0	0	27
13	0	3	5	0	0	23

[a/] Unit C, Series Cf-70L.

[b/] Total includes categories listed plus 2 first-form reproductives.

Table 10. Response of the Formosan subterranean termite to an agar-sawdust media containing various concentrations of methyl-p-hydroxybenzoate. Baton Rouge, La. 1970.[a]

	Preoviposition period[b]			Incubation period[c]		
	Concentrations			Concentrations		
	0.00	0.09	0.225	0.00	0.09	0.225
	8	9	8	49	45	52
	8	8	10	46	45	51
	8	8	10	46	52	48
	8	10	10	49	46	44
	9	9	10	47	44	45
	9	8	8	46	52	46
	11	9	9	49	46	48
	8	9	10	49	51	49
	9	9	10		55	45
	9	8	9			46
	8	10	9			46
	8	9	9			44
			9			
			10			
			10			
			9			
Average	8.58	8.83	9.375	47.63	48.44	47.00

[a] Observations taken on those jars in which cavity could be observed. This produced an unequal number of observations.

[b] Incubation period equals time after oviposition began until the first egg hatched. Eggs incubated at 26±0.5°C.

[c] Preoviposition period given in days after pairing.

Table 11. Analysis of variance of total number of individuals of C. formosanus developed in laboratory colonies from virgin, first-form reproductives in various concentrations of methyl-p-hydroxybenzoate at 3 sampling dates after pairing. Baton Rouge, La. 1970.[a/] [b/]

Source	Degrees of freedom	Sum of squares	Mean square	F
Total	44	6863.28		
Dates	2	20.58	10.29	0.06^{ns}
Concentrations	2	297.91	148.96	0.91^{ns}
Dates x concentrations	4	192.22	48.06	0.27^{ns}
Error	36	6362.57	176.46	

[a/] Unit C, Series Cf-70L. Based on data shown in Appendix Tables 6, 7 and 8.

[b/] Total number of individuals in each colony per sampling date were analyzed for variance.

Table 12. Analysis of variance of preoviposition period length in laboratory colonies initiated by virgin, first-form reproductives in various concentrations of methyl-p-hydroxybenzoate. Baton Rouge, La. 1970.[a]

Source	Degrees of freedom	Sum of squares	Mean square	F
Total	39	29.97		
Concentrations	2	4.64	2.32	3.841*
0.00, 0.09 vs 0.225	1	4.265	4.265	7.061*
0.00 vs 0.09	1	0.375	0.375	0.620^{ns}
Error	37	22.33	0.604	

[a]Unit C, Series Cf-70L. Based on data shown in Appendix Table 9.

Table 13. Analysis of variance of the number of third and fourth instar individuals of C. formosanus present 96 days after pairing in laboratory colonies initiated by paired virgin first-form reproductives in a sawdust-agar media containing various concentrations of methyl-p-hydroxybenzoate. Baton Rouge, La. 1970.[a/] [b/]

Source	Degrees of freedom	Sum of squares	Mean square	F
Total	14	339.330		
Concentrations	2	67.733	38.867	1.50^{ns}
Error	12	271.600	22.633	

[a/] Unit C, Series Cf-70L. Based on data shown in Appendix Tables 7, 8 and 9.

[b/] Third instar individuals include larvae and presoldiers and fourth instar individuals consists of soldiers in 5 colonies at each concentration of methyl-p-hydroxybenzoate.

Table 14. Measurements (mm) of first instar larvae from first egg laying period in young developing colonies of C. formosanus, Baton Rouge, La. 1970.[a]

Head width	Pronotum width	Body length	Antennal segment number[b]
0.475	0.285	2.00	9/11
0.484	0.304	1.35	9/11
0.475	0.304	1.93	9/11
0.494	0.304	1.35	9/11
0.513	0.304	2.03	9/11
0.475	0.294	1.58	9/11
0.522	0.304	2.05	9/11
0.494	0.285	1.48	9/11
0.475	0.285	1.70	9/11
0.484	0.304	1.41	9/11
0.532	0.285	2.00	9/11
0.484	0.294	1.33	9/11
0.475	0.304	2.05	9/12
0.494	0.304	1.62	9/11
0.513	0.304	1.98	9/11
0.475	0.304	1.56	9/11
0.475	0.304	2.05	9/11
0.494	0.294	1.56	9/11
0.504	0.304	1.75	9/11
0.484	0.304	1.25	9/11
0.494	0.304	1.95	9/11
0.484	0.304	1.50	9/11
0.475	0.304	1.70	9/11
0.494	0.304	1.95	9/11

[a] Unit E, Series Cf-70L.

[b] Antennal segment number is the number of segments with setae over the total number of segments.

Table 15. Measurements (mm) of second instar larvae of C. formosanus developed during first oviposition period in laboratory colonies from paired virgin, first-form reproductives held at 26±0.5°C. Baton Rouge, La. 1970.[a/]

Head width	Pronotum width	Mesonotum width	Body length	Antennal segment number[b/]
0.627	0.304	0.380	2.772	10/11
0.618	0.342	0.380	2.118	11/11
0.665	0.352	0.380	2.387	11/11
0.608	0.323	0.371	2.502	10/11
0.665	0.342	0.380	2.426	10/11
0.646	0.361	0.399	2.618	10/11
0.627	0.342	0.371	2.926	10/11
0.665	0.361	0.418	2.888	11/11
0.665	0.342	0.399	2.964	10/11
0.627	0.361	0.380	2.772	11/11
0.665	0.380	0.399	2.156	10/11
0.665	0.342	0.399	2.810	10/11
0.665	0.342	0.399	2.387	11/11
0.684	0.352	0.399	2.849	10/11
0.665	0.323	0.390	2.656	9/11
0.646	0.342	0.371	2.080	11/11
0.627	0.323	0.361	1.925	10/11
0.684	0.352	0.399	3.350	11/11
0.665	0.323	0.380	2.502	11/11
0.684	0.323	0.380	2.618	10/11
0.665	0.342	0.418	2.502	11/11
0.665	0.342	0.380	2.888	10/11
0.646	0.342	0.380	2.656	10/11
0.665	0.352	0.380	2.849	11/11

[a/] Unit E, Series Cf-70L.

[b/] Antennal segment number is the number of segments with setae over the total number of segments.

Table 16. Measurements (mm) of third instar larvae of C. formosanus developed during first oviposition period in laboratory colonies from paired virgin, first-form reproductives held at 26±0.5°C. Baton Rouge, La. 1970.[a]

Head width	Pronotum width	Mesonotum width	Body Length	Antennal segment number[b]
0.817	0.406	0.475	3.388	11/12
0.817	0.418	0.456	3.542	11/12
0.836	0.446	0.475	3.773	11/12
0.817	0.418	0.475	3.465	11/11
0.884	0.475	0.484	3.272	11/11
0.893	0.446	0.513	3.350	11/12
0.817	0.399	0.456	2.656	11/12
0.788	0.418	0.475	2.811	11/12
0.855	0.456	0.503	2.964	11/12
0.817	0.428	0.484	3.311	11/12
0.855	0.437	0.484	3.196	11/12
0.779	0.399	0.475	3.465	11/12
0.808	0.437	0.475	3.350	11/12
0.826	0.437	0.475	2.772	11/12
0.817	0.446	0.494	3.157	11/12
0.817	0.446	0.484	2.772	11/12
0.817	0.446	0.494	2.580	11/12
0.808	0.428	0.475	3.388	11/12
0.855	0.456	0.494	3.196	11/12
0.770	0.418	0.475	3.272	11/12
0.817	0.446	0.466	2.618	11/12
0.779	0.437	0.484	3.426	11/12
0.836	0.446	0.484	3.350	11/12
0.855	0.456	0.504	3.388	11/12

[a] Unit E, Series Cf-701.

[b] Antennal segment number is the number of segments with setae over the total number of segments.

Table 17. Measurements (mm) of fourth instar larvae of C. formosanus developed during first oviposition period in laboratory colonies from paired, virgin, first-form reproductives held at 26±0.5oC. Baton Rouge, La. 1970.[a]

Head width	Pronotum width	Mesonotum width	Body length	Antennal segment number[b]
0.817	0.437	0.494	3.350	12/12
0.855	0.475	0.522	3.581	12/13
0.893	0.513	0.522	3.465	12/13
0.874	0.494	0.532	3.658	12/13
0.902	0.513	0.570	3.542	12/13
0.874	0.513	0.551	3.812	12/13
0.912	0.522	0.608	3.080	12/13
0.912	0.475	0.570	3.080	12/13
0.902	0.494	0.532	3.734	12/13
0.912	0.475	0.522	3.850	12/13
0.900	0.478	0.506	3.391	12/12
0.881	0.488	0.525	2.939	12/13
0.862	0.468	0.530	3.413	12/13
0.862	0.488	0.526	3.225	12/12
0.825	0.488	0.542	3.412	12/13
0.825	0.450	0.500	3.225	12/13
0.862	0.450	0.524	3.450	12/12

[a] Unit E, Series Cf-70L.

[b] Antennal segment number is the number of segments with setae over the total number of segments.

Table 18. Measurement of fifth instar larvae of C. formosanus developed from first oviposition period in laboratory colonies from paired virgin, first-form reproductives held at 26±0.5°C. Baton Rouge, La. 1968-1970.[a/]

Head width	Pronotum width	Mesonotum width	Body length	Antennal segment number[b/]
0.931	0.532	0.599	4.054	13/13
0.950	0.598	0.665	3.540	13/13
0.959	0.564	0.627	4.04	13/13
0.931	0.541	0.551	2.964	12/13
0.950	0.570	0.589	3.657	13/13
0.931	0.560	0.570	3.311	13/13
0.956	0.562	0.572	3.787	13/13
0.956	0.543	0.560	3.412	13/13
0.956	0.468	0.475	3.187	13/13
0.956	0.543	0.620	2.850	13/14
0.937	0.543	0.525	3.712	13/13
0.956	0.534	0.569	3.412	13/13
0.950	0.532	0.608	3.540	13/14
0.950	0.608	0.589	4.339	13/13
0.912	0.570	0.608	3.825	13/13

[a/]Unit E, Series Cf-70L.

[b/]Antennal segment number is the number of segments with setae over the total number of segments.

Table 19. Measurements (mm) of sixth instar larvae of C. formosanus developed during third oviposition period in laboratory colonies from paired virgin, first-form reproductives held at 26±0.5°C. Baton Rouge, La. 1968-1970.[a]

Head width	Pronotum width	Mesonotum width	Body length	Antennal segment number[b]
1.083	0.703	0.722	5.139	14/14
1.130	0.646	0.665	4.111	14/14
1.102	0.684	0.684	5.376	14/14
1.064	0.722	0.684	5.261	14/14
1.121	0.684	0.684	5.319	14/14
1.064	0.703	0.741	5.090	14/14
1.102	0.741	0.798	5.376	14/14
1.064	0.722	0.703	4.747	14/14
1.140	0.760	0.798	5.376	14/14
1.159	0.684	0.703	5.204	14/14
1.111	0.674	0.703	4.918	14/14
1.130	0.665	0.684	4.975	14/14

[a] Unit E, Series Cf-70L.

[b] Antennal segment number is the number of segments with setae over the total number of segments.

Table 20. Measurements (mm) of presoldiers of C. formosanus developed during first oviposition period in laboratory colonies, from paired virgin, first-form reproductives held at 26±0.5°C. Baton Rouge, La. 1970.[a]

Head width	Pronotum width	Mesonotum width	Body length	Antennal segment number[b]
0.798	0.475	0.513	3.997	11/12
0.779	0.484	0.551	4.111	11/11
0.722	0.456	0.513	3.940	11/12
0.760	0.446	0.484	3.997	11/12
0.779	0.456	0.494	4.111	11/12
0.779	0.475	0.494	3.141	11/12
0.817	0.504	0.522	3.483	11/12
0.760	0.437	0.484	4.026	11/12
0.798	0.437	0.513	3.540	11/12
0.741	0.456	0.513	3.883	11/12

[a]/Unit E, Series Cf-70L.

[b]/Antennal segment number is the number of segments with setae over the total number of segments.

Table 21. Measurements (mm) of soldiers of C. formosanus developed during first oviposition period in laboratory colonies from paired virgin, first-form reproductives held at 26±0.5°C. Baton Rouge, La. 1970.[a]

Head width	Pronotum width	Body length	Antennal segment number[b]
0.969	0.608	4.854	12/12
1.007	0.608	3.997	12/12
0.950	0.608	3.426	12/12
0.874	0.589	4.282	12/12
0.922	0.570	4.282	11/11
0.969	0.627	4.911	12/12
0.950	0.598	4.340	12/12
0.988	0.608	4.397	12/12
0.931	0.608	4.453	12/12
0.874	0.570	3.997	12/12
0.836	0.542	3.540	12/12
0.931	0.608	4.397	12/12
0.925	0.600	4.000	12/12

[a] Unit E, Series Cf-70L.

[b] Antennal segment number is the number of segments with setae over the total number of segments.

Table 22. Measurements (mm) of soldiers of C. formosanus found most frequently after the first oviposition period in laboratory colonies from paired virgin, first-form reproductives held at 26±0.5°C. Baton Rouge, La. 1968-1970.[a]

Head width	Pronotum width	Body length	Antennal segment number[b]
0.969	0.684	4.625	13/13
0.988	0.684	4.625	13/13
0.931	0.570	3.825	13/13
0.912	0.608	4.682	13/13
1.045	0.722	5.424	13/13
1.007	0.665	5.367	13/13
1.102	0.722	5.710	13/13
1.026	0.722	4.625	13/13
1.007	0.684	5.767	13/13
1.064	0.703	5.196	13/13
1.026	0.703	5.196	13/13
1.083	0.693	5.024	13/13

[a] Unit E, Series Cf-70L.

[b] Antennal segment number is the number of segments with setae over the total number of segments.

Table 23. Soil temperature at three depths in C. formosanus cage study in New Orleans, La. 1968-1970.[a/] [b/]

Date Sampled	Cage No.	Temperature Inside Cage			Temperature Outside Cage		
		5"	15"	20"	5"	15"	20"
Dec. 12, 1968	61	18.33	16.11	16.67	18.33	16.39	16.39
Dec. 12, 1968	109	18.33	16.11	16.67	17.22	16.67	16.67
Jan. 4, 1969	16	11.11	12.22	14.44	12.78	12.78	13.89
Jan. 4, 1969	38	11.67	13.33	13.89	11.67	12.78	13.89
Feb. 8, 1969	15	21.67	17.78	17.78	21.11	18.33	17.78
Feb. 8, 1969	77	20.00	18.33	18.33	21.11	18.33	17.78
March 2, 1969	8	16.67	14.44	14.44	16.11	13.89	14.44
March 2, 1969	54	15.00	13.89	14.44	15.56	13.89	14.44
April 14, 1969	95	26.67	21.67	21.39	25.56	21.67	21.11
April 14, 1969	69	27.22	22.78	21.67	26.67	22.78	21.67
April 25, 1969	75	28.33	22.78	22.50	30.28	23.33	22.22
April 25, 1969	4	28.89	22.78	22.22	30.00	22.78	22.22
May 29, 1969	97	30.00	27.78	26.67	33.89	25.56	25.56
May 29, 1969	53	31.67	28.89	27.22	33.89	28.33	25.56
July 2, 1969	26	40.56	33.33	32.78	40.00	35.00	31.11
July 2, 1969	49	38.89	32.22	32.37	40.56	35.00	31.67
July 3, 1969	21	41.11	32.27	31.11	39.44	35.59	32.22
July 3, 1969	56	41.11	33.33	31.11	40.00	33.89	32.22
July 31, 1969	72	28.89	29.44	28.33	29.44	29.44	30.56
July 31, 1969	60	31.11	28.89	28.33	30.56	29.44	30.00
Sept. 14, 1969	58	27.78	27.22	27.22	26.67	27.78	27.22
Sept. 14, 1969	36	27.78	27.22	27.78	26.67	27.78	27.78

Table 23. (continued)

Date Sampled	Cage No.	Temperature Inside Cage 5"	15"	20"	Temperature Outside Cage 5"	15"	20"
Oct. 9, 1969	84	24.44	26.11	26.11	24.44	26.11	26.11
Oct. 9, 1969	79	25.00	26.67	26.67	26.11	26.67	26.67
Nov. 10, 1969	99	22.78	20.56	21.67	21.67	21.67	22.22
Nov. 10, 1969	34	21.67	21.11	21.11	21.67	20.56	21.11
Dec. 14, 1969	91	16.11	16.67	16.67	17.50	16.11	16.67
Dec. 14, 1969	76	17.22	16.67	16.67	17.22	16.11	16.67
Jan. 22, 1970	39	8.33	11.11	11.67	8.33	11.11	12.78
Jan. 22, 1970	27	8.33	11.11	11.11	18.89	11.11	12.22
March 13, 1970	33	19.44	16.67	17.22	19.44	16.39	17.22
March 13, 1970	86	19.72	16.11	16.11	19.44	16.11	16.39
July 7, 1970	97	30.56	28.33	28.89	29.44	29.44	29.44
July 7, 1970	41	33.89	30.00	28.89	37.22	34.44	30.56
July 14, 1970	100	28.33	27.22	26.67	29.44	26.11	26.11
July 14, 1970	104	28.33	25.67	26.67	28.33	26.11	26.11

[a]/Soil temperature was measured at three different depths: 5 in., 15 in., and 20 in. Analysis of variance presented in Table XV.

[b]/Temperature is in degrees Centigrade.

Table 24. Percent of moisture in soil at various depths in C. formosanus cage study in New Orleans, La. 1968-1970.[a/]

Date Sampled	Cage No.	Percent moisture inside cage			Percent moisture outside cage		
		5"	15"	20"	5"	15"	20"
Nov. 12, 1968	1	8.27	7.57	11.47	9.50	4.64	5.25
Nov. 12, 1968	18	9.94	9.94	7.93	15.35	9.68	9.57
Dec. 12, 1968	61	11.99	11.25	12.92	8.08	13.31	11.29
Dec. 12, 1968	109	10.63	18.42	15.87	8.71	19.78	7.75
Jan. 4, 1969	16	16.09	13.34	31.95	18.50	14.73	21.49
Jan. 4, 1969	38	15.56	13.26	20.86	14.80	13.13	19.91
Feb. 8, 1969	15	12.54	10.41	11.18	14.36	6.39	21.80
Feb. 8, 1969	77	12.74	9.93	10.97	9.91	7.77	10.16
March 2, 1969	8	7.95	10.87	11.95	9.37	7.82	12.38
March 2, 1969	54	7.81	7.98	9.17	6.55	8.30	11.54
April 14, 1969	95	8.94	9.14	10.04	6.43	8.42	8.85
April 14, 1969	69	7.30	6.94	8.01	8.68	7.35	8.25
April 25, 1969	75	8.93	6.90	9.05	7.85	4.79	10.35
April 25, 1969	4	4.80	5.94	5.66	5.88	5.92	16.58
May 29, 1969	97	8.46	6.57	8.47	8.50	6.48	7.12
May 29, 1969	53	6.38	8.03	10.49	3.40	6.00	19.31
July 2, 1969	26	1.82	1.91	1.23	1.07	0.75	6.65
July 2, 1969	49	1.22	3.61	3.33	1.03	0.79	5.61
July 3, 1969	21	1.72	3.44	2.26	1.16	0.399	4.97
July 3, 1969	56	0.74	4.49	5.565	1.06	0.75	6.65
July 31, 1969	72	9.04	9.12	4.51	7.85	8.37	12.46
July 31, 1969	60	7.74	7.43	8.96	12.54	7.50	8.52

Table 24. (continued)

Date Sampled	Cage No.	Percent moisture inside cage 5"	15"	20"	Percent moisture outside cage 5"	15"	20"
Sept. 14, 1969	58	15.03	9.67	4.05	16.87	7.05	4.96
Sept. 14, 1969	36	16.029	9.071	3.076	18.852	5.169	4.482
Oct. 9, 1969	84	3.521	1.830	1.212	2.229	0.932	2.49
Oct. 9, 1969	79	7.922	3.25	1.71	1.492	3.516	1.852
Nov. 10, 1969	99	4.52	2.11	1.69	7.72	0.61	0.71
Nov. 10, 1969	34	10.65	4.64	4.203	6.12	2.33	3.79
Dec. 14, 1969	91	8.688	10.692	12.873	8.710	6.499	7.18
Dec. 14, 1969	76	8.22	8.243	10.519	8.334	7.23	16.378
Jan. 22, 1970	39	11.81	10.37	9.28	5.50	5.14	9.53
Jan. 22, 1970	27	12.96	9.09	10.10	10.30	6.01	29.08
March 13, 1970	33	13.406	12.680	27.723	12.26	7.784	17.346
March 13, 1970	86	11.430	12.050	12.992	17.141	10.528	18.736
July 7, 1970	97	7.026	7.829	6.427	2.856	3.434	4.08
July 7, 1970	41	12.714	6.604	6.259	5.194	3.453	4.853
July 14, 1970	100	10.864	10.450	19.9	10.449	13.489	11.762
July 14, 1970	104	11.353	11.651	15.198	15.466	15.744	24.776

[a]/Percent of moisture in soil was measured at 3 different depths: 5 in., 15 in., and 20 in. Analysis of variance presented in Table XVI.

Table 25. Number of individuals of C. formosanus developed in field colonies from paired virgin, first-form reproductives in stakes. New Orleans, La. 1970-1971.[a/]

Days after pairing	Eggs	Larval Instars					Pre-soldier	Soldier	Total[b/]
		1st	2nd	3rd	4th	5th			
13	8	0	0	0	0	0	0	0	10
	11	0	0	0	0	0	0	0	13
35	26	0	0	0	0	0	0	0	28
	25	0	0	0	0	0	0	0	27
52	11	6	7	0	0	0	0	0	26
	22	5	10	0	0	0	0	0	39
67	16	9	5	19	0	0	2	0	53
	10	3	2	6	0	0	0	1	24
82	18	2	4	7	0	0	1	1	35
	10	5	6	19	0	0	2	1	45
95	8	8	2	13	5	0	0	1	39
	19	3	3	22	0	0	2	3	54
109	14	8	8	25	13	0	1	5	76
	2	5	4	13	5	0	0	4	35
138	0	3	2	2	34	0	0	6	49
	0	0	10	20	10	0	0	6	48
175	0	0	2	9	44	0	0	8	65
	0	0	0	12	42	0	0	7	63
207	0	0	3	21	43	0	0	6	75
	0	0	4	22	52	0	0	7	84
239	0	0	3	21	51	0	0	8	84
	0	0	4	22	55	0	0	9	92

Table 25. (continued)

Days after pairing	Eggs	Larval Instars 1st	2nd	3rd	4th	5th	Pre-soldier	Soldier	Total[b]
278	0	0	0	0	16	0	0	2	20
	18	0	12	33	59	0	0	14	138
313	0	0	7	17	35	0	0	11	72
	0	0	4	6	38	0	0	7	57

[a] Series Cf-70F, Unit A.

[b] Totals equal categories listed plus 2 first-form reproductives.

Table 26. Depth (cm) of the nursery area of C. formosanus and soil temperature (°C) and soil moisture percent in cages on various sampling dates. New Orleans, La. 1970-1971.[a/] [b/]

Sampling date	Days after pairing	Nursery depth[c/]	Soil Temperature		Percent moisture in soil at nursery
			Nursery depth	7.62 cm depth	
May 22, 1970	13	19.50	25.56	27.78	8.355
May 22		16.50	25.00	28.33	7.680
June 12	35	15.00	28.33	28.33	17.810
June 12		13.50	28.33	27.78	15.360
June 29	52	15.50	30.00	29.44	11.422
June 29		17.00	29.44	29.72	10.753
July 14	67	18.00	26.67	26.11	10.457
July 14		20.00	26.67	26.67	9.780
July 29	82	16.00	30.56	31.67	8.608
July 29		14.00	28.89	30.00	5.233
Aug. 11	95	12.50	28.88	29.44	10.881
Aug. 11		15.00	28.88	29.44	9.965
Aug. 25	109	14.00	27.78	27.78	14.01
Aug. 25		15.00	28.33	27.78	12.56
Sept. 23	138	12.50	27.22	26.67	11.65
Sept. 23		10.00	27.22	27.22	10.45
Oct. 30	175	13.00	22.78	22.78	13.32
Oct. 30		14.00	22.78	23.33	13.60
Dec. 2	207	25.00	19.44	18.33	10.77
Dec. 2		20.00	19.44	17.22	11.06
Jan. 3, 1971	239	38.00	14.44	15.00	14.66
Jan. 3		38.00	14.44	15.56	10.71

Table 26. (continued)

Sampling date	Days after pairing	Nursery depth[c]	Soil Temperature		Percent moisture in soil at nursery
			Nursery depth	7.62 cm depth	
Feb. 11	278	38.00	13.88	15.56	9.76
Feb. 11		18.00	13.88	16.11	10.43
Mar. 8	313	10.16	18.61	18.69	12.73
Mar. 8		7.62	19.17	19.44	11.54

[a] Series Cf-70F, Unit A.

[b] Colonies established in southern "yellow" pine stakes from paired virgin, first-form reproductives.

[c] Stake (30.48 cm in length) imbedded vertically about 7.62 cm below the soil surface.

VITA

Edgar George King, Jr., was born October 3, 1943, at Corpus Christi, Texas. He graduated from Dry Creek High School in Dry Creek, Louisiana, in June, 1961. He obtained a Bachelor of Science degree in Biology Education from McNeese State College in Lake Charles, Louisiana, in 1966. He obtained a Master of Science degree in Entomology from Louisiana State University in Baton Rouge, Louisiana, in August, 1968.

On August 14, 1964, he was married to Theda Carole Sanderson of Adington, Texas. He has two children: Lainie Lynn and Kristin Leigh.

He is presently a candidate for the degree of Doctor of Philosophy in Entomology at Louisiana State University.

EXAMINATION AND THESIS REPORT

Candidate: Edgar George King, Jr.

Major Field: Entomology

Title of Thesis: Biology of the Formosan subterranean termite, Coptotermes formosanus Shiraki, with primary emphasis on young colony development

Approved:

Major Professor and Chairman

Dean of the Graduate School

EXAMINING COMMITTEE:

Date of Examination:

May 13, 1971