UNITED STATES DEPARTMENT OF AGRICULTURE

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Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. | PROFESSIONAL PAPER | January 29, 1917

THE RED SPIDER ON COTTON

By

E. A. McGREGOR and F. L. McDONOUGH
Scientific Assistants

CONTENTS

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THE RED SPIDER ON COTTON.

By E. A. McGregor and F. L. McDonough,
Scientific Assistants, Southern Field Crop Insect Investigations.

CONTENTS.

The common red spider, *Tetranychus bimaculatus* Harvey, is very generally distributed in the United States. The map (fig. 1), which contains 297 records of occurrence in 34 States, shows the distribution of the majority of reported cases.

The species first became conspicuous as a pest to cultivated crops in New England and the Northeast. The early complaints related largely to greenhouse and dooryard plants, and it was not until 1855 that Glover reported some injury to cotton by the pest. As settlement moved westward, records of occurrence from the Middle West and, finally, the Pacific Slope, appeared in our literature. With the exception of an outbreak in Louisiana, reported by Prof. H. A. Morgan in 1893, severe occurrence of the red spider on cotton had not been reported until 1903, at which time complaints of damage came from South Carolina and Georgia. In 1904 Mr. E. S. G. Titus (1905, *a*, *b*), then of this bureau, found severe infestation in fields about Batesburg, S. C., and the following year he reported severe injury in North Carolina, South Carolina, Georgia, and Alabama. Since then the additional records of Dr. F. H. Chittenden and Messrs. G. P. Weldon, D. T. Fullaway, E. L. Worsham, H. F. Wilson,

NOTE.—This bulletin is of interest to those who are subjected to loss or annoyance by the red spider.

W. B. Parker, H. E. Ewing, and others, as well as the writers, have established the presence of the red spider from Maine to Florida and westward to Texas, California, and the Hawaiian Islands. It is said to be generally distributed in New England, New York, Iowa, Illinois, the southern parts of Wisconsin and Michigan, western Colorado, the Willamette Valley of Oregon, and the interior regions and southern part of California.

ZONAL DISTRIBUTION IN THE SOUTHEAST.

In the course of our work on distribution it early became evident that the majority of the occurrences in the Southeast were confined to a zone the outer margin of which lies from 60 to 80 miles from the

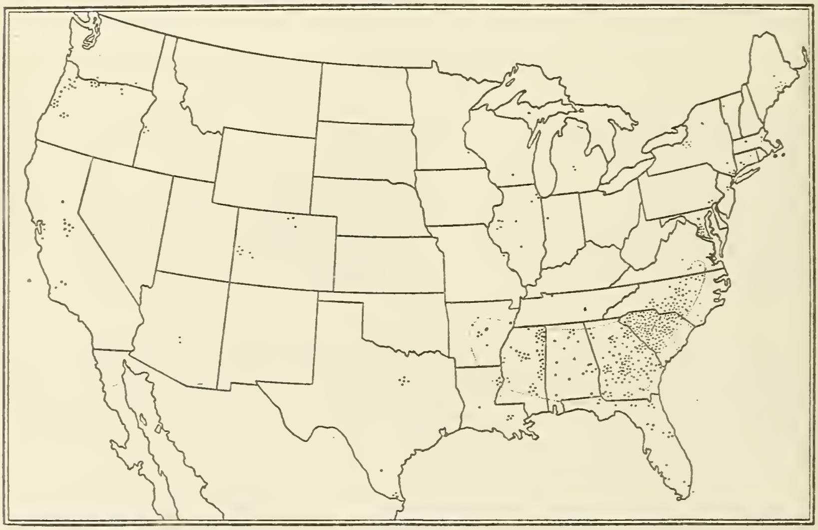

FIG. 1.—Distribution of the common red spider. Large dots represent specific occurrences; dotted line incloses the zone of heaviest occurrence in the Southeast. (Original.)

coast and whose inner margin is from 200 miles (along the Atlantic coast) to 275 miles (along the Gulf coast) inland (fig. 1). In general this zone coincides with the portion of the Piedmont Plateau possessing clay or sandy loam soil and excludes the coastal strip of sandy soil. The infested area includes the central belt of oak, hickory, and longleaf pine hills, the sandhills belt, and the granite and metamorphic gray and red lands. The coastal free area includes the marshes, swamps, and live-oak lands of the coast and the longleaf pine flats and savannas near the coast. Whether this restricted distribution is due to the diversity of plant life or to the differences in climatic conditions prevailing in the respective regions it is difficult to determine. Considering the great adaptability of the red spider to hosts, it would appear that the matter of the host flora must be one of minor influence. The material difference in humidity, rainfall, and temperature between these coastal and inland zones probably explains the restriction of occurrence.

CLASSIFICATION AND SYNONYMY.

Owing to the extreme minuteness of red spiders generally, to marked variations due to age, host plant, environment, or other causes, and to the microscopic characters which are employed in the taxonomic treatment of the group, the spinning mites have afforded much speculation among specialists and have caused considerable duplication and confusion of names.

Ewing has published his opinion that *T. bimaculatus* Harvey, *T. sexmaculatus* Riley, and *T. gloveri* Banks are identical with *T. telarius*. The final settlement of this question will be possible only after a careful comparative study has been made of material collected from the localities and hosts recorded for the respective European species. The following list represents the synonymy of the original European red spider (*T. telarius*) as claimed by various workers since Linnæus, chiefly for the purpose of indicating the present confusion in the group.

TETRANYCHUS TELARIUS L.

1761. *Acarus telarius* L.; 1804, *Trombidium t.* Herm.; 1834, *Tetranychus t.* Dugès.
1804. *Trombidium tiliarium* Herm.; 1834, *Tetranychus t.* Dugès; 1867, *Acarus t.* Turpin; 1875, *Tetranychus t.* Koch.
1804. *Trombidium maius* Herm.; 1834, *Tetranychus m.* Dugès.
1804. *Trombidium tenuipes* Herm.; 1834, *Tetranychus t.* Dugès.
1804. *Trombidium socium* Herm.; 1867, *Acarus s.* Muller; 1875, *Tetranychus socius* Koch.
1832. *Tetranychus lintearius* Dufour; 1867, *Acarus l.* Boisduval; 1877, *Tetranychus l.* Murray.
1867. *Acarus russulus* Boisduval; 1875, *Tetranychus r.* Koch.
1867. *Acarus tini* Boisduval; 1877, *Tetranychus t.* Murray.
1867. *Acarus cucumeris* Boisduval; 1877, *Tetranychus c.* Murray.
1867. *Acarus rosarum* Boisduval; 1877, *Tetranychus r.* Murray.
1867. *Acarus cinnabarinus* Boisduval; 1877, *Tetranychus telarius* var. *c.* Murray.
1867. *Acarus haematodes* Boisduval; 1877, *Tetranychus telarius* var. *h.* Murray.
1867. *Acarus vitis* Boisduval; 1877, *Tetranychus v.* Murray.
1867. *Tetranychus ferrugineus* Boisduval.
1875. *Tetranychus urticae* Koch.
1875. *Tetranychus fervidus* Koch.
1875. *Tetranychus populi* Koch.
1875. *Tetranychus piger* Donnadieu.
1875. *Tetranychus minor* Donnadieu.
1875. *Tetranychus longitarsis* Donnadieu.
1875. *Tetranychus plumistoma* Donnadieu.
1875. *Tetranychus rubescens* Donnadieu.
1875. *Phytocoptes epidermi* Donnadieu.
1875. *Phytocoptes gallarum* Donnadieu.
1875. *Phytocoptes nervorum* Donnadieu.
1876. *Tetranychus pilosus* C. and F.
1890. *Tetranychus 6-maculatus* Riley.
1892. *Tetranychus bimaculatus* Harvey.
1900. *Tetranychus gloveri* Banks.

FOOD PLANTS.

As the result of the investigations at Batesburg, S. C., supplemented by observations throughout the cotton belt, this mite has been taken from 183 species of plants, including weeds, ornamentals, and garden and field crops. Upon most of these the pest has been seen only occasionally, but it is found commonly throughout the active season upon the following plants: Cotton (*Gossypium* spp.), cultivated violet (*Viola* spp.), (Pl. IV, fig. 4), Jerusalem oak (*Chenopodium botrys*), wild blackberry (*Rubus* spp.), wild geranium (*Geranium* spp.), ironweed (*Sida rhombifolia*), garden bean (*Phaseolus* spp.), pokeweed (*Phytolacca americana*), tomato (*Lycopersicon lycopersicon*), dahlia (*Dahlia* spp.), (Pl. IV, fig. 3), sweet pea (*Lathyrus odoratus*), (Pl. IV, fig. 5), and hollyhock (*Althaea rosea*).

Of these 183 host plants, 100 (or 55 per cent) are cultivated species and 83 (or 45 per cent) are native wild species. It should be stated, however, that in the preparation of this host list more time was devoted to house yards than to rural localities. It seems reasonable to suppose, therefore, that the common red spider occurs on fully as many wild plants as on cultivated species. The fact that Harvey's (1892) 37 host plants reported from New England, and Ewing's (1914) 30 hosts from the Northwest are practically all cultivated species may be accounted for by presuming that these investigators did not extend their research to the wild plants.

Throughout the past five years of the red-spider investigation it has been brought to our attention repeatedly that certain plants possess a peculiar importance due to their restriction to certain seasons; hence they may thus form a series of links in the cycle of infestation.

The cultivated violet, which has come to be recognized as perhaps the most important wintering host, and as a source of dispersion to neighboring weeds and near-by cotton in the spring, is probably the most commonly infested plant in the South.

The pokeweed (*Phytolacca americana*) occupies an important position as a host, but its exact status has never been clearly determined. Among farmers in various parts of the cotton belt there is a strong belief that red-spider infestation, called by them "rust," has its origin in pokeweed. The result of much careful study during the winter and early spring months seems to refute the idea that pokeweed normally supports mites during these periods. It does, however, function as a very desirable secondary host during the early season migratory movements of the mites by intercepting a few individuals. These intercepted mites multiply rapidly, until the pokeweed no longer furnishes sufficient nourishment, and at such times the infestation spreads to cotton if it is available. (Pl. V, fig. 6.)

Native blackberry vines also constitute an important overwintering host, since many of the leaves remain attached throughout the winter (in the Southeast) and it is usually an easy matter to find red spiders actively feeding on these leaves. Such occurrences give rise to the opinion that much of the infestation in rural localities arises from the wild blackberry.

Several early vernal plants or weeds (escapes) play an important rôle in the seasonal development and spread of the red spider. The more important of these are hedge nettle (*Stachys arvensis*), wild geranium (*Geranium carolinianum*), sow thistle (*Sonchus asper*), evening primrose (*Oenothera laciniata*), sunflower (*Helianthus annuus*), and vetch (*Vicia sativa*). During March and April these plants are usually to be found in beds and borders in sheltered positions and the seasonal development of the red spider progresses faster than elsewhere, owing to the higher temperatures which obtain in these locations. Such beds are prolific dispersion sources.

Garden beans are also important hosts, and throughout June, July, and August are seldom free from mites, at times becoming so heavily infested that their color turns yellow and many of the leaves fall. They are thus a constant menace to surrounding crops.

Tomato vines are known to afford an opportune shelter for mites, and after the abundant appearance of enemies of the red spider, at a time when other infested plants have become cleared of mites, tomato leaves may usually be found to harbor large numbers. This doubtless comes about through the fact that tomato vines rarely support enemies of the red spider. Hence they serve to harbor the mites during periods of heavy mortality until the time arrives when the latter may spread with impunity to other hosts.

Since 1855, when Glover reported injury to cotton by a red spider, Prof. H. A. Morgan (1897), Mr. E. S. G. Titus (1905, *a*, *b*), and other investigators have published on the damage to cotton by this pest. As indicating the very general occurrence of the mite on cotton, it is of interest that in the course of visits to many points in sections of every cotton State, the common red spider was found in every single locality. The majority of these records on cotton concern very light outbreaks.

LIFE-HISTORY SUMMARY.

The eggs of the red spider are deposited on the under surface of leaves of a great variety of plants. The eggs hatch in a few days and the 6-legged larvæ at once begin to feed by inserting their sharp probosces into the tissue of the leaf. The larval activities are confined to the immediate region of birth, and the larvæ soon molt into 8-legged nymphs. Females require two nymphal stages before becoming adult, while males require only a single nymphal stage between the larva and the adult. The female protonymph, like the larva, after a period about equal to that required by the latter, molts to the secondary nymph or deutonymph. The activities of the deutonymph are very similar to those of the protonymph and the duration of the stage is about equal to the time required by the latter. The third molt gives issue to the female. The single nymphal stage of the male exhibits the same biologic activities as do nymphs of the female. The time required for this stage, however, is a trifle longer than that consumed by the female primary nymphal stage, yet slightly shorter than the combined periods of the two nymphal stages. In summer the female requires, usually, about 10 or 11 days for the completion of a generation, while the male requires about 9 or 10 days.

During the course of the year, in the latitude of Batesburg, S. C., there are ordinarily 16 or 17 generations, whereas in cooler portions of the United States, naturally, there are fewer broods. In the South the red spider passes the winter chiefly in the adult stage, and even propagates considerably at a temperature slightly above freezing. Feeding continues intermittently on several species of plants which bear leaves throughout the winter season.

DESCRIPTION AND HABITS.

THE EGG.

Description.—The eggs (Pl. II, fig. 1) are almost perfect spheres. When first deposited they are about as clear as water, but as incubation progresses they become opaque, turning a dark straw color just before hatching. A series of spots becomes apparent, and in the later stages of incubation the carmine eyes of the embryo are visible through the shell. The eggs are deposited singly on the underside of the host leaf and directly on the surface unless copious webbing is present, in which case eggs are frequently attached to the fibrils slightly above the surface of the leaves. Although very minute in size, the eggs are relatively large as compared with the size of the female red spider. A series of measured eggs averaged 0.129 mm. in diameter.

Number laid.—The number of eggs deposited by a single female is subject to considerable variation, depending, apparently, on temperature, locality, and suitability of food, but observations show that practically all of the eggs hatch. Perkins in 1896 states that in Vermont the brood varies between 50 and 100 eggs, that oviposition covers on an average about 7 days, and that the average daily deposition is about 10 eggs. Worsham (1910) records 80 eggs as the average full brood in Georgia, with the daily deposition varying from 1 to 12 per day, and covering an oviposition period of from 6 to 10 days. He states that 94 eggs was the largest number recorded from a single female. Ewing (1914), working in Oregon, found that females averaged 41 eggs per brood, with 63 as the greatest number. His records show 9 eggs as the maximum deposition per day, with 1 as a minimum, and he found that this fluctuation was induced largely by temperature and nutrition conditions.

In the course of the five seasons' observations at Batesburg many colonies have been reared under control. From a series of 90 such broods the summaries given in Table I are derived:

TABLE I.—*Records of oviposition of the red spider.*

Largest brood	110
Average for 20 largest broods	68.01
Average for 10 largest broods	80.10
High daily depositions 12,[1] 13,[2] 14,[3] 15,[4] 16,[5] 17,[5] 19.[1]	
Maximum daily oviposition	19
Total eggs from 38 broods	1,893
Total egg-laying days (38 broods)	320
Average eggs per day per female	5.92
Average ovipositing days per female	14
Maximum ovipositing days per female	36

From these rearings it follows that for South Carolina the female under proper conditions will produce a brood of from 75 to 110, probably averaging about 85, and that the eggs are deposited usually in from 10 to 12 days at the rate of from 8 to 14 per day.

Incubation period.—The duration of the incubation period varies largely with the temperature in the different localities. Perkins (1897) found that 7 days were required in Vermont for this period. Ewing (1914) states that an average of 5.5 days were consumed at Corvallis, Oreg., between deposition and hatching. In Georgia from 3 to 4 days were required for incubation, according to Worsham. In a series of 71 breeding-cell tests (each cell containing the progeny of 1 female) the average duration of this period at Batesburg was found to be 3.93 days during May, June, July, August, and September.

In hatching, the shell splits more or less completely around and the larva easily extricates itself. During severe occurrences of infestation the leaves of the host plant may be seen thickly covered with the bleached and empty eggshells, which disclose the cause of death of leaves long after the disappearance of the pest has occurred.

The effect of temperature upon the incubation of the red-spider egg is very marked. In midsummer, at Batesburg, with mean daily temperatures between 80° and 90° F., incubation rarely requires more than 4 days. One rearing beginning March 12 consumed 15 days for the hatching period. Eggs, in one case, deposited November 16 hatched in 23 days. During December, January, and February eggs may remain dormant for from 1 to 3 months, hatching with the advent of sufficiently mild weather. The relationship between mean temperatures and the length of the egg period is shown in Table II and figure 2. The eggs of a colony are usually clustered upon

[1] 3 cases. [2] 5 cases. [3] 4 cases. [4] 2 cases. [5] 1 case.

the leaf surface or among the fibrils of the webbing and rarely involve an area greater in size than that of a dime.

TABLE II.—*Duration of the egg stage of the red spider.*

Brood.	Average date of deposition.	Average date of hatching.	Average duration.	Mean temperature for period.
			Days.	*°F.*
1......	Mar. 12	Mar. 27	15.0	54
2......	Mar. 24	Apr. 4	11.5	58
3......	Apr. 4	Apr. 13	10.0	60
4......	Apr. 27	May 3	6.0	67
5......	May 19	May 23	4.0	75.2
6......	June 10	June 13	4.0	81
7......	July 16	July 19	3.5	80.7
8......	Aug. 20	Aug. 23	4.0	79.8
9......	Sept. 2	Sept. 5	4.0	78.9
10.....	Sept. 11	Sept. 18	8.0	69
11.....	Sept. 14	Sept. 19	6.0	70.5
12.....	Sept. 30	Oct. 7	8.0	68.3
13.....	Oct. 31	Nov. 16	17.0	58.9

THE LARVA.

Description.—The newly hatched larva (Pl. II, fig. 2) is round, colorless, and 6-legged, and its body does not exceed that of the egg

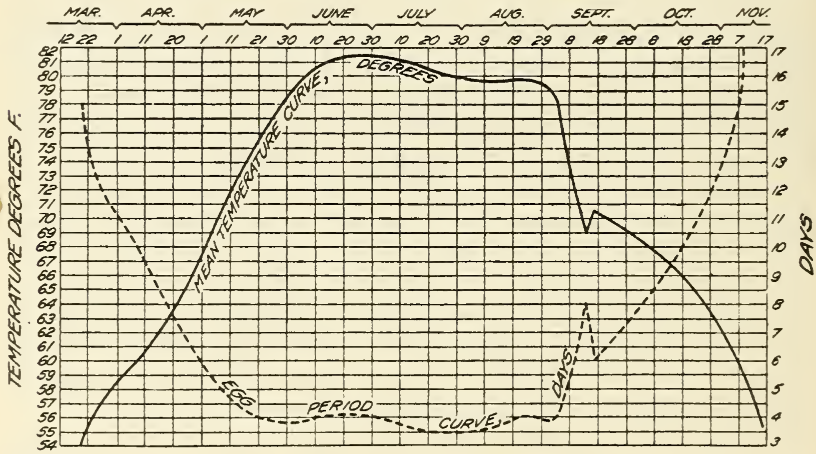

FIG. 2.—Simultaneous curves of temperature and incubation of the red spider, showing the intimate relation between prevailing temperature and the time required for the development of the egg. (Original.)

in size. The two portions of the body, cephalothorax and abdomen, are rather distinctly marked at this time by a transverse suture. The most conspicuous feature of the newly-hatched larva is its bright carmine eyes. It begins feeding at once, and as feeding progresses the larval color deepens to a green or ferruginous green. A characteristic feature of the larva is the shortness of the legs due to inflation of the slightly hardened leg segments. Although the tarsus and the femur are the longest joints of the larval legs, there is no material difference in the length of the joints such as develops in the later stages. The patellæ and tibiæ are only slightly longer than wide. The onychium, which in the adult becomes conspicuously attenuated, appears as a mere abrupt narrowing of the tarsus in the larva. The larval palpal characters agree very closely with those of the adult, except that the terminal "finger" of the "thumb" seems relatively more slender. The larval body bristles are proportionally shorter and stouter than in the adult. A large series of measurements of larvæ give the following dimensions: Length, 0.151 mm.; width, 0.116 mm.

Length of larval instar.—The time required for the completion of the larval stage is subject to considerable variation, mainly attributable to temperature and moisture conditions. The larva is much less resistant to adverse minimum temperatures than the egg. While in summer this stage rarely requires more than 2 days, in the early spring and late fall records as long as 15, 16, and 17 days are frequently obtained. From data derived from 61 colonies we have computed the average interval between hatching and the first molt to be 1.94 days. Basing his computations on 6 completed records, Ewing (1914) states that the average larval period at Corvallis, Oreg., is 3.33 days. Perkins (1897) found 4 days to be the average time required in Vermont for the completion of this stage.

As has been recorded by a few other workers, the larval stage (as well as the nymphal stages) exhibits an active period and a resting period. The resting stage in South Carolina requires but a few hours for its completion. In 1898 Von Hanstein designated this resting stage by the term "Nymphochrysallis," which he states lasted from 24 to 30 hours at Berlin.

Molting.—The five cases of molting observed occupied from 2 minutes to 4 minutes 20 seconds. The operation is initiated by a brief series of struggles which result in the partial rupture of the skin at the line of the postcephalothoracic suture. The separation is complete over the back and extends laterally down either side, so that the two halves of the old skin are merely connected by a ventral strip. The primary nymph disengages its forelegs and anterior portion of the body. This accomplished, the free legs are used to pull with, and by means of a twisting, wriggling movement the nymph extricates legs III and IV and walks out over the front portion of the cast skin and is entirely free. The exuvium, as a rule, is left *in situ*. The fourth pair of legs, which become evident with the completion of the larval molt, at first appear atrophied and useless, but in a very few minutes the nymph acquires use of its new appendages.

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FIRST NYMPHAL STAGE (THE PROTONYMPH).

As has been stated previously, it is only the female which passes through a second nymphal stage.

Description.—The primary nymph (Pl. II, fig. 3) differs from the larva in having 4 pairs instead of 3 pairs of legs, in the somewhat increased size, and in the more oval outline of the body. Furthermore, the bristles are slightly longer, and the segments of the legs become elongated in proportion to their width. The color of the protonymph is usually darker than that of the preceding stage and the lateral pigment blotches become more evident in this stage. One of the most noticeable modifications in the primary nymph is the considerable elongation of the abdomen, the suture separating the latter from the cephalothorax lying in a position slightly more than one-third the body length from the anterior margin of the cephalothorax, whereas in the larva the suture nearly bisects the body. A series of measurements of the protonymph averaged, length, 0.213 mm.; width, 0.145 mm.

The habits of the primary nymph are similar to those of the larva. It moves about more freely than the larva. Investigators of red spiders have claimed that the ability to spin webbing appears for the first time in the protonymph, but no effort has been made to establish this point.

"Premolting" period.—Perkins (1897) makes no mention of a quiescent period preceding the molting of the primary nymph. Ewing's life-history table shows an average duration of 1⅗ days for the resting period before the molting of this stage. At Batesburg the "premolting" period of the protonymph occupies a very few hours. During these quiescent periods the body assumes a pearly or silvery appearance. Von Hanstein (1902) called this quiescent period of the primary nymph the "Deutochrysallis."

Duration of the protonymphal period.—With the records of 6 individuals upon which to base his conclusions, Ewing found that in Oregon the protonymphal stage required from 2 to 4 days, with an average of 3.16 days. At Batesburg 37 colonies completed the primary nymphal stage. In March, in one case, this stage required 6 days for completion, but in the summer the period is occasionally concluded in 1.5 days. The average duration of the female protonymphal stage for all records at Batesburg is 2.18 days.

Molting process.—Of all the red-spider stages, those which are distinguished with the greatest difficulty are the primary and secondary nymphs of the female. It is natural to presume, therefore, that no radical changes occur in connection with the molting process, and this is borne out by observations. The time required was slightly over 3 minutes in the case of the one operation observed. (See fig. 3 for the cast skin of the protonymph.)

SECOND NYMPHAL STAGE (THE DEUTONYMPH).

Description.—The deutonymph, which occurs only in the case of the female, resembles the protonymph except that it is larger and more elongate. In the advanced condition of this stage (Pl. II, fig. 4) it also resembles the adult female. Although pigmentation is intensified as the mite approaches maturity, there is usually an absence of the characteristic reddish color. As the deutonymph approaches maturity it can be distinguished from the maturing male nymph, as the latter is smaller, more cuneate posteriorly, and exhibits a tinge of amber or ferruginous. A series of measured deutonymphs averaged, length, 0.360 mm.; width, 0.218 mm.

Duration of the deutonymphal period.—Perkins (1897) found that in Vermont an average of 2 days was required for the completion of the second nymphal stage under summer conditions. Ewing's 5 completed deutonymphal breedings averaged 2.6 days. The portion of this interval occupied by the quiescent period (the "Teleiochrysallis" of von Hanstein) is not clearly indicated in Ewing's bulletin, but appears to be approximately 1 day.

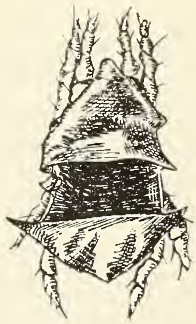


Fig. 3.—Cast skin of the red spider shed at the time of second molt, still united by the ventral tissue. (Original.)

In the Batesburg investigations 25 colonies completed the second nymphal stage of the female. One deutonymph, the egg of which was deposited on September 27, required 13 days for its development. Exhibiting the other extreme, a few individuals of this stage matured in approximately 1.25 days in midsummer. The average duration for the second nymphal stage during the active season is 1.9 days.

Habits.—The deutonymph is probably the most voracious of the immature mites. It roves about considerably on its native leaf. Ewing (1914) records a well developed spinning ability on the part of the deutonymph. The first two stages are not adapted to traveling over the soil surface, owing to their frailty, but the last immature state is more hardy and active, and individuals are often capable of successfully establishing themselves after traversing considerable distances. This fact has been determined by "tanglefoot" tests, and by finding deutonymphs on cotton seedlings which were younger than the mites.

Molting process.—Upon two occasions, in the early morning, females issued from the second nymphal skin. The transverse split occurs practically as in the two preceding molts. In one instance, following a night minimum of 46° F., the morning was cool, and this condition doubtless worked to retard the duration of the process, which occupied nearly 4 minutes. The other observed molt took place on a warm morning and required less than 3 minutes for its completion. The male has been seen to assist in the molting of the female deutonymph. The attending male, following the transverse splitting of the skin, inserted his palpi, on one occasion, under the old skin, and forcibly pulled it over the end of the female's abdomen.

THE ADULT.

Description of Female (Pl. II, fig. 5).

Color variable; at times rusty green, sometimes greenish amber, or yellowish, at times almost black, but more often brick red or ferruginous red. Pigmented blotches occur almost invariably on the sides of the body, which are usually coalesced to form two large dark spots, one on each side extending from the back of the cephalothorax to the posterior region of the abdomen. These are often interrupted posteriorly to form a large anterior and a small posterior spot. These spots arise from underlying paired organs. Almost directly over coxæ II are the carmine eyespots located on each side, near the margin of the cephalothorax. Legs pale amber, much paler than ground color of body. Palpi pale salmon. Dorsal bristles pale, not arising from tubercles. Body pyriform oval, widest across posterior region of cephalothorax; bristles in four rows, each succeeding pair becoming shorter; the frontal pair a little over half as long as the subfrontal pair, which, like the median pair next behind, are two-fifths the greatest width of body. Mandibular plate about twice as long as broad, tapering slightly forward, broadly rounded at tip, with a slight median notch. "Thumb" of palpus in shape somewhat like a truncated cone, the dorsal face about one-third longer than greatest width at base, the upper surface twice slightly depressed transversely, with an intervening dilation, bearing on its tip a subcylindrical "finger" which is about two-fifths as wide at its base as the distal end of the "thumb." On its upper side, just above the "finger," are two stout, straight hairs arising close together, one medially and the other laterally, which do not greatly exceed in length the "finger." Near the middle of the upper side is a smaller "finger" three-fourths the length and one-half the width of the terminal "finger" and very similar to the latter. Between this dorsal "finger" and the base of the "thumb" are 2 strong, curved hairs about equaling those at tip of "thumb," and at middle of latero-ventral aspect of "thumb" arises a hair about equaling the latter. The penultimate palpal joint bears the usual claw, which reaches about to the basal "finger," and also bears 2 bristles, one arising dorsally at base of claw which hardly equals the length of claw, and one arising near center of outer side which about equals the dorsal bristle. Legs I hardly equal the length of body from the anterior margin of cephalothorax to tip of abdomen; relative lengths of segments of leg I, coxa 25, trochanter 15, femur 53, patella 23, tibia 30, tarsus 49; femur almost 4 times as long as thick; tip of tarsus (the onychium) bearing a claw which is strongly arcuate and 4-cleft to its middle. Arising also from the onychium, laterad of base of claw on either side is an enlarged process which immediately splits into 2 nearly straight hairs, each of which bears a capitate tip. These 4 capitate hairs spread spokelike in the same plane and their relative lengths are similar to those of the fingers of the human hand viewed from the top. The location of bristles near the onychium is not constant, varying with the locality, etc., 1, 2, or 3 hairs occurring at the point of abrupt enlargement near the tarsal end which reach almost to the tips of the capitate hairs, and 2, 3, or 4 hairs occurring at a distance from the onychium about twice as great as that of the distal hairs. (Pl. III, figs. 13, 14.) A series of measured females gave the following dimensions: Length (front of cephalothorax to tip of abdomen), 0.424 mm.; width (across posterior margin of cephalothorax), 0.278 mm.; length of foreleg, 0.325 mm.

Longevity.—The duration of life of the adult female may be divided into two periods—a short period immediately following the deutonymphal molt during which no eggs are laid, and a rather extended egg-laying period, which, as determined by experiments at Batesburg, is 18.8 days. Perkins states that in warm, dry weather the female begins to oviposit in about 48 hours after the last molt, and that in cooler weather egg laying may not begin for several days. Von Hanstein (1901) found the preoviposition period of *Tetranychus althaea* to be eight days or more. Ewing (1914) records the average duration of the period previous to egg laying to be three and four-fifths days. During this inactive period the female mates, feeds to some extent, and exhibits a desire to migrate.

The adult life, from the last molt to death, as computed from 23 females, is 12.43 days for the summer season in South Carolina. The longest individual record of longevity at Batesburg is 39 days, covering a period from September 1 to October 9, most of which was during warm weather. The next longest record was 23 days, covering a period from September 1 to September 24, also during warm weather. Perkins states that in Vermont the females under favorable conditions may live at least three weeks and probably longer. Ewing found the average longevity of the female during the early fall in Oregon to be 21⅓ days. Morgan (1897) claimed that females live only from five to seven days after reaching maturity. The virile late-fall female often lives five months. Very little is known concerning the longevity of the male.

Color variations.—That red spiders vary in color has been observed for a long time. It was observed in the case of the European species, and seems to have been instrumental largely in the formation of numerous synonyms by early writers. For a long time it was held that this diversity in color was due mainly to the varying nature of the host plants.

Ewing (1914) conducted a series of experiments for the purpose of ascertaining the nature, situation, and composition of what he styles the six principal pigments of the common red spider, namely, green, yellow, orange, carmine, black, and brown. In summarizing he states that the green color is due to the presence of chlorophyll in the blood or tissues of the mites; that the yellow color arises from a pigment derived from and closely allied to the chlorophyll green pigment and which is elaborated from the green pigment; that the orange color is due to a pigment of that color which is dissolved in the cell fluids or the blood and is quite permanent, is unaffected by age, and is never found except in adults on certain hosts; that the blackish color does not arise from a distinct pigment, but is due to the concentration of the yellow pigment in the food material; that the brown color also is due to a superabundance of the yellow pigment; and, finally, that the carmine of the region of the eyes is due to the presence of a permanent pigment which is present even before hatching. Ewing states that in his experience reddish individuals are exceptional. The experiments conducted by Ewing are a distinct step in advance and, it is hoped, will stimulate additional research in that direction. Perkins was of the opinion that dark-colored females are ones that have been impregnated, and that light-colored females are weak sexually and have either no offspring or impotent progeny.

As a rule the females we have observed are either brick-red, orange, amber-yellow, greenish, or brownish-green. During the period from April to September, inclusive, the vast majority of adult females in the South are a conspicuous brick-red color. Toward late fall the females often assume a salmon-yellow color in the Southeast. Von Hanstein (1902) also found this to be the case in Europe with *T. althaea*, and he considered that the color was associated with preparation for wintering. It certainly is very striking that the red type of female almost disappears in the fall and is replaced by the orange-yellow type.

Description of Male.

The color of the male is rusty salmon; the lateral spots are less conspicuous and usually located near the front of the abdomen; the cephalothorax is often nearly clear straw color. Eyes crimson, relatively more conspicuous than in the female. The legs I are usually of a deep salmon color (this not being the case with the female). Body cuneate-ovate, widest at the anterior region of the abdomen, the cephalothorax rounded in front, abdomen tapering to an acute point posteriorly; bristles arranged very similarly to those of the female, but of considerably greater length and prominence, the frontal pair not over half as long as the subfrontal pair, which, like the median pair next behind, are in length equal to two-thirds the greatest width of the body. Relatively the legs are longer in the male than in the female. Tip of upper side of third joint of palpi with a short, stout, curved spine. The penis (Ewing, 1913) is short, stout, and has a hook at its end which turns upward and ends in a flattened barb. A measured series of males yielded the following dimensions: Length (anterior margin of cephalothorax to tip of abdomen), 0.256 mm.; width, 0.142 mm.; foreleg, 0.256 mm.

Color variations.—The color variations of the male are very slight compared with those of the female. Nearly all individuals conform to one type, which is of an amber-yellow color.

GENERAL FEATURES.

Structural variations.—The microscopic characters of the palpus of the red spider (Pl., III, figs. 1 to 7) are rather variable. The relative dimensions of the terminal "finger" show considerable diversity. The number of bristles between the terminal "finger" and the sub-basal "finger" varies at least from 1 to 3; also, the size and outline of the sub-basal "finger" is subject to some variation. (Pl. III, figs. 13, 14.) Similarly, the character of the tarsal appendages (Pl. III, figs. 8 to 12) exhibits some modifications.

Proportion of sexes.—Worsham (1910) states that in Georgia less than one-fourth of the fertilized eggs produced males. In a large number of rearing tests conducted at Batesburg the total male and female progeny from fertilized eggs was found to be 39.7 per cent and 60.3 per cent, respectively. The ratio of four males to six females represents fairly well the usual proportion of the sexes. When development is normal, the ratio of females to males (based on the foregoing computation of sex ratio) will remain about six to four. At the time of the active migratory movements of females, with their resulting isolation without male individuals, reproduction takes place parthenogenetically for awhile. Since unfertilized eggs invariably bring forth male individuals, the progeny of these isolated unfertilized migrants will be males, and following such migrations a superabundance of males is frequently observed; also, the ability of males to evade capture by predatory enemies or to withstand the action of wind and rain may account partly for the increased number of males which occurs at times. In the fall there is a tendency for the males to predominate which insures the fertilization of the females during the winter.

Copulation.—Several writers have described the act of copulation of the red spider. Perkins (1897) states that the sexes pair at once after the last molt and that one female may receive several males if they are at hand, but that impregnation occurs but once. Von Hanstein (1902), writing of a European form, records many details which agree with those exhibited by the American form. Males are often observed waiting on quiescent deutonymphs, which they excitedly stroke and overrun, as though trying to assist in the molting process. A typical case of copulation may be described as follows: The female, issuing from her deutonymphal skin is immediately attended by one or more males. The female remains comparatively quiet and the male crawls directly under her from behind. The legs I of the male are reached up around the hind portion of the female's abdomen, and the tip of the male's abdomen is then bent sharply upward and slightly forward (fig. 4) until the genital aperture of the male comes in contact with the vulva, which is subterminal. At the approach of a second male the engaged individual usually "backs out" from under the

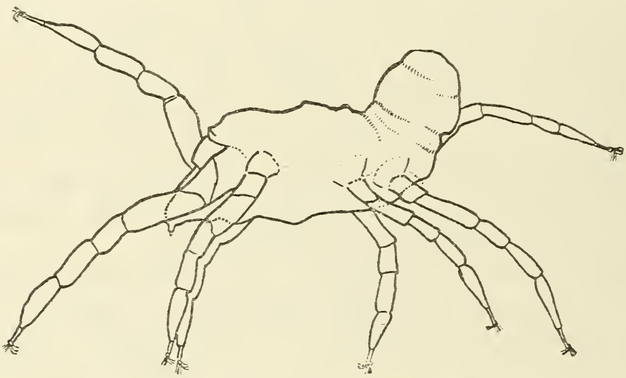


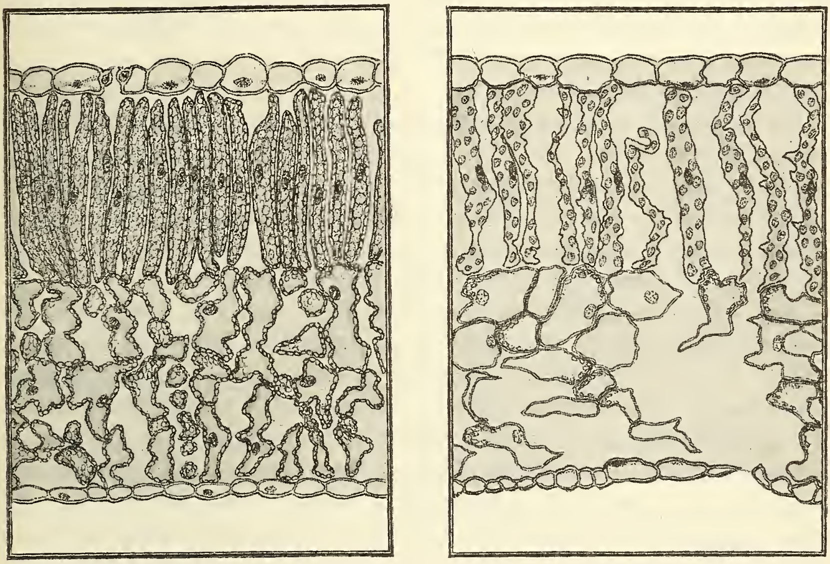
FIG. 4.—Outline sketch of male red spider, showing the characteristic copulatory attitude with reflexed abdomen. (Drawn with camera lucida. 175.) (Original.)

female and upon the departure of the intruding male resumes his former position.

Parthenogenesis.—Perkins recorded that females readily deposit eggs upon failure to mate and that from these unfertilized eggs only males develop. He also states that, after producing a number of eggs, if impregnated subsequently, such females produce a majority of female eggs. Banks (1900) says that the first eggs laid by unfertilized females "produce only males, which, when adult, will pair with the females, and the latter will then lay eggs producing both sexes." Morgan determined that eggs from unfertilized females were viable and capable of development. Ewing reared to adult 52 eggs of three virgin females and all of them became male.

While it has been known that unfertilized eggs become male individuals, no effort has been made, apparently, to test the potency of agamic males. Upon a few occasions parthenogenetic males have been isolated with virgin females, which deposited the usual number of eggs and developed individuals of both sexes in the usual proportion. Since ordinarily these virgin females would have deposited eggs producing males, it is demonstrated by the equal representation of female progeny in such matings that the parthenogenetic male is completely potent.

Parthenogenesis has a very important rôle in the biology of the common red spider. Earlier writers have shown that it works to maintain a relative equilibrium between the individuals of the sexes. Migrating females very frequently establish themselves without having been fertilized, and they are very likely to be without males subsequently. Thus in the event that they arrive unfertilized, their offspring will all be male, and upon the maturing of these male broods



a *b*

FIG. 5.—*a*, Cross section of normal cotton leaf; *b*, cross section of cotton leaf injured by the red spider. The puncture is near lower right-hand corner. Highly magnified. (McGregor.)

the "pioneer" females will at once begin laying fertilized eggs, which will maintain the sexes nearly even.

Feeding and injury to plants.—All stages of the red spider, as before stated, feed actively upon the leaf of the host plant. The feeding operation is accomplished by means of sharp, slender, lance-like mouth parts which are thrust through the epidermis well into the leaf, usually on the underside. In the case of cotton, which is typical, the puncture is made through the underside. The consequent siphoning out of the cellular material in the immediate vicinity of the puncture results in the impoverishment of the immediately adjacent tissue (see fig. 5). The parenchymal cells are ruptured and the palisade cells become shrunken and distorted. Each incision of the stylets causes a blackish spot, and after much feeding the infested leaf becomes thickly spotted underneath. There is a change of color in the portions of the leaf attacked which develops especially on the surface immediately over the injured area. In the early stages of infestation this coloring reveals itself as small blood-red blotches, which vary with the number of mites present and with the extent of surface attacked. As leaves become more heavily infested the entire leaf often becomes involved and the effect is soon very marked. The petiole droops to a marked extent, and the entire leaf turns rusty red and later becomes brown and dry. The lower leaves are first attacked, but infestation spreads upward until the plant becomes almost completely defoliated. If the progress of the pest is checked, through natural conditions or by spraying, the health of the foliage is frequently restored and only a few leaves may be shed.

The nature of the injury to plants other than cotton is not materially different from that just described. It is not, however, usual for most plants to exhibit the red blotching. In the case of garden beans, hollyhock, sweet peas, and many other hosts (Pl. IV, figs. 2, 5, and 7) the badly affected leaves assume an ashy hue due to the presence of innumerable grayish puncture specks.

Web spinning.—For more than 100 years the red spider and its close relatives have been known as spinning mites or "spinnemilbe," owing to the ability of these creatures to construct webbing. There is still uncertainty, however, regarding the nature and location of the spinning apparatus, some workers claiming that the glands are located near the mouth, while others contend that the threads issue from the anal end of the body. Ewing (1914) asserts that the silk emerges near the anus and that the four-pronged[1] tarsal claw and the tennent hairs, found on the tarsi, are used in its manipulation.

The fibrils formed by this species are so exceedingly fine that they are almost invisible. Many of them together are visible as a silvery sheen on the much-infested surface (Pl. IV, figs. 1 and 2). The strands are not arranged as a symmetrical web, but merely extend from point to point on the leaf, from leaf to stem, or from one leaf to another. Under normal conditions it appears that the thread is not produced during the ordinary wanderings of the mite, but becomes elaborated at special times, as when the host becomes nonsucculent through drought, when the supporting plant becomes overrun by the pest, or in the presence of numerous enemies. As the leaf curls through the loss of juices the threads become separated from the leaf, so that some mites are under and some on the web. The web is normally confined to the underside of the leaf, but on

[1] In his description of the tarsus Ewing (1914) describes it as "divided into six prong-like elements."

heavily infested plants it may occur on all parts of the host, the whole apical portion of the plant having a silvery appearance.

There has been considerable conjecture concerning the function of the webbing. The surface of the leaf is preferred for oviposition, and it is apparently only when overcrowding has resulted in a confusing maze of fibrils that the females resort to the webbing as a medium upon which to place the eggs. Hundreds of mites in experiments have been observed to molt or to prepare to molt, and without exception they have fixed themselves for the quiescent period directly upon the surface of the leaf.

It has been thought by some writers that the travel of red spiders is facilitated by the presence of the web and that travel upon certain hirsute plants is practically impossible without the aid of webbing. In our work mites have been seen crawling readily over the surfaces of all sorts of pubescent and hirsute plants which possessed no trace of webbing. We have tested larvæ, nymphs, and adults on the pilose surface of velvet and find that they travel readily over the innumerable projections of the pile.

The suggested aerostatic rôle of the webbing in conveying mites through the air seems improbable. We have never seen web appearing as though damaged by wind, and neither in the experiment by Mr. E. E. Munger during 1912 in California on wind dispersion nor in those of a similar nature conducted at Batesburg has a trace of web been detected on the screens coated with a sticky substance, although many red spiders have been thus taken.

We believe that the function of the webbing is that of protection. Among the agencies against which this protection undoubtedly serves are: Spattering raindrops; upward bombardment of soil particles during heavy storms; jarring of foliage caused by driving storms, wind, or sudden contact; flooding, in the case of prostrate plants; the attack of predatory insects, etc. We have often examined infested leaves the undersides of which were heavily coated with soil particles, and after carefully removing the web found the mites uninjured and active behind the protective canopy. On other occasions following heavy downpours leaves not supplied with webbing have frequently been observed completely freed of the red spider, whereas leaves bearing webbing, although subjected to the same storms, still retained a great many mites. Again, low, prostrate plants have frequently been examined following flooding rains and the lowest leaves often found to be heavily coated beneath with a deposition of scum that had been left upon the retreat of the surface water. In such cases, when web had intervened between the mites and the water, the creatures survived the flooding and could be found pursuing their various activities without serious impediment.

In the course of many field examinations we have often seen predatory insects which had been entangled in the red spider's webbing and had perished. *Triphleps insidiosus* and other species have been frequently caught in this manner. As Quayle (1912) has recorded, Arthrocnodax appears very much at home among the fibrils of the mite web and probably derives some protection from the chalcidid Aphanogmus.

Clustering before rain.—Immediately before heavy rains mites are often seen clustered in groups. This was never seen at any other time than just prior to the first drops of a heavy rain.

NATURE AND EXTENT OF DAMAGE TO COTTON IN THE SOUTH.

The detailed account of the specific feeding method and immediate injury inflicted by the red spider we have already presented. It has been shown that severe infestation causes such a lessened vitality, and possibly toxic condition, that a shedding of the leaves and bolls is induced. In severe cases the death of the stalk usually follows the complete defoliation of the plant. However, the loss of foliage (Pl. V, figs. 1–3) is always accompanied by the shedding of the bolls, which may amount to the total elimination of the fruit or to the loss merely of the younger bolls. In the case of stalks which have suffered the complete loss of foliage but which have retained certain of the oldest bolls, the latter may open and produce lint, if sufficiently mature. These defoliated plants are rarely productive of any considerable amount of cotton, though in some cases they develop considerable adventitious foliage and may become restored almost to normal appearance.

The damage worked by red spiders in cotton fields varies in intensity and extent according to the nature of the dispersion centers, and depends on whether control measures have been applied and upon other factors. In 97 cases brought to our attention during one season (1912) the average infested area for each case was 21 acres. In other words, a total of about 2,037 infested acres of cotton was voluntarily reported from South Carolina during one season. It is a conservative estimate to presume that this does not represent over 10 per cent of the total affected acreage in the State for that year. This would make the infested area in South Carolina about 20,370 acres, which would normally produce a crop of about 13,580 bales or 6, 790,000 pounds. The proportionate part of this output that might be expected to be lost through the ravages of the red spider is about two-fifths, or 2,716,000 pounds. At 12 cents per pound for the staple, this lost lint will represent a tax of $325,920 to the State, and the value of seed correspondingly lost would ordinarily amount to $67,900. Our figures thus indicate that during the season of 1912 the red spider caused a loss of about $393,820 to the cotton planters of the State of South

Carolina. Considering the fact that North Carolina, Georgia, Alabama, and Mississippi are known to suffer from the pest practically to the same degree as does South Carolina, it is within all probability that the Southeast, during a severe red-spider year, may suffer a loss of $2,000,000 from the ravages of this pest. As discussed under another heading, the occurrence of the pest during certain years is comparatively light, and the resulting injury is correspondingly reduced.

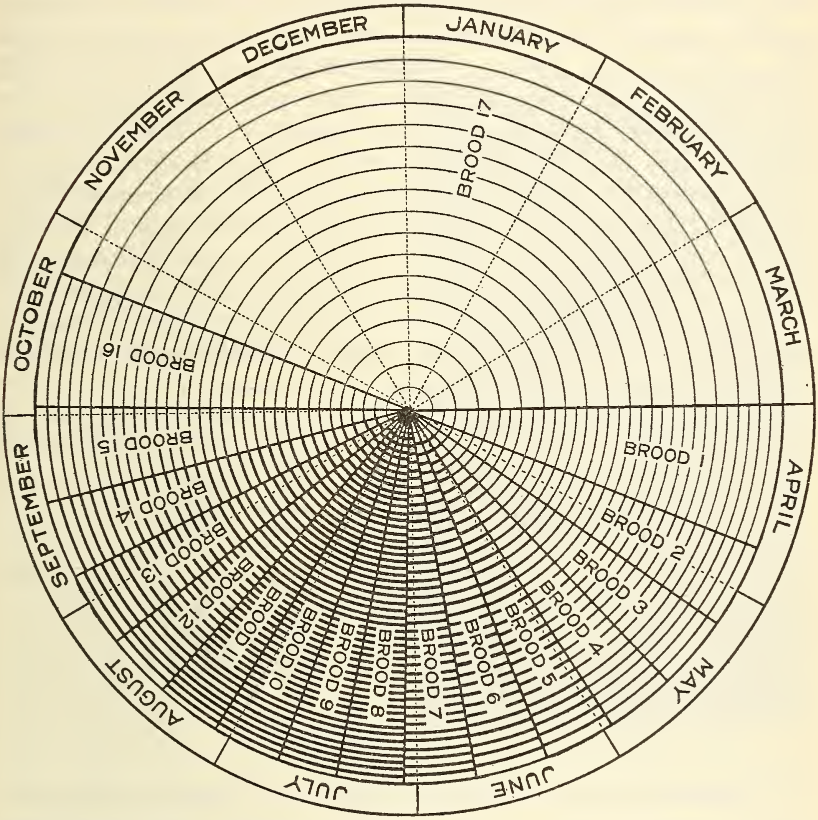


FIG. 6.—Diagram illustrating the sequence of the usual 17 generations of the red spider in the course of one year. (Original.)

GENERATIONS OF THE RED SPIDER.

Regarding the number of generations at any given locality very little has been published. Ewing (1914) states that in Oregon the activities usually begin early in May and that hibernation commences in October. This furnishes an active season of about 180 days, which, divided by 19.7 days (the duration of the life cycle based on his averages), gives nine generations occurring at Corvallis for the season. Worsham (1910) states that in Georgia there are 10 successive generations in seven months, each requiring about three weeks for completion.

At Batesburg the average time required throughout the active season for the completion of a generation is 10.7 days. Since there are normally about 180 active days per season at that locality, it follows that there should be approximately 17 successive broods in South Carolina. This estimate is borne out further by the actual observations in the field.

In 1911 the wintering brood (eggs of the preceding fall and winter) reached maturity about March 11; the 1911–12 wintering individuals matured about April 17; March 25 marked the arrival of the 1913 initial brood of adults; and in 1914 the wintering generation again completed its development about March 25. The average date of appearance of the first spring brood at Batesburg is computed from the foregoing records to be March 31. The time required for a single generation varied from 170 days during the winter of 1911–12, and 35 days in March and early April, to 10 days throughout the summer. The generations, as indicated in Table III and figure 6, are the composite averages of all our continuous records of the past four years and undoubtedly represent the normal sequence of broods in South Carolina.

TABLE III.—*Seasonal sequence of the 17 annual red-spider broods at Batesburg, S. C.*

Brood.	Commencement.	Completion.	Duration.	Brood.	Commencement.	Completion.	Duration.
			Days.				*Days.*
1	Mar. 31	Apr. 22	22	11	Aug. 3	Aug. 12	10.7
2	Apr. 23	May 5	13	12	Aug. 13	Aug. 23	10.7
3	May 6	May 17	12	13	Aug. 24	Sept. 3	11
4	May 18	May 29	12	14	Sept. 4	Sept. 15	13
5	May 30	June 9	11	15	Sept. 16	Sept. 30	15
6	June 10	June 20	10.7	16	Oct. 1	Oct. 22	22
7	June 21	July 1	10.7	17	Oct. 23	Mar. 30	159
8	July 2	July 11	10.7				
9	July 12	July 22	10.7		Total		365
10	July 23	Aug. 2	10.7				

In sheltered locations winter development may continue sufficiently long to result in the maturing of one or more extra generations. While instances of this are comparatively rare, they are of considerable biologic and economic importance.

Rearing experiments.—Practically all of our experimental data covering life history and biological statistics were secured through the use of a special type of rearing cell which is attached directly to the leaf of the living plant (fig. 7).

The individuals to be reared or experimented with are carefully introduced into these cells by means of the finest camel's-hair brushes. The felt confining pad permits the free passage of air, so that the conditions within the cell are nearly normal. It was found that in rearing cells attached close to the ground quicker development resulted than in those attached higher on the plant. As this arises through heat reflection from the soil, the rearing cells were attached usually at points 3 or 4 feet from the ground in order to eliminate this surface radiation in so far as possible.

SEASONAL HISTORY.

Over-wintering habits.—Several European writers have stated that the common red spider of the Continent passes the winter in a state of hibernation under bark scales or in the ground. Dugès found this species under stones and concluded that they reached the ground with the falling leaves. Von Hanstein (1902) found them during the winter in large numbers in the ground near trees which had been severely infested. He states that mites are often so thick about the crown of the tree roots that when the soil is removed they become plainly visible from some little distance, and adds that the red spiders fashion wintering quarters in the protective crevices of the bark. In Colorado, Weldon (1909) determined that the winter is spent in the ground, and states that myriads of red spiders were found below the soil surface at the crowns of trees upon which they had been feeding. Some were found at a distance of 10 feet from the trees, where they had crawled beneath clods of soil to hibernate. Weldon states that hibernation begins before the cold weather sets in, the first downward migration of mites occurring toward the end of July. Wilson (1911) (Batesburg, 1910) entertained the belief that the red spiders overwinter on cotton plants near the base of the stalk, and was certain that they hibernate about the roots of cultivated violets. Worsham (1910) seems to have been the earliest investigator to recognize the fact that in the Southeast, at least, the red spider passes the winter actively in the adult stage, and even propagates sparingly at temperatures slightly above freezing. He found small colonies housed during the winter on

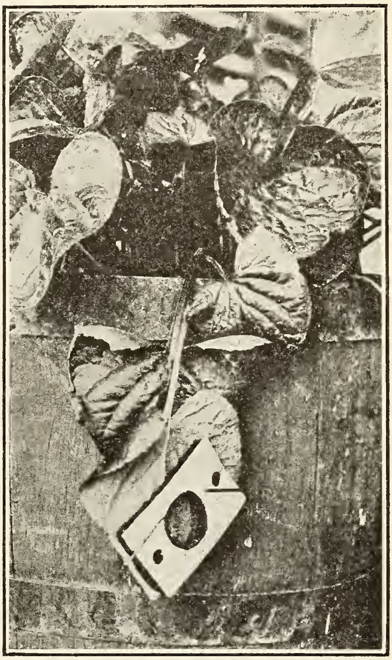


FIG. 7.—Type of isolation cell employed for the life-history and other developmental studies of the red spider. Attached to violet leaf. (Original.)

several species of plants then bearing green leaves. Ewing (1914) states that in Oregon the females enter the period of hibernation in October, and that males are not found during winter.

At Batesburg we have repeatedly investigated hibernation. Old cotton stalks, trash from in and around recently infested cotton fields, dormant weed stalks, violet roots and crowns, and similar material (gathered from localities of recent infestation) were collected during winter and placed in a large Berlese apparatus. The results were always negative. Many examinations have been made of dormant cotton stalks and other plants which had, during the previous season, harbored mites. We have never recovered living red spiders from these dormant hosts. In short, there is absolutely no evidence which would lead to the belief that hibernation occurs in South Carolina. The pest maintains itself throughout the winter on several species of wild and dooryard plants. We have traced infestation through four successive years, from the primary sources to cotton fields and back to the wintering hosts, and have established the botanical sequence which constitutes the successive migratory steps of seasonal activities.

The dispersion of the pest is determined largely by the nature and location of the plants upon which the mites overwinter. These hosts are divisible into summer hosts and winter hosts. Under summer hosts we place such species as harbor mites through the summer and which remain green throughout the winter, thus furnishing continuous feeding during all months of the year. Hosts of this kind are of vast importance in that they obviate the necessity of fall migration on the part of the mites. Among the more important plants of this type are the cultivated violet, strawberry, hollyhock, mustard, privet, and grass (*Panicum scoparium*). It is probably true that comparatively few infestations in cotton arise directly from these summer hosts. The balance of the mites persist through winter on the winter hosts. These include the native weed species which germinate or put out basal leaves in the fall, and to which a certain percentage of the migrants, from cotton and other annual plants, disperse. Whereever these weeds are allowed to grow in great profusion they are usually found to be infested, and when occupying positions close to cotton fields they constitute centers of direct invasion. Among the more common of the winter hosts in South Carolina are *Stachys arvensis*, *Geranium carolinianum*, *Rubus* sp. (wild blackberry), *Chenopodium botrys*, *Sonchus asper*, and *Oenothera laciniata*. Since the great mass of red spiders pass the winter on the wild plants, it is evident that these plants are of great importance. They occur commonly in dense borders along ditch banks, in field borders adjoining areas planted to cotton, in dooryards, and bordering roadsides.

Practically all of the winter hosts possess only prostrate leaves during the late fall and winter. This makes the foliage more accessible to the mites which may be crawling about in search of green plants, and, likewise, the basal leaves favor greatly the reestablishment of red spiders which may become stranded while being carried in surface water.

Appearance of spring adults.—The date which marks the maturity of the progeny of the females which wintered through from the preceding fall is subject to some variation. In 1911 the first spring brood was maturing as early as March 11, while in 1912 the first females did not appear until about April 17. In both 1913 and 1914 this brood matured about March 25.

Time of violet devastation.—Usually toward the end of May the cultivated violet plants in the Southeast become so completely overrun with red spiders that they are killed to the ground. The first indication of damage to violets is the presence of russet spots on the leaves. As the infestation increases the appearance of violet borders is as though they had been fire swept. Those who see them invariably believe they have been killed by drought. (Pl. IV, fig. 4.) When violets grow within a few hundred feet of cotton they may constitute the immediate source of infestation.

The average date of maximum injury to cultivated violets, as shown by the observations of the last four years, is found to be May 25. This is important in the seasonal history of the red spider, since the death of so many violet plants precipitates the migration of the mites, with the result that the pest becomes established on many new hosts.

Time of establishment on cotton.—The earliest date for the establishment of the red spider on cotton varies somewhat from season to season. The time depends largely on the date of appearance of the crops, since we frequently find females established on seedlings which are only three or four days old. Mites have occasionally been seen established on cotton as early as the 1st of May, but for the seasons 1911, 1912, 1913, and 1914 the average for the first records on cotton is computed to be May 20. The lower (sandy) section of South Carolina averages one-half month earlier in the pest's appearance than does the upper (clay) section, June 25 marking the time of the beginning of damage for the former and July 10 for the latter.

Time of severest infestation.—The progress of infestation in a given field depends on several interrelated factors, such as temperature, precipitation, natural enemies, etc. Furthermore, there are successive waves of infestation occasioned by the favorable and the inimical natural agencies. In 1911, at Batesburg, a cotton field was seen very acutely infested on June 12, while in 1913 fields were seen badly infested as late as September 6. Most of the severe infestation, however, occurs during July and August. By averaging the dates of occurrence of a considerable number of acute cases in our files we obtain July 26 as the date of heaviest infestation.

Approximate date of reduction in numbers.—During each of the four years of the red-spider investigation there has occurred at some time of the season a sudden reduction in the numbers of the pest due to the abundance of natural enemies. Unfortunately, this is not general and simultaneous throughout the South. Furthermore, the mite reduction occurs at different times from season to season. In 1911 it did not take place in central South Carolina until about the 1st of September, whereas in 1912 the pest was controlled as early as July 10. In 1913, July 20 marked the approximate date of decimation, and in 1914 the phenomenon occurred about July 20. For the four seasons, the average date of the reduction of the red spider by its insect enemies is found to be about July 15.

Following these seasonal decimations the mites are often reduced almost to extinction, which naturally reacts against the predatory species in due time, and in their absence a secondary impetus is usually noted in the development of the red spider. These second-

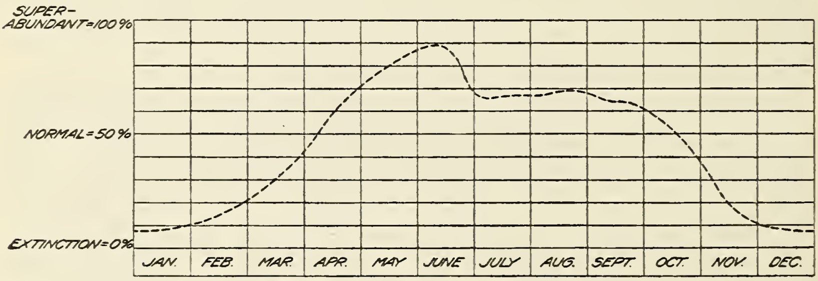


FIG. 8.—Curve representing the 4-year composite seasonal status of the red spider in central South Carolina. The depression of the line in June represents the decimation arising through the activity of predatory enemies. (Original.)

ary occurrences seldom result in serious infestations, but have the result of restoring somewhat the status of previous cases. This numerical revival may be looked for usually between the middle and last of August in South Carolina. (See fig. 8 for seasonal status curve.)

Fall and early winter status.—In parts of the world where the red spider hibernates the mites prepare to leave their host plants at the approach of winter and seek shelter in the ground or under the bark scales at the base of the trunk or stem of trees. In South Carolina, the mature mites assume the characteristic orange-yellow color with the arrival of late fall.

The mites which live through the winter are to be found usually on the basal leaves of a few dooryard plants, such as English violet, hollyhock, strawberry, and mustard, and upon several native species of weeds, etc., which offer green leaves. Every stage, from egg to adult, of both sexes has been repeatedly encountered during winter. The immature individuals produced in brief intervals of favorable weather are almost certain to perish with the return of lower temperatures.

Variation in abundance from year to year.—It is noticeable that the degree of occurrence varies greatly from year to year. We find from a study of the various natural influences that it is possible to foretell the probable status of the pest during a given season with considerable assurance. The red spider is extremely resistant to adverse meteorological conditions, and no matter how severe the winter, a considerable proportion of the mites come through safely. On the other hand, many of the insect species which are predatory upon the red spiders, being of a more susceptible nature, are less likely to survive the hardships of a severe winter. Theoretically, after a mild winter there should be an abundance both of mites and predators, while after a severe winter the mites should survive in a much greater proportion than their enemies. This condition has obtained during the past four years, mild winters being followed by mild red-spider seasons, while severe winters have been followed by seasons of heavy mite occurrence.

DISPERSION.

When the food supply on favorable host plants becomes exhausted dispersion to new food plants takes place, and it is usually by a succession of such dispersions that cotton finally becomes infested.

Ground travel.—On many occasions red spiders have been observed crawling on the ground in the vicinity of grossly infested plants, frequently crawling up and down the stems in search of more favorable hosts upon which to feed. In order to ascertain whether red spiders leave the plants of their own volition and crawl upon the ground in attempts to extend their range, the following experiment was instituted.

Tests of red-spider movements.—Large sheets of sticky fly paper were carefully fitted about the bases of cotton stalks. The sticky surfaces were permitted to remain in this position for periods varying from 24 to 48 hours. At the conclusion of these exposures careful examinations were made, of which the following specific results are rather typical: Five red spiders were observed on the inner edge, which came in contact with the base of the stalk; 29 mites were caught on the extreme outer edge, which was flush with the finely packed soil; 5 red spiders were found ensnared at dfferent points in the central area of the sticky surface. The only possible deduction is that the first-mentioned 5 individuals were intercepted as they were descending the stem; that the 29 mites were trapped as they were crawling over the ground surface, presumably toward the cotton stalk; and that the last-mentioned 5 undoubtedly dropped directly from the overhanging foliage.

Manner of travel.—An extensive series of experiments concerning the travel of red spiders has been performed. The female travels in a comparatively straight course, being influenced by the light. (Pl. VI.) The female travels faster than the male and her effort is extended over a relatively large space in an apparent attempt to locate new food plants. The very frequent observance of solitary females on seedling plants is positive evidence that they establish themselves through the agency of ground travel.

The male, on being removed from the host plant and tested on a comparatively smooth surface, confines his wanderings to a small area. The tracings made of male travel are seen to cross and recross until a maze of lines results. No evidence of phototropism has been observed in many cases of male travel. There seems to be an instinctive tendency to remain within a limited area. The entire area traversed in an hour by the average male on a smooth surface rarely exceeds in size that of a watch crystal. The aversion to roaming probably originates from the instinctive desire to remain with the females of the colony. It is not essential to the propagation of the species that migrating females, which failed to mate before undertaking their journeys, should become fertilized immediately upon establishing themselves on the new host. As has been emphasized previously, the early eggs of such sterile females produce only males, which, upon maturity, immediately fertilize the females, so that the subsequent progeny will be of either sex.

TABLE IV.—*Distance and rate of travel of male and female red spiders on coarse paper surface.*[1]

	Male.				Female.									
	Warm Day.				Warm day.					Cool day.				
Exp. No.	Time.	Distance.		Rate per minute.	Exp. No.	Time.	Distance.		Rate per minute.	Exp. No.	Time.	Distance.		Rate per minute.
	Mins.	*Ft.*	*In.*	*Inches.*		*Mins.*	*Ft.*	*In.*	*Inches.*		*Mins.*	*Ft.*	*In.*	*Inches.*
1	30	4	2½	1.68	15	31	10	11	4.25	27	60	9	0	1.80
2	30	5	9	2.30	16	26	10	7	4.85	28	60	8	10½	1.77
3	30	5	6	2.20	17	60	18	9	3.75	29	60	6	1¾	1.23
4	30	5	2	2.06	18	60	26	0	5.20	30	60	6	3	1.25
5	12	2	1	2.08	19	30	13	9	5.50	31	30	4	½	1.60
6	8	2	0	3.00	20	60	20	9½	4.16	32	30	3	10½	1.55
7	15	5	7	4.47	21	30	13	1½	5.25	33	45	9	1¼	2.43
8	15	4	5	3.53	22	30	8	10½	3.55					
9	40	12	7	3.78	23	21	11	11	6.80					
10	16	3	7¾	2.73	24	31	10	10	4.20					
11	15	5	4½	4.30	25	26	10	7	4.90					
12	15	4	8	3.73	26	30	13	8	5.47					
13	45	9	3¾	2.48										
14	30	7	3	2.90										
Av.				2.95					4.82					1.66

[1] The mean temperature at the time of conducting the warm-day experiments was 91.2° F., and at the time of conducting the cool-day experiments was 62.7° F.

Rate of travel.—In order to ascertain the rate of movement of wandering red spiders a series of laboratory experiments was conducted. A large sheet of coarse wrapping paper was fastened tightly on a 4 by 6 table. The red spiders to be tested were liberated at the center and their progress was traced for periods varying from 5 to 90 minutes.

The influence of temperature on the rate of travel was very marked, and was established by conducting the foregoing tests on both hot and cool days. It also develops that the average rate of travel by the female red spider in summer is 4.82 inches per minute, while that of the male under similar conditions is 2.95 inches per minute. (See Table IV.)

SOURCES OF DISPERSION.

When cotton fields occur in urban localities it often happens that infestations arise directly from garden or dooryard plants, such as the violet, sweet pea, dahlia, hollyhock, garden bean, etc. (Pl. IV, figs. 3–5; Pl. V, fig. 4.) As has been pointed out, however, the pest more usually reaches cotton in the course of a series of migrations, beginning with the primary hosts as foci, and advancing from host to host as the native species appear above the ground in spring. The plants which so happen to harbor the pest in situations adjacent to cotton, when the latter appears, become the immediate sources of dispersion to the cotton field.

Weed borders (Pl. V, fig. 5), which have been known to give rise to very acute infestations in adjoining cotton fields, and which prevail throughout the entire year, have been made the subject of continued observation, with the result that the position of such weeds in the problem is now quite clearly understood. There are certain weed species that at times occur in almost pure growths; that is, countless thousands of seedlings of a given species may grow in continuous, dense borders. This was often noticed at Batesburg, where at times weed infestation became so acute that entire borders of *Geranium carolinianum*, *Stachys arvensis*, etc., wilted, and finally succumbed entirely. It is just such cases as these that produce a migration of red spiders to the cotton fields. A rather complete list of the native plants at Batesburg which are of great importance in advancing the red spider to cotton in the spring is given in Table V.

TABLE V.—*List of important spring weed hosts of the red spider, Batesburg, S. C.*

Stachys arvensis.
Chenopodium botrys.
Sida rhombifolia.
Geranium carolinianum.
Trifolium repens.
Sonchus asper.
Vicia sativa.
Taraxacum officinale.
Gnaphalium spathulatum.
Rumex obtusifolius.
Oenothera laciniata.
Oxalis stricta.
Panicum scoparium.
Helianthus annuus.
Convolvulus sp.
Plantago lanceolata.
Croton texensis.
Rumex crispus.
Stellaria sp.
Solanum carolinense.
Solanum nigrum.
Ipomoea purpurea.
Passiflora incarnata.
Lechea villosa.
Brassica campestris.
Wild grass.
Rubus sp.
Phytolacca americana.
Ambrosia artemisiaefolia.
Amaranthus hybridus.
Datura stramonium.
Erigeron sp.
Xanthium americanum.

WATER DISPERSAL.

For a long time investigators of the red spider found it difficult to explain why isolated infestations existed in fields comparatively remote from the source of dispersion. It has been known for years that heavy rains dislodge many red spiders, and it has been taken for granted that these mites were destroyed. We have established the fact, however, that 9 hours' submergence in water is necessary to cause the death of red spiders. Beaten to the ground by the heavy downpour of rains, countless thousands of mites are carried along in the surface water and may even find their way into the smaller creeks. Provided the red spiders are not injured, they may revive and become established many rods, perhaps, from the scene of detachment. Table VI presents the data on submergence of mites and the resulting mortality.

TABLE VI.—*Submergence and red spider mortality, Batesburg, S. C., 1914.*

Experiment No.	Exposure.	Interval before examination.	Mortality.	Condition of individuals not recovering.	Experiment No.	Exposure.	Interval before examination.	Mortality.	Condition of individuals not recovering.
	Hours.	*Hours.*	*Per cent.*			*Hours.*	*Hours.*	*Per cent.*	
1	24	12	100	Macerated.	11	12	4	100	Shrunken.
2	24	12	100	Do.	12	9	3	100	Do.
3	24	3	100	Shrunken.	13	10	6	100	Macerated.
4	24	3	100	Do.	14	11.5	6	100	Do.
5	12	2	100	Do.	15	5	10	50	Do.
6	7	15	[1] 70	Macerated.	16	8.25	4	83	Shrunken.
7	2.5	4	0		17	10.25	6	[1] 95.3	Macerated.
8	17.5	5	100	Shrunken.	18	9	4	100	Shrunken.
9	8	6	50	Shriveled.	19	7	8	95	Macerated.
10	10	6	100	Shrunken.					

[1] A minute air bubble, about which were some of the mites, remained in the vial.

From Table VI it is seen that the shortest period of submergence that will suffice to kill all red spiders is 9 hours. All individuals survived a submergence of 2½ hours, and 50 per cent revived after an exposure of 8 hours.

Observance of water dispersal in the field.—The actual dispersion of red spiders by surface water has been observed repeatedly in the field. In Plate VII a typical case of this sort in a cotton field is illustrated. The primary source of dispersion consisted of cultivated violets growing in a dooryard, indicated by *A*. Upon becoming overcrowded a migration took place from these plants which brought many of them across the street (*B*) and into the cotton field (so indicated), where they became concentrated at (*C*), the point nearest to the violets. This infestation, limited to one end of the field, is indicated by ringed stalks. The heavy rains dislodged great numbers of red spiders and carried them along in the little streams which ran between the cotton rows. This surface water converging at the lowest point of the field, a large percentage of the stranded mites revived and reestablished themselves upon the cotton plants immediately at hand. Thus, at *D* there began a secondary development which tended to spread throughout the field. Naturally this dispersal is repeated with each heavy storm, with the result that these concentrations at the lower points of the fields become more and more severe.

Not all of the mites which are conveyed by the surface streamlets reach the ground through the effect of rains, as many are dislodged by falling leaves, through the weakening effect of heavy infestation, or by early frosts.

PLANT TO PLANT TRAVEL.

It is commonly the case during times of severe infestation that mites spread directly from one plant to another through the interlacing of branches. Such dispersion is facilitated by the close planting of cotton and, inversely, is discouraged by wide spacing. It is difficult to say whether dispersion is accomplished more by means of ground travel or by leaf to leaf travel.

WIND DISPERSAL.

Several investigators have suspected that red spiders may be conveyed considerable distances by heavy winds, but it remained for Mr. E. E. Munger, of California, to conduct serious tests during 1913. He employed sticky fly paper at different heights above the ground and at varying distances from the source, which happened to be a badly infested almond orchard. Mr. Munger found quantities of mites on the sticky surface placed under the following conditions: Twelve feet from the ground and 100 feet from the orchard, 30 feet from the ground and 250 feet from the orchard, and 50 feet from the ground and 650 feet from the infested orchard. All of these tests were made at times when the usual light summer winds were blowing.

We conducted similar tests at Batesburg and were able to corroborate to some extent the results of Munger. In one test we suspended by a string a board bearing on each side two sheets of sticky fly paper. The trap board was then attached to a wire stretched between poles. A sticky substance was smeared on the suspending string to prevent the mites from reaching the sticky surface by crawling. The suspended board was free to swing in any direction, so that mites being borne by the wind from any direction would be intercepted. An orange tree which harbored *Tetranychus mytilaspidis* stood about 300 feet from the exposed sticky surface, and several other host plants infested with *T. bimaculatus* grew within 20 to 25 feet. After an exposure of 36 hours the sticky paper was examined. Ten adult specimens of *T. mytilaspidis* and several immature individuals of *T. bimaculatus* were caught.

During the periods of drought and food scarcity mites have been seen to seek the highest or terminal points of branches, and this habit of the red spider may be closely associated with dispersion by wind. Naturally, this act would bring them to points where the effect of the wind would be greatest.

OTHER DISPERSION AGENCIES.

Several additional agencies have been suggested by various writers as means of spread of the red spider. The operation of cultivating the crop has long been considered to be instrumental in conveying mites from point to point about cotton fields. Titus (1905) maintained that the members of hoe gangs and cultivators are the most common means of distribution. He claimed that mites cling to any substances that brush against them, and in this manner are rapidly and thoroughly scattered over fields. The effect of distribution along rows and across fields, following the routes taken by farm hands, can, he claims, be traced easily by the resulting infestation along these routes. The present writers are inclined to minimize this accidental type of dissemination. Even when manipulated with the finest camel's-hair brush a certain percentage of individuals are killed.

Allied with this form of dispersion is that of accidental transportation by larger insects. Titus states that mites have been taken from several insects, such as grasshoppers and small Hemiptera, which often visit cotton plants. Such agencies of dispersion as insects, domestic animals, poultry, and wild birds should be considered as being of minor importance.

CLIMATIC CONTROL.

Although climatic influences exert an immediate reducing effect over limited areas from time to time, the hardiness and the widespread occurrence of the species insure the survival of sufficient numbers to reinfest localities that may have been thus partially freed. Owing to the fact that there is such a continuous succession of overlapping broods and that every stage from egg to adult occurs simultaneously, it is obvious that the most extreme weather factors can not be expected completely to eradicate the pest.

Climatic conditions do, however, influence the development of the red spider to a marked extent, and this influence may be either detrimental or beneficial. In the occurrence of the seasonal cycle the status of the red spider invariably undergoes a series of fluctuations. Beginning in January (see fig. 8, p. 26) we find the pest maintaining itself. In February no pronounced gain is ever made, although the development of the species may undergo some slight advance or setback due to weather. During March there is a gradual trend toward an optimum, but the pest usually suffers one or more retarding checks from adverse weather conditions. Through April and May the progress of infestation is usually most rapid, so that by the 1st of June development has nearly reached its maximum. Usually some time in June or early July a sudden decimation occurs which reduces the status to normal or below. This reduction is followed by a reaction, so that some time between the middle of July and the last of August infestation again increases. From that time until October, usually, development is subject to fluctuations varying considerably in extent, but the autumn period is characterized by a rather abrupt diminution until, by the end of November as a rule, the minimum again is reached.

Rainfall.—During times of little rainfall and high temperature reproduction goes on very rapidly; on the other hand, long, heavy rains work havoc. In spite of the fact that the mites inhabit the underside of the leaves, many are washed off by rains and others are destroyed by the upward bombardment of sand particles. In fact, it appears true that a few heavy rains, especially if they continue for some time, reduce, temporarily at least, the degree of infestation. Although a temporary reduction of the pest is occasioned by heavy rains, many of the washed-off adults may be carried considerable distances in the surface water at these times, only to revive upon stranding, and to establish new colonies remote from the scene of their rearing. Thus rain has the effect of greatly decreasing the percentage of infestation, while at the same time considerably extending distribution. In one instance a violet leaf, heavily coated with soil, was examined and there remained, out of a recent large colony, only one female, one primary nymph, and numerous eggs. Of eight females remaining on another leaf seven were dead and one alive following a heavy dashing rain.

The progress of infestation in cotton fields has been closely followed on several occasions. The fluctuations in one of these fields, as indicated by careful counts of infested and uninfested plants in large series, was as follows: May 27, 57.5 per cent; June 10, 75 per cent; June 17, 33.3 per cent; June 25, 77.7 per cent, and June 27, 55.5 per cent. A heavy rain fell on June 16, causing the reduction of 41.7 per cent; another fell June 26, causing the reduction of 22.2 per cent.

Drought.—Long-continued drought works, at least indirectly, to the detriment of the red spider. Perkins believed that the pest developed fastest under hot, dry conditions, but also demonstrated that mites are capable of living quite well under very moist conditions. Titus (1905) states that infestation rarely becomes serious unless accompanied by long-continued dry weather. Worsham (1910) asserts that dry and warm weather is essential for the maximum propagation of the spiders and that only during a prolonged drought do their ravages assume serious proportions. Ewing (1914) writes that it is during July and August that the red-spider injury becomes most serious and that these are the hottest and driest months in western Oregon.

Investigations at Batesburg have further confirmed the rule that the most rapid multiplication of the red spider is coincident with periods of maximum temperatures and minimum precipitation. On the other hand, the great rapidity of mite development reacts on the species to its detriment. This reaction occurs in several forms. First, the superabundance of the pest on hosts occasions the drying of the foliage, so that the tissue becomes unattractive. This causes widespread migratory movements, with the result that myriads of the mites perish because of the intense heat of the soil or failure to discover new hosts. Secondly, the concentrated massing of red spiders at such times is to the benefit of their predatory enemies, with the result that the predators in turn increase at their maximum rate.

INSECT ENEMIES OF THE RED SPIDER.

The investigations conducted at Batesburg have added substantially to a knowledge of the insect enemies of the red spider. Three insects were observed by J. C. Duffey (1891) to feed on red spiders at the St. Louis Botanical Gardens in 1891. These were *Scolothrips sexmaculatus*, a chrysopid larva, and *Scymnus punctum*. The latter was observed to exert great control. Morgan (1897) states that a very small black lady beetle (*Pentilia* sp.) was the only insect enemy of the cotton mite noticed during 1893 in Louisiana. Perkins (1897), in his account of the common red spider, mentions no predatory enemies. Titus (1905) records chrysopid larvæ, a species of Pentilia, and other coccinellids as feeding on mites at several localities in 1905.

Chittenden (1909) observed larvæ of *Scymnus punctum, Cecidomyia coccidarum, Chrysopa rufilabris,* and all stages of *Thrips sexmaculatus* to be predatory on red spiders on the Kentucky coffee tree (*Gymnocladus dioica*) at Washington, D. C., during July and August, 1906. He states that the Scymnus larvæ were the most effective. In Colorado, Weldon (1909) found lacewing-fly larvæ and *Scymnus punctum* to be the principal enemies of the red spider. Worsham (1910) states that the only natural enemy observed during the studies in Georgia was *Stethorus punctum,* which fed, both in the larval and adult forms, on the mites and the eggs. It was Quayle (1913) who first gave us a considerable list of red-spider enemies. He does not, however, differentiate between the predators of *T. mytilaspidis, T. sexmaculatus,* and *T. bimaculatus.* He states that most of the observations were made on the citrus mite. Parker's investigations (1913) in central California during 1911 and 1912 revealed the presence of the following predators, which he states he has seen preying upon red spiders: *Triphleps tristicolor* (nymph and adult), *Scymnus nanus, Scymnus marginicollis, Pentilia* sp., and *Chrysopa californica.* The lacewing-fly larvæ were most active. Finally, Ewing (1914) lists the following species as actively predatory on the red spider in Oregon: the mite *Seius pomi, Triphleps insidiosus,* syrphus-fly larvæ, and *Stethorus punctum.* Other species of mites and insects are mentioned by Ewing either as having been reported elsewhere on the Pacific Coast or as being probable enemies. Ewing estimates Seius to be the most valuable red-spider enemy in Oregon. All told, these enemies of the common red spider make a total of a dozen species which, to date, have been reported as definitely feeding upon *Tetranychus bimaculatus.* Neither Parker nor Ewing appears to believe that substantial control accrues from the activities of the red-spider enemies.

In the case of each of the seasons 1911, 1912, 1913, and 1914, during which the red spider has been under observation at Batesburg, S. C., a sudden decimation of a more or less complete nature has occurred. Figure 8, page 26, presents a diagram which consists of a composite curve representing the average seasonal status of the red spider in South Carolina for 4 years. The low summer point, reached in July, indicates graphically the combined control value of predatory species. The red spider at the present time is known to be the host of 31 species of arthropod enemies. Of these, 5 are mites (Acarina), 3 are thrips (Thysanoptera), 4 are bugs (Hemiptera), 4 are lacewing flies (Neuroptera), 2 are midges (Diptera), 4 are syrphid flies (Diptera), 8 are lady-beetles (Coleoptera), and 1 is a noctuid moth (Lepidoptera). These predators, in turn, are known to be attacked by 75 species of predators and parasites.

Plate VIII is a diagram which, to some degree, graphically indicates the complex relation which the red spider bears to its environment. In a number of instances these predatory species also operate against other small insects, such as aphids, scale insects, mealy bugs, white flies, etc. So far as is known, only two predators are enemies exclusively of the red spider, namely, the two midges. One predatory species, the cotton leafworm (*Alabama argillacea*), is only incidentally an enemy of red spiders, through the fact that myriads of mites are devoured along with the cotton foliage. This defoliation occurs generally over the cotton belt from time to time. Two of the predators, in turn, become enemies of other predators as well as of the mites. The most heavily parasitized of the predators are the chrysopids and the syrphids, the mortality of which becomes rather high at certain times.

ARACHNIDA, ACARINA.

GAMASIDAE.

Seius quadripilis Banks.—This mite was collected by Mr. G. A. Runner at Key West, Fla., on a wild grass infested with the red spider, and also at Orlando, Fla., on infested chinaberry leaves by Mr. W. W. Yothers. Its abundance at these localities suggests that it probably exerts considerable control.

Macrocheles sp.—This mite has been found on pokeweed (*Phytolacca americana*) heavily infested with the red spider at Batesburg. It has been observed actively at work in mite colonies, and is doubtless of economic value.

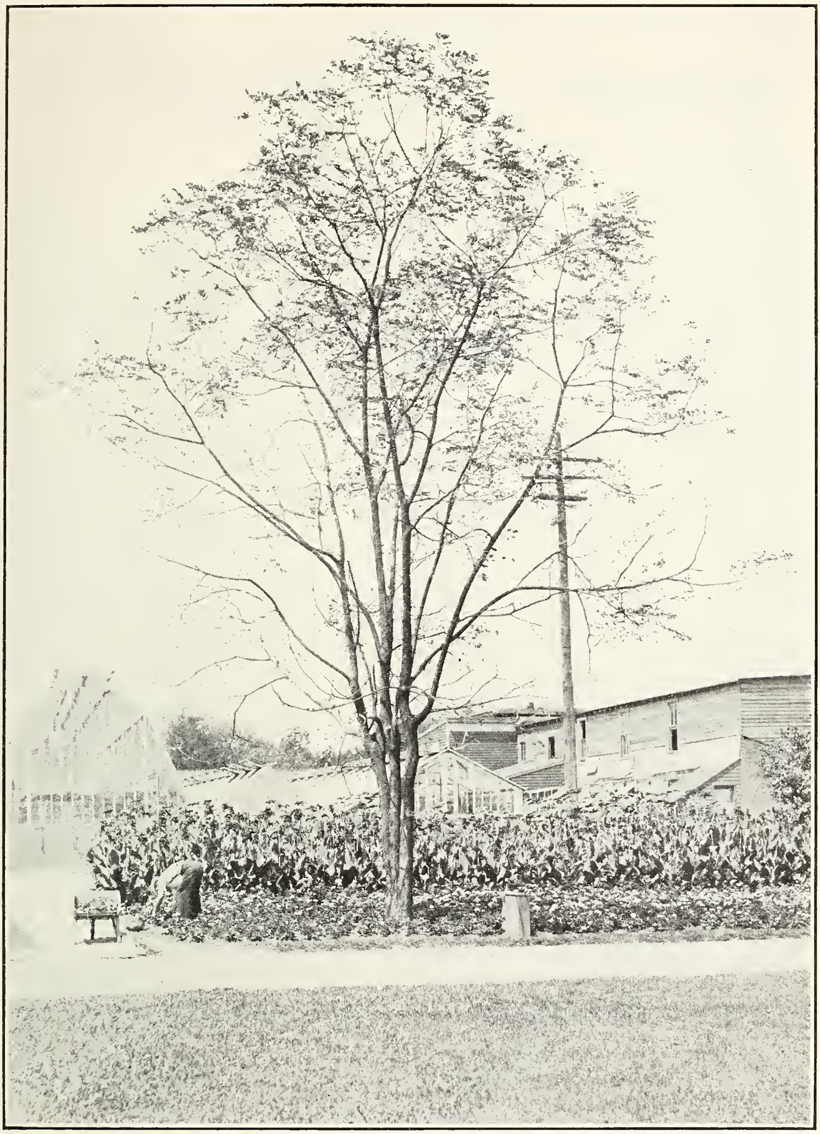
Laelaps macropilis Banks.—Mr. J. D. Mitchell found this mite on two occasions at Victoria, Tex., where it was doing good control work on heavily infested sweet peas. Mr. W. W. Yothers also sent it on badly infested chinaberry leaves from Orlando, Fla., where the species was responsible for the marked decimation of the red spider which occurred in the late summer. This mite is an important enemy of the red spider.

RHYNCHOLOPHIDAE.

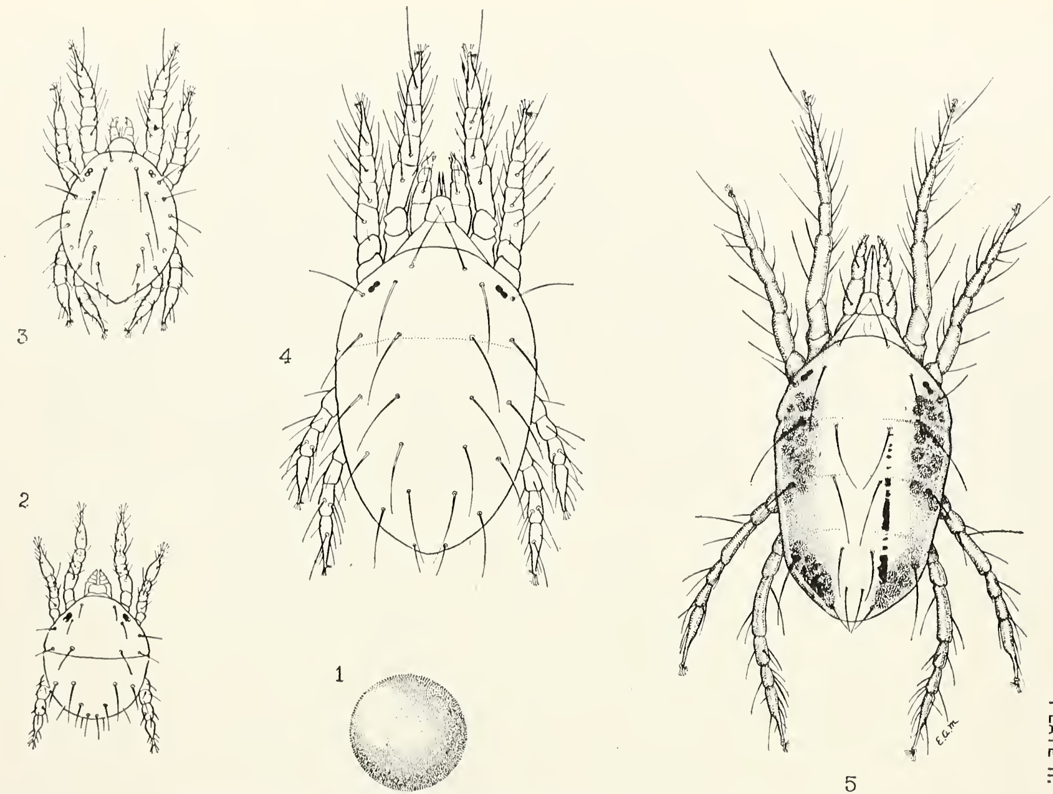
Rhyncholophus pilosus Banks.—This species was observed at Batesburg destroying the red spider on "mare's tail" (*Lechea villosa*) and on Boston ivy.

ANYSTIDAE.

Anystis agilis Banks.—This mite (fig. 9) is frequently seen crawling about in unlikely places in search of food. It is extremely active and follows a tortuous course that sooner or later brings it to its victims. We have collected it from mite-infested elderberry (*Sambucus* sp.) at Batesburg, but have made no accurate estimate of its control value. Ewing reports finding considerable numbers of this mite upon violets, heavily infested with red spiders, in Oregon.

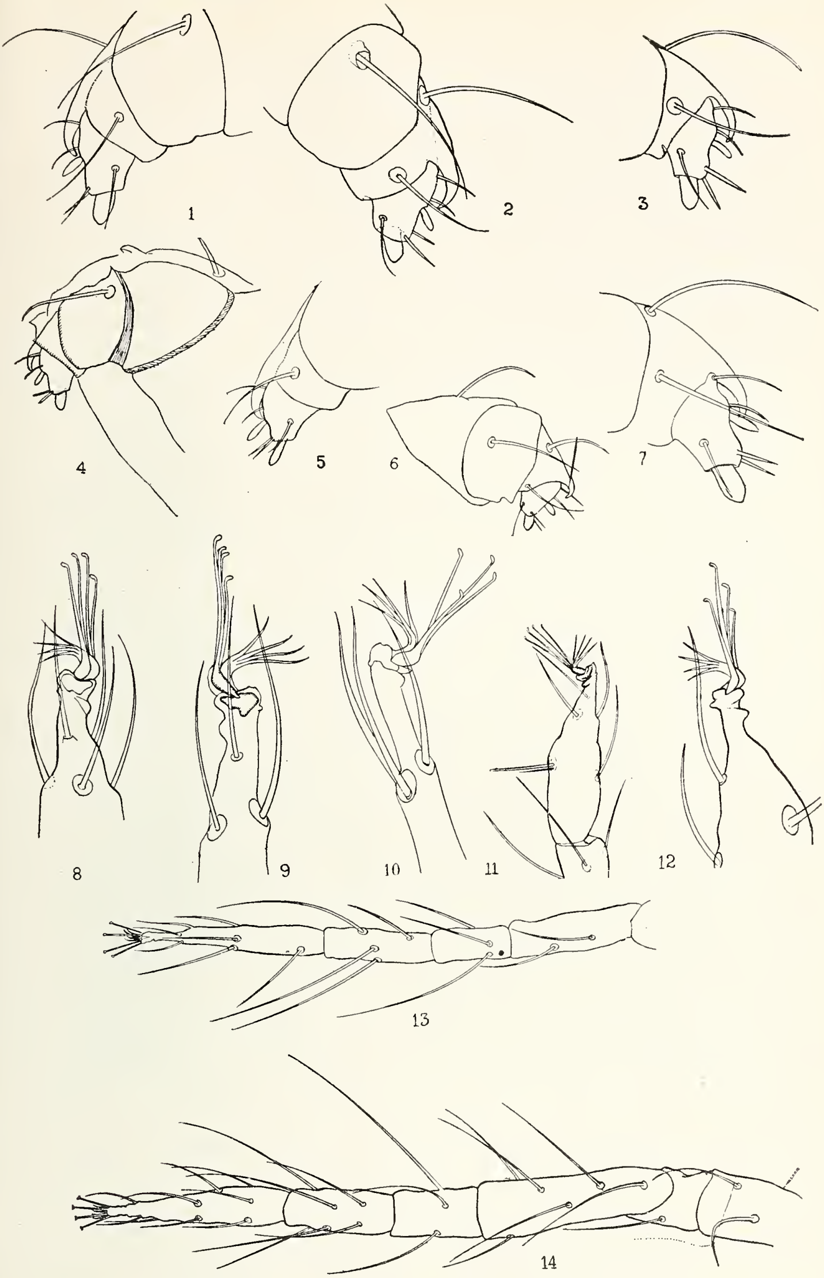


KENTUCKY COFFEE TREE (GYMNOCLADUS CANADENSIS) WHICH HAS LOST MOST OF ITS FOLIAGE THROUGH THE WORK OF THE RED SPIDER (TETRANYCHUS BIMACULATUS). (ORIGINAL.)



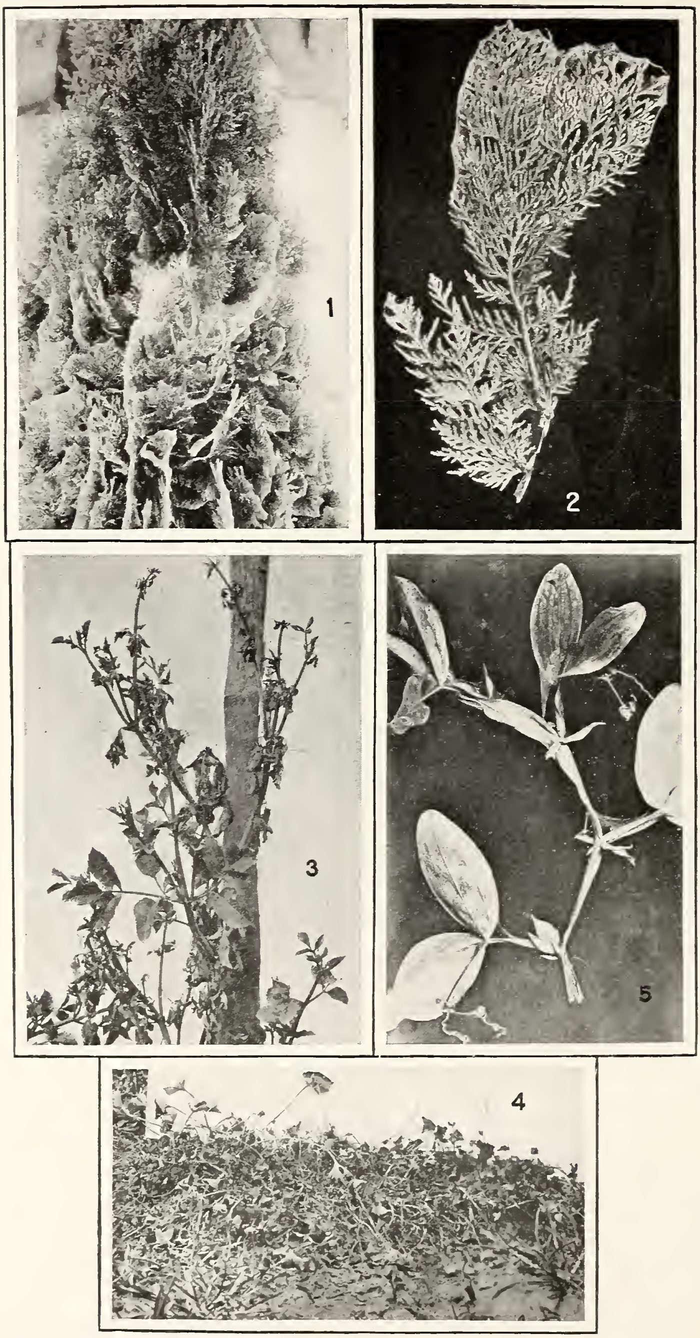
DEVELOPMENT OF THE COMMON RED SPIDER (TETRANYCHUS BIMACULATUS).

FIG. 1.—The egg. FIG. 2.—The newly hatched larva. FIG. 3.—The recently molted protonymph. FIG. 4.—The mature deutonymph just prior to the final molt. FIG. 5.—The adult female. (Highly magnified.)



VARIATIONS IN THE MICROSCOPIC CHARACTERS OF THE PALPUS AND TARSUS AND THE BRISTLE ARRANGEMENT ON THE LEG OF THE COMMON RED SPIDER.

FIG. 1.—Female on pokeweed, Dothan, Ala.; left palpus, lateral view. FIG. 2.—Female on cotton, Batesburg, S. C.; right palpus, lateral view. FIG. 3.—Female on cotton, Mount Pleasant, Miss.; right palpus, lateral view. FIG. 4.—Female on hops, Sacramento, Cal.; left palpus, lateral view. FIG. 5.—Larva on cotton, Batesburg, S. C.; left palpus, lateral view. FIG. 6.—Larva on beans, Hagerstown, Md.; right palpus, lateral view. FIG. 7.—Female on chinaberry, Orlando, Fla.; right palpus, lateral view. FIG. 8.—Deutonymph on cotton, Batesburg, S. C.; tarsal appendages. FIG. 9.—Female on chinaberry, Orlando, Fla.; tarsal appendages. FIG. 10.—Female on cotton, Mount Pleasant, Miss.; tarsal appendages. FIG. 11.—Larva on beans, Hagerstown, Md.; tarsal appendages. FIG. 12.—Larva on cotton, Mount Pleasant, Miss.; right leg IV. FIG. 13.—Female on cotton, Batesburg, S. C.; left leg I, dorsal view. FIG. 14.—Female on chinaberry, Dothan, Ala.; left leg I, ventral view. All drawn with oil-immersion and camera lucida. Highly magnified. (Original.)



RED-SPIDER INJURY TO VARIOUS HOSTS.

FIG. 1.—Arborvitæ tree heavily coated with mite webbing. FIG. 2.—A branchlet from the tree shown in figure 1, showing enshrouding web. FIG. 3.—Dahlia plant with leaves distorted and shriveled through mite activity. FIG. 4.—Bed of violets dead to the ground from excessive infestation. FIG. 5.—Blanched sweet-pea foliage, also showing webbing. (Original.)

COTTON INFESTATION BY THE RED SPIDER AND SOME IMMEDIATE SOURCES OF DISPERSION.

FIG. 1.—Cotton plants in advanced stage of infestation. FIG. 2.—Cotton plants in the final stages of mite attack. FIG. 3.—Cotton field with plants in the condition shown in figure 2; arrow indicates original source. FIG. 4.—Dooryard flower beds, a serious factor in dissemination when present near cotton fields. (Note cotton growing adjacent.) FIG. 5.—Weed border by the side of cotton field, a common source of infestation. FIG. 6.—Cotton field destroyed by red spiders, and two large pokeweeds from which the infestation arose. (Fig. 3, McGregor; figs. 1, 2, 4, 5, 6, original.)

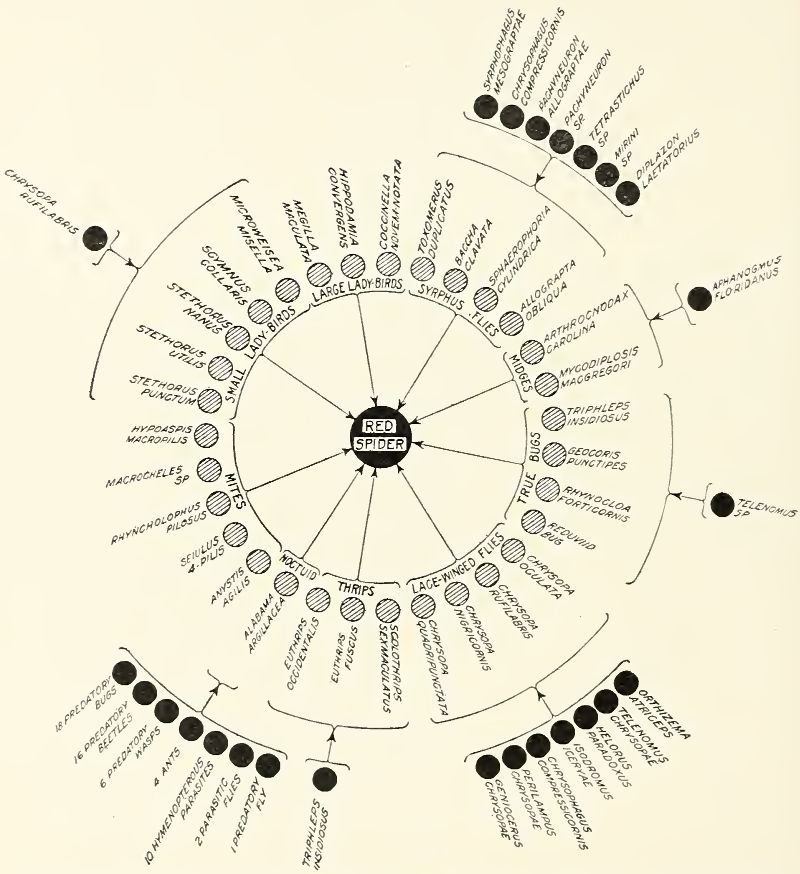


DIAGRAM ILLUSTRATING COMPLEX RELATIONSHIP OF RED SPIDER TO ITS ZOOLOGICAL ENVIRONMENT.

Nine groups of predators embracing 31 species are seen to attack the red spider, and in turn 7 of these predator groups are attacked by a total of 75 species of parasites and predators. (Original.)

INSECTA, THYSANOPTERA.

THRIPIDAE.

Scolothrips sexmaculatus Perg.—This species of thrips, as previously recorded, was mentioned by Duffey (1891) as being predacious on the red spider at St. Louis. Chittenden (1909) observed this thrips to be predatory on mites on the Kentucky coffee tree at Washington in 1906. Quayle (1913) states that he has repeatedly observed it to feed on the citrus mite, usually attacking the egg and younger spiders, and occasionally eating the adult mites. At Batesburg this thrips has been under observation during four seasons. It appears to be about the earliest predacious enemy of the red spider, having been seen on March 11, 1914, as the nymph. It becomes common in May and very abundant throughout June, July, August, and September, and has been seen as late as December 10. Upon several occasions it has been seen to attack mites in the field. The 6-spotted thrips has been observed feeding upon red spiders at the following localities: Emporia, Va.; Raleigh, Charlotte, and Laurinburg, N. C.; Clemson College, Columbia, Leesville, and Batesburg, S. C.; and Mount Pleasant, Miss. Yothers reports it actively predacious in mite colonies on velvet bean, at Orlando, Fla.

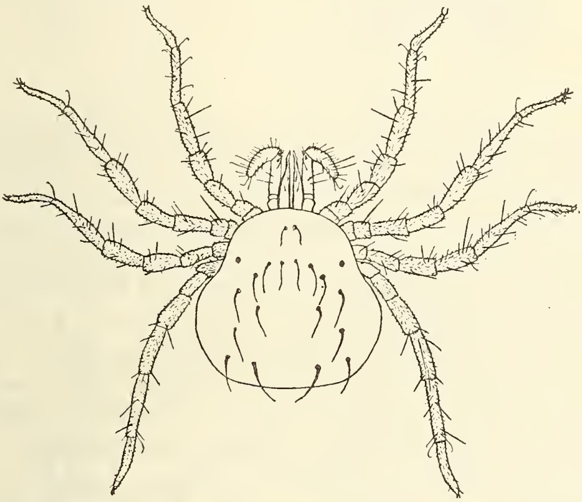


FIG. 9.—*Anystis agilis*, an enemy of the red spider. Highly magnified. (Ewing.)

A few tests were conducted for the purpose of ascertaining the capacity of this thrips for the various stages of the red spider, and data (Table VII) were secured from six specimens. These 6 thrips (all nymphs) consumed 232 eggs and 5 nymphs and adults in 10 feeding days, which gives an average consumption of 23.7 eggs and active individuals per feeding day, 98 per cent of which were eggs. It is probable that the daily average of No. 2 (Table VII), which was over 35 eggs per day, represents the normal capacity of the species.

TABLE VII.—*Red spiders consumed by Scolothrips sexmaculatus, Batesburg, S. C.*

Individual No.	Feeding days.	Consumption.			
		Eggs.	Active individuals.	Eggs and active individuals.	Average per day.
1	1	7	....	....	....
	2	2	....	9	4.5
2	1	47	....	....	....
	2	93	....	....	....
	3	18	....	....	....
	4	5	....	....	....
	[1] 5	13	....	176	35.4
3 and 4	1	8	1	9	9.0
5	1	35	....	35	35.0
6	1	4	4	8	8.0
Total 6	10	232	5	237	[2] 23.7

[1] This was first adult day. [2] Average.

Moulton, the first investigator to establish that thrips in general are preyed upon by the insidious bug, states that *Triphleps insidiosus* is the most serious enemy of thrips. Quaintance also states that thrips, in addition to being attacked by the insidious bug, are parasitized by nematode worms. At Batesburg we find that *T. insidiosus* is very often present with Scolothrips and other thrips, and that it commonly feeds upon Scolothrips in the absence of more desirable food. The time required by Triphleps adults to drain a thrips averages about 2½ minutes. A half-grown chrysopid larva was observed to grasp and drain a nymphal thrips in 1 minute 35 seconds, and immediately seized other thrips, repeating the operation.

Euthrips fuscus Hinds.—This thysanopteron, while frequently collected in red-spider colonies, has not been observed in the act of devouring red spiders; but our observations and those of other workers indicate that this species is also an occasional enemy of the mites.

Euthrips occidentalis Perg.—This species has also been seen from time to time in red-spider colonies. The evidence concerning it is not absolute, but it is believed to be, like the two foregoing thrips, a predatory species.

HEMIPTERA.

ANTHOCORIDAE.

Triphleps insidiosus Say.—This predacious bug (fig. 10) seems to have been first recorded as a natural enemy of the red spider by the senior author in an earlier (1912) circular. Since then it has been recorded as predatory on the common red spider by Quayle (1913) and Ewing

(1914); and Parker (1913) states that a closely allied species, *T. tristicolor*, was the most numerous red-spider enemy in the hop fields, but that no controlling effect could be detected.

This predator, coming upon a red spider like a flash, thrusts its sharp proboscis through the mite's back and siphons out the body contents. In the case of one bug, the first mite was drained in about five minutes, but each succeeding meal was of shorter duration, so that the average time required for each meal was found to be about three minutes. The actions of the nymph (fig. 11) are similar. Both adults and nymphs feed upon the mites in all stages from egg to adult, but the Triphleps adult will not ordinarily consume mite eggs unless other food is scarce. The operation of draining an egg requires about two minutes.

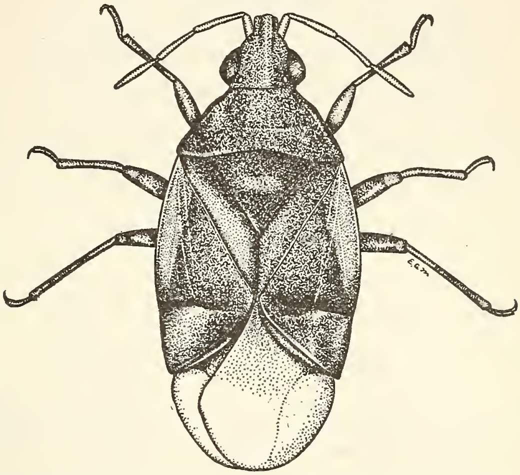


FIG. 10.—*Triphleps insidiosus*, an important enemy of the red spider: Adult. Much enlarged. (McGregor).

These bugs pass the winter in the adult stage and usually become active some time in April, although they have been seen as early as the middle of March. Triphleps becomes extremely abundant by the first of July, and assists greatly in the reduction of the red spiders. Although it seeks hibernation toward the end of October, individuals are commonly seen some years as late as the middle of this month.

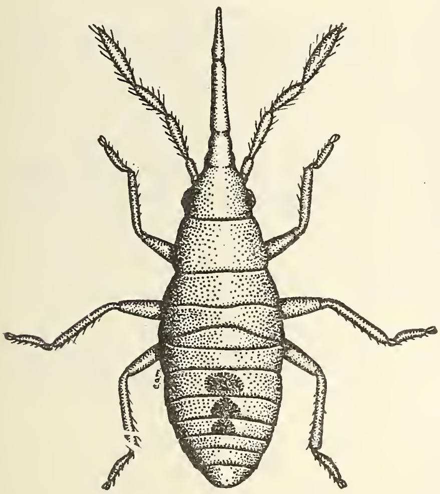


FIG. 11.—*Triphleps insidiosus:* Nymph. Greatly enlarged. (McGregor.)

By referring to Tables VIII and IX it will be seen that 8 individuals collected as various instars of the nymph drained 1,856 red spiders in 57 feeding days. The average daily consumption of the nymph was 33.16 mites, that of the adult was 28.88, and the daily average for all individuals was

32.56 mites. The predatory capacity of the first instar is not known, since we have never reared individuals from the egg. The second nymphal instar consumes on an average 80.5 mites, the third instar consumes 112, and the fourth averages 146 between molts. The average duration of the second instar is found to be 3.22 days, that of the third instar 2.66 days, and the fourth instar requires 4.36 days. The maximum recorded consumption for one day was 68 adult mites. Moulton states that in California the life cycle of *T. insidiosus* requires only 15 days, but the foregoing data would indicate that in the Southeast a little longer period is required.

TABLE VIII.—*Predatory activity and development of Triphleps insidiosus, Batesburg, S. C.*

Individual No.	Feeding days.	Stage of predator.		Mites consumed.	Total consumption.	Remarks.
		Nymph.	Adult.			
1	1	×	....	43	176	Collected as young nymph; molted after 3 days to adult.
	2	×	....	56		
	3	×	....	30		
	4	....	×	24		
	5	....	×	23		
2	1	×	....	25	167	Collected as nymph; molted after 5 days to adult.
	2	×	....	39		
	3	×	....	29		
	4	×	....	28		
	5	×	....	15		
	6	....	×	31		
3	1	×	....	24	144	Do.
	2	×	....	33		
	3	×	....	20		
	4	×	....	24		
	5	×	....	19		
	6	....	×	24		
4	1	×	....	22	179	Collected as nymph; molted after 6 days to adult.
	2	×	....	31		
	3	×	....	34		
	4	×	....	12		
	5	×	....	42		
	6	×	....	12		
	7	....	×	26		
5	1	×	....	17	297	Collected as very young nymph in beginning of 2d instar; molted on 4th day; molted on 7th day; molted on 11th day to adult.
	2	×	....	7		
	3	×	....	25		
	4	×	....	32		
	5	×	....	47		
	6	×	....	34		
	7	×	....	55		
	8	×	....	18		
	9	×	....	29		
	10	×	....	33		
6	1	×	....	57	57	Nymph escaped.
7	1	×	....	13	438	Very small nymph at collection; molted on 4th day; molted on 6th day; molted on 10th day to adult.
	2	×	....	36		
	3	×	....	16		
	4	×	....	60		
	5	×	....	38		
	6	×	....	43		
	7	×	....	68		
	8	×	....	63		
	9	×	....	39		
	10	....	×	37		
	11	....	×	25		
8	1	×	....	17	398	Collected as very young nymph, possibly molted once; molted on 4th day; molted on 7th day; molted on 10th day.
	2	×	....	33		
	3	×	....	28		
	4	×	....	18		
	5	×	....	35		
	6	×	....	28		
	7	×	....	62		
	8	×	....	43		
	9	×	....	34		
	10	×	....	59		
	11	....	×	41		
Total...	57	49	8	....	1,856	

SUMMARIES.

Average daily consumption per nymph	33.16
Average daily consumption per adult	28.88
Average daily consumption per bug for all individuals	32.56
Duration of second nymphal instar	3.22
Duration of third nymphal instar	2.66
Duration of fourth nymphal instar	4.36

TABLE IX.—*Consumption of red spiders by each instar of Triphleps insidiosus, Batesburg, S. C.*

Individual No.	Consumption for 2d instar.	Consumption for 3d instar.	Consumption for 4th instar.
	Mites.	*Mites.*	*Mites.*
1	....	....	120
2	....	....	129
3	....	....	153
4	....	....	136
5	....	113	135
6	65	98	213
7	96	125	136
Average..	80.5	112	146

The occurrence of *T. insidiosus* on mite-infested leaves is recorded from Emporia, Va.; Raleigh, Charlotte, Greensboro, Wilmington, and Buies, N. C.; Leesville, Spartanburg, Clemson College, Batesburg, and other points in South Carolina; Macon and Savannah, Ga.; Tallahassee, Fla.; Girard, Ala.; and Meridian, Miss.

LYGAEIDAE.

Geocoris punctipes Say.—This hemipteron has not previously been considered in literature as a mite predator. Heidemann states that little is known about its life history. Observations at Batesburg are confined to the season of 1914, *G. punctipes* having been detected during August of that year. Eggs, seen in the midst of red-spider colonies on cotton leaves, were collected for rearing, and immediately upon hatching certain of the nymphs were placed in isolated cells with red spiders and their eggs. It was found that the newly hatched nymphs readily devoured the red spiders as well as some of the eggs. The egg of *G. punctipes* is cylindrical and elliptical in shape, fluted, of a pale amber color, and is deposited in the center of the mite colonies. Table X presents the data we have secured on the life history.

TABLE X.—*Life history of Geocoris punctipes, Batesburg, S. C.*

Individual No.	Collected.	Hatched.	First molt.	Second molt.	Third molt.	Fourth molt.	Incubation period (days).[1]	First instar (days).	Second instar (days).	Third instar (days).	Fourth instar (days).	Period collected to adult (days).
1	Aug. 8	Aug. 14	Destroyed				6					
2	...do	Aug. 11	Aug. 16	Aug. 21	Lost		3	5	5			
3	Aug. 10	Aug. 13	Aug. 22	Aug. 25	Sept 2	Sept. 9	3	9	3	8	7	30
4	...do	Aug. 14	Destroyed				4					
5	...do	...do	...do				4					
6	...do	Aug. 13	...do				3					
7	...do	...do	...do				3					
8	Aug. 26	Aug. 28	...do				2					
9	...do	Aug. 31	...do				5					
	Averages						3.66	7	4	8	7	30

[1] Since the date of deposition of the eggs was not known, our records for incubation are all a trifle short.

It will be seen that the average time required for incubation is about 4 days, that the first nymphal instar requires from 5 to 9 days, the second instar from 3 to 5 days, the third instar 8 days, the fourth instar 7 days, and that the period from deposition to adult is doubtless about 30 days. Table XI presents our data relative to the capacity of this hemipteron as a red-spider enemy.

TABLE XI.—*Record of red spiders devoured by reared nymphs of Geocoris punctipes, Batesburg, S. C.*

Day.	Red spiders consumed by— Nymph No. 1.	Nymph No. 2.	Nymph No. 3.	Total.	Day.	Red spiders consumed by— Nymph No. 1.	Nymph No. 2.	Nymph No. 3.	Total.
1st	[1] 30	8	7		18th		95		
2d	[1] 3	5	23		19th		80		
3d	23	13	20		20th		70		
4th	30	20	29		21st		98		
5th	35	23	8		22d		114		
6th	22	43	33		23d		106		
7th	21	34	40		24th		50		
8th	31	12	50		25th		103		
9th	42	38	52		26th		111		
10th	38	52	21		27th		[2] 83		
11th	54	43	37						
12th	69	31	69						
13th		67	56		Total red spiders	398	1,589	505	2,492
14th		84	60		Total days	12	27	14	53
15th		63							
16th		65							
17th		78			Average per day (red spiders)	33.2	58.8	36.1	47.0

[1] These 33 were eggs, the diet being changed on the following day to mites.
[2] Nymph became adult on the twenty-seventh day.

From Table XI it is seen that 3 individuals with a total of 53 feeding days ate 2,492 red spiders, or an average of 47 per nymph. The first instar consumed, on an average, 141 adult red spiders; 161 were drained by the second instar, 602 by the third, and 665 mites were eaten by the fourth instar. The adults exhibited an average consumption of 83 mites per day. Although a number of eggs were eaten, Geocoris did not seem to take readily to a diet of mite eggs.

In the course of the experiments with this red-spider enemy it developed that a certain percentage of its eggs are parasitized. A scelionid, *Telenomus* sp., was reared from eggs collected in the field and required a developmental period of 11 days.

Capsidae.

Rhinacloa forticornis Reuter. A nymph of this bug about two-thirds grown was observed in red-spider colonies in a cotton field, actively feeding on mites. It was transferred to a rearing cell and kept under close observation. The bug showed a strong liking for red spiders and developed to adult in the cell. Table XII contains the record of this individual.

Table XII.—*Consumption of red spiders by Rhinacloa forticornis, Batesburg, S. C.*

[Nymph collected Oct. 2, 1914.]

First day (molted Oct. 3)	60
Second day	72
Third day	71
Fourth day	65
Fifth day	61
Sixth day	67
Seventh day (molted Oct. 9)	46
First adult day	39
Total	481
Total feeding days	8
Average per day	60.1
Total consumption by last instar	382

In eight feeding days this capsid bug ate 481 red spiders, or an average of 60 mites per day. Two molts occurred during the observations, the final nymphal instar lasting six days and requiring, before completion, the additional consumption of 382 adult mites.

Reduviidae.

A species of reduviid bug was seen commonly on infested leaves during August and September at Batesburg. Both the eggs and nymphs were abundant at times in and about red-spider colonies on tomato leaves. An egg collected August 10, 1914, hatched August 12 and the nascent nymph was immediately placed into a breeding cell with red spiders. Seven mites were eaten the first day, 14 the second, 7 the third, 6 the fourth, 17 the fifth, 22 the sixth, and 18 the seventh. A total of 88 red spiders were destroyed in seven days, making an average of 12.6 per day.

NEUROPTERA.

CHRYSOPIDAE.

Four species of lacewing flies have been collected during the investigation at Batesburg. Lacewing flies are frequently seen on cotton leaves associated with common red spiders. Only one species, *Chrysopa rufilabris* Banks, is very abundant in South Carolina.

Chrysopa rufilabris Banks.—This species appears in late spring or early summer, the earliest record being May 6, 1914, on which date eggs and larvæ were seen. Together with the thrips, this chrysopid appears to be the earliest red-spider enemy. When an early season prevails, this predator becomes abundant about the middle of June, but, as a rule, this does not take place until July. It is not as hardy as are some of the more coriaceous enemies of the red spider, and seeks winter quarters comparatively early in the season. In fact, the species reaches its optimum development during August, and is rarely seen in any stage later than September 25. This red-spider enemy is recorded from Emporia, Va.; Wilmington, Greensboro, Charlotte, Buies, and Laurinburg, N. C.; Spartanburg, St. Matthews, Leesville, Batesburg, and numerous points in South Carolina; Savannah, Ga.; Tallahassee, Fla.; Girard, Ala.; and Dallas, Tex.

At certain times during the season *Chrysopa rufilabris* has been seen to exert marked control of the red spider, and its value as an enemy of the cotton red spider can hardly be overestimated. During June, 1914, from the 10th to the 22d, lacewing-fly larvæ were abundant, crawling in myriads on tree trunks, the ground, the ceilings of porches, and similar positions. At these times man experiences much annoyance from the mandibles of larvae which drop from piazza ceilings.

Tables XIII, XIV, and XV present data on the life history of *Chrysopa rufilabris*.

TABLE XIII.—*Egg period of Chrysopa rufilabris, Batesburg, S. C.*

Individual No.	Egg collected.	Hatched.[1]	Incubation period.
			Days.
1	June 8	June 11	3
2	July 15	July 18	3
3	July 15	July 18	3
4	Aug. 3	Aug. 8	5
5	Aug. 3	Aug. 8	5
6	Aug. 9	Aug. 13	4
	Average		4

[1] These 6 rearings are the longest of a large series and probably represent about the normal period for this stage.

TABLE XIV.—*Larval period of Chrysopa rufilabris. (Individual No. 1.)*

Hatched,	Aug. 3
Pupated	Aug. 22.
Length of larval period	18 days.

No. 4 of Table XVI was the only larva which was reared through from egg to pupa, and, as will be seen, the entire mite consumption for the individual was also secured. The larval period is 18 days, which is a trifle shorter than Davidson secured from his data based on 2 individuals. No attempt was made to determine the duration of the larval instars, but incidentally the length of the first instar was established as about 4 days. Table XV presents statistics on the pupal stage of *Chrysopa rufilabris.*

TABLE XV.—*Records of the pupal period of Chrysopa rufilabris, Batesburg, S. C.*

Individual No.	Pupated.	Issued.	Pupal period.	Average pupal period.	Individual No.	Pupated.	Issued.	Pupal period.	Average pupal period.
			Days.	*Days.*				*Days.*	*Days.*
1	June 9	June 17	8		8	July 26	Aug. 4	9	
2	...do.....	...do.....	8		9	Aug. 3	Aug. 15	12	
3	July 8	July 15	7		10	Aug. 14	Aug. 21	7	
4	July 10	July 17	7	8.6	11	Aug. 18	Aug. 25	7	8.6
5	July 22	Aug. 2	11		12	Aug. 25	Sept. 2	8	
6	July 23	Aug. 1	9		13	Sept. 3	Sept. 16	13	
7	July 24	...do.....	8		14	Sept. 9	...do.....	7	

From these 14 pupal records it is seen that the duration of the transformation period at Batesburg varies from 7 to 13 days, with 8.6 days as the weighted average. Thus, exclusive of a possible preoviposition interval, we find that the cycle of the chrysopid from the deposition of the egg to the issuance of the adult is about 30 days, approximating 4 days for the egg stage, 18 days for the larva, and 8.6 days for the pupal stage. In the Southeast there are probably four generations of lacewing flies in a season.

TABLE XVI.—*Rate of destruction of red spiders by the larva of Chrysopa rufilabris.*

Larva No.	Hatched.	Red spiders consumed.											
		1st day.	2d day.	3d day.	4th day.	5th day.	6th day.	7th day.	8th day.	9th day.	10th day.	11th day.	12th day.
	1914.												
1	July 17	18	(1)										
2	July 18	31	32	33	34	48	23		(2)				
3	....do.	26	16	43	30	51	40	84			(3)		
4	Aug. 3	9	28	14	29	30	37	26	41	39	48	59	63
5	Aug. 8	24	37	35	(1)								
6	July 15	19	29	35	39	39	17	39	(2)				
7	July 16	21	27	20	18	33	26	21	15		(2)		
8	July 19 [4]									47	62	58	66
9	....do. [4]										56	59	69
10	Aug. 22 [5]												
11	Aug. 18 [6]												
12	Aug. 14 [7]												
13	Aug. 20 [5]												

1 Dead.
2 Lost.
3 Entangled.
4 Collected as half-grown larva.
5 Collected as two-thirds-grown larva.
6 Collected as mature larva
7 Collected as large larva.

TABLE XVI.—*Rate of destruction of red spiders by the larva of Chrysopa rufilabris*—Con.

Larva No.	Hatched.	Red spiders consumed.							Pupated.	Length of larval period.	Feeding days.	Total feeding days.
		13th day.	14th day.	15th day.	16th day.	17th day.	18th day.	Total for larval period.				
	1914.											
1	July 17										1	
2	July 18										6	
3	do										7	
4	Aug. 3	77	99	110	224	119	198	1,250	Aug. 22	18	18	
5	Aug. 8										3	
6	July 15										7	
7	July 16										8	86
8	July 19[1]	75	101	113	199	122	203		July 30		10	
9	do.[1]	58	117	147	220	116	207		Aug. 29		9	
10	Aug. 22[2]	80	106	130	156	170	211		do		6	
11	Aug. 18[3]					127	188		Aug. 21		2	
12	Aug. 14[4]			145	189	129	193		Aug. 19		4	
13	Aug. 20[2]		98	129	219	130	208		Aug. 26		5	

[1] Collected as half-grown larva.
[2] Collected as two-thirds grown larva.
[3] Collected as mature larva.
[4] Collected as large larva.

In summarizing Table XVI it is found that 6,956 adult red spiders were consumed by 13 Chrysopa larvæ in 86 feeding days, or an average daily consumption of about 81. The one larva for which complete data are recorded consumed altogether 1,250 mites. The largest daily feeding was 224 mites. As the larva grows the appetite increases remarkably so that an individual which ate only 20 mites per day following hatching will consume ten times that number just prior to pupation. Larvæ numbers 8, 9, 10, 11, 12, and 13 were collected in the field in various stages of maturity, so that only the feeding of the final days can be shown. It is probable that the figures consistently represent the normal activity of this species as a red-spider eradicator. The appetite for mite eggs was not determined, but we have often seen larvæ in the act of devouring them. Probably numerous eggs were eaten along with the mites in all the foregoing records. Three minutes appears to be the average time required by larvæ in devouring a mite.

We have followed the process of the fabrication of the cocoon of *Chrysopa rufilabris* from beginning to end. Working in a looped attitude, the successive layers of silk are secreted from the tip of the abdomen, which is moved shuttle-like from side to side. Contrary to long-accepted belief, it has been established that the circular lid, which permits the exit of the adult fly, is prepared by the larva as the last act before entering the resting stage.

During the four seasons of our investigations at Batesburg it has been determined that a considerable percentage of mortality to chrysopids arises through parasitism. The results of a series of studies on lacewing-fly parasites has been published. (McGregor, 1914.) In a series of 99 cocoons collected in the field, 48 yielded parasites, thus indicating a parasitism of 48.4 per cent. Of a series of 93 chrysopid eggs, 7 were parasitized, which represents an egg parasitism of 7.5 per cent. The total parasitism, from species issuing from the egg and from species issuing from the cocoon, is computed at about 55.9 per cent. These parasites, as identified by J. C. Crawford, are as follows. Reared from cocoon: *Chrysopophagus compressicornis* Ashm., *Perilampus chrysopae* Crawford, *Geniocerus chrysopae* Crawford, *Isodromus iceryae* How., *Orthizema atriceps* Ashm. and *Heloris* sp. Reared from egg: *Telenomus chrysopae* Ashm.

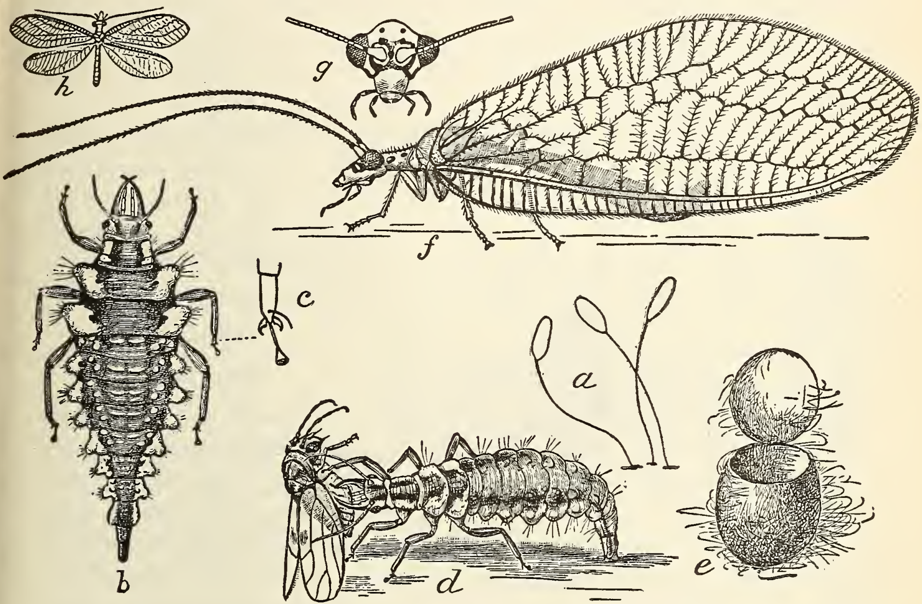


FIG. 12.—The golden-eyed lacewing fly (*Chrysopa oculata*): *a*, Eggs; *b*, full-grown larva; *c*, foot of same; *d*, larva devouring an insect; *e*, cocoon; *f*, adult insect; *g*, head of same; *h*, adult, natural size. All enlarged except *h*. (Marlatt.)

Table XVII presents our data relative to the parasitism of chrysopid eggs by *Telenomus chrysopae*.

TABLE XVII.—*Parasitism of chrysopid eggs by Telenomus chrysopae Batesburg, S. C.*

Individual No.	Egg collected.	Host.	Parasite issued.	Interval from collection to issuance.
				Days.
1	July 10, 1914	Cotton	July 13, 1914	3
2	do	Clematis	July 19, 1914	9
3	July 11, 1914	Cotton	do	8
4	July 15, 1914	Elm	July 23, 1914	8
5	do	Cotton	July 20, 1914	5
6	July 17, 1914	do	July 24, 1914	7
7	do	Clematis	July 26, 1914	9

During 1914 chrysopids were particularly abundant. They were in fact the most common predatory species. The "stalked" eggs were everywhere in evidence and the adults, which are nocturnal, rose in swarms from under the foliage as one brushed through the cotton rows.

Chrysopa quadripunctata Burm.—This species is also fairly common in the Southeast. It is most noticeable during July and August, and its larva doubtless contributes to the predatory work of *Chrysopa rufilabris.*

Chrysopa oculata Say.—Adults of this lacewing fly (fig. 12) have been reared from larvæ actively feeding on red spiders. It is not particularly common in South Carolina, however, and as a red spider enemy probably is not of primary importance.

Chrysopa nigricornis Burm.—This species has been reared on a few occasions from larvæ collected on cotton infested with red spiders. Its status is probably about the same as that of *C. oculata.*

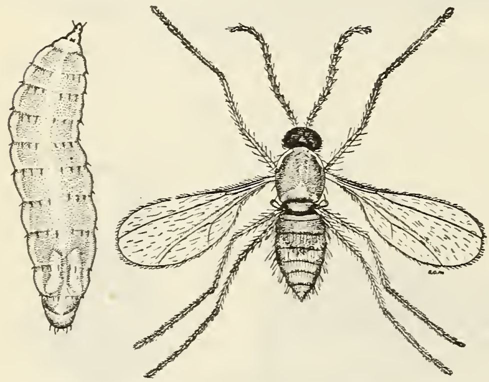


FIG. 13.—*Arthrocnodax carolina*, a predacious enemy of the red spider. At left, mature predacious larva, magnified 60 times; at right, adult female, greatly enlarged. (McGregor.)

DIPTERA.

ITONIDIDAE.

Arthrocnodax carolina Felt.—This midge (fig. 13, at right) was recognized, early in the investigation, as one of the most important enemies of the red spider, at times ranking first. Its attack is almost entirely confined to the eggs of the red spider, but an occasional mite is destroyed. The earliest seasonal record of occurrence is April 30, 1914. It is first seen usually about the early part of May and becomes abundant during the middle of May. This species does not usually reach its highest development until August, although a large amount of control work is evident during July. Arthrocnodax is always to be seen during September, sometimes commonly in large mite colonies, but becomes rare in October, during which month usually only pupæ can be seen. This important predator has been collected in mite colonies at Chase City and Emporia, Va.; Charlotte, Wilmington, Laurinburg, and Buies, N. C.; Allendale, Anderson, Batesburg, Brownsville, John's Island, Leesville, St. Matthews, and other points in South Carolina; Macon and Savannah, Ga.; Orlando, Fla.; Girard, Albertville, and Boaz, Ala.; and Tallulah and Mound, La.

Several larvæ of this midge of various sizes were collected in the field and reared to adult on mite eggs and mites. Table XVIII presents the data which bear on the larval period.

TABLE XVIII.—*Duration of the larval stage of Arthrocnodax carolina, Batesburg, S. C.*

Individual No.	Larva collected.	Condition at collection.	Pupated.	Interval from collection to pupation.
				Days.
1	Sept. 28, 1914	One-half grown	Oct. 1	3
2	Oct. 7, 1914	Small	Oct. 9	2
3	do	do	do	2
4	Oct. 8, 1914	Nascent (?)	Oct. 13	5
5	do	Very small	Oct. 11	3
6	Oct. 10, 1914	Large	do	1
7	Oct. 11, 1914	do	Oct. 12	1
8	Oct. 13, 1914	Two-thirds grown	Oct. 14	1
9	Oct. 21, 1914	Nascent (?)	Oct. 26	5
10	Oct. 26, 1914	Small	Oct. 29	3
11	do	Rather large	Oct. 28	2
12	Oct. 27, 1914	Nascent (?)	Nov. 1	5

Probable larval period, 5 days.

From the foregoing records it may be seen that very small individuals completed their larval development in from three to five days. Since several of these gave every evidence of being newly born at the time of collection and had no appearance of having fed, it is evident that some of our records represent the entire larval period. The larva (fig. 13, at left) is a small, glistening, amber-yellow grub with a pointed, protractile head which bears a pair of retractile, snail-like tentacles. A series of larvæ measured: Length, 1.5 mm.; width, 0.33 mm.

Table XIX includes the completed records on the duration of the pupal stage which are available.

TABLE XIX.—*Duration of the pupal period of Arthrocnodax carolina, Batesburg, S. C.*

Individual No.	Larva pupated.	Adult issued.	Pupal period.
			Days.
1	Oct. 8.	Oct. 15.	7
2	Oct. 10.	Oct. 18.	8
3	Oct. 11.	Oct. 19.	8
4	do	Oct. 20.	9
5	Oct. 12.	Oct. 21.	9
6	do	Oct. 20.	8

Average pupal period, 8.2 days.

The data contained in Table XIX obtained from October rearings indicate that the pupal period of this predator under summer conditions does not exceed eight days, and at times may be a trifle less.

The cocoon (fig. 14) is elliptical, whitish (except in the case of the wintering pupæ), 1 mm. in length by 0.55 mm. wide, and is spun on the underside of the leaf in the protecting angles of the midveins, etc. (fig. 14). In selecting a site for the cocoon the larva incloses within the preliminary fibrils two or three mite eggs, presumably for nourishment while spinning the cocoon. A larva was seen to attach a fibril deftly to the dorsal bristles of an adult female that happened to wander in among the guy-fibrils of the cocoon. "Staked out" in this manner the female remained tethered long enough to deposit two eggs in the precise position suitable to the convenience of the spinning larva. No effort is made, apparently, to conceal the summer cocoons, but the overwintering cocoons are designed with the idea of concealment. Specimens of the latter type are very inconspicuous, owing to the fact that they assume almost the exact color shade of the surface upon which they are constructed.

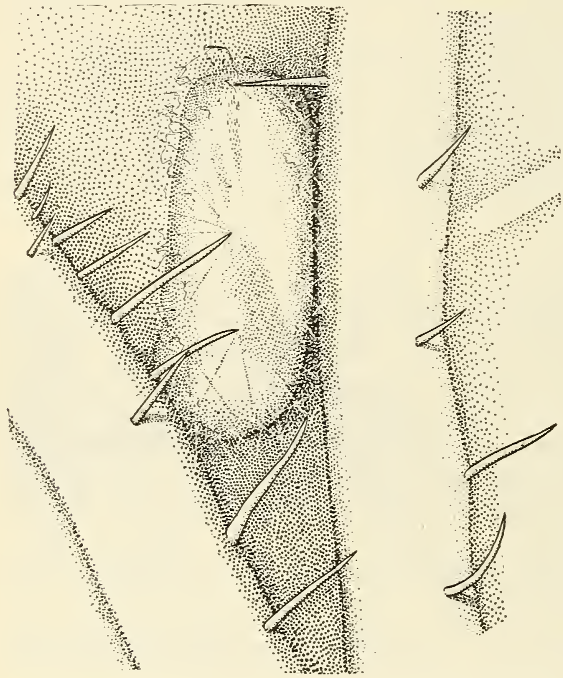


FIG. 14.—Cocoon of *Arthrocnodax carolina* on underside of violet leaf. (Drawn by camera lucida.) (Original.)

Assuming the incubation period to be about 3 days (as is the case with certain similar forms), with 5 days for the larval stage and 8 days for the pupa, the entire cycle from deposition to the issuance of the adult midge will be approximately 16 days. We are inclined to believe that under optimum conditions the cycle may be completed in somewhat less time than this. Table XX presents the records of predation which we have secured.

TABLE XX.—*Consumption of red-spider eggs* [1] *by Arthrocnodax carolina, Batesburg, S. C.*

Larva No.	Collected.		Feeding.					Total consumption (eggs).	Total feeding days.	Pupated.	Average consumption per day (eggs).
	Date.	Condition.	First observed day.	Second observed day.	Third observed day.	Fourth observed day.	Fifth observed day.				
1	Aug. 29, 1914	Half grown	21	29	25			75	3	Sept. 1	25
2	Sept. 7, 1914	Small	136	19				155	2	Sept. 9	77.5
3	do	do	35	38				73	2	do	36.5
4	Sept. 8, 1914	Very minute	53	30	12			95	3	Sept. 11	31.7
5	Sept. 10, 1914	Large	42					42	1	do	42
6	Sept. 11, 1914	do	58					58	1	Sept. 12	58
7	Sept. 13, 1914	Two-thirds grown.	67					67	1	Sept. 14	67
8	Sept. 26, 1914	Small	53	38	22			113	3	Sept. 29	37.7
9	do	Rather large	51	43				94	2	Sept. 28	47
10	Oct. 27, 1914	Nascent (?)	81	30	43	40	89	283	5	Nov. 1	56.6
		Total						1,055	23		45.9

[1] In addition to eggs, some immature mites were also eaten and they are included in the daily consumption figures.

In the foregoing tests 10 larvæ ate 1,055 eggs in 23 feeding days, which yields an average daily consumption of 45.9 eggs per day. The largest number of eggs eaten in one day was 136. The fact that this species often multiplies with great rapidity is explained in part by the very short life cycle. Considering that each larva averages 46 mite eggs per day, and that as high as 52 midges have been seen on a leaf, the remarkable control exerted by this midge may be comprehended.

This predacious species is seldom observed on cotton until infestation has assumed threatening proportions, and many mites in all stages and innumerable eggs are present. As Quayle (1913) has remarked, this species more often operates in colonies which are covered with webbing, but whether this is instinctive or merely incidental would be difficult to determine. The larvæ are surprisingly agile. Coming in contact with a mite egg, the head end is instantly thrust against the shell, through which the piercing device is forced and the feeding begins. Large larvæ devour an egg in from 1 to 2 minutes, while the smaller larvæ require more time according to their size.

Arthrocnodax carolina is parasitized by the minute chalcidid fly *Aphanogmus floridanus* Ashm.

Mycodiplosis macgregori Felt.—During the season 1914 we have also detected a second itonidid species which is predacious upon the red spider. The larva of Mycodiplosis can not be distinguished in the field from that of Arthrocnodax, and the habits and life histories are doubtless much the same. This species is seemingly somewhat later than Arthrocnodax, being occasionally found at Batesburg as late as early December. No special experiments have been undertaken to determine the egg-eating capacity of Mycodiplosis, but from a few field observations we are convinced that its appetite is about the same as that of *Arthrocnodax carolina.*

SYRPHIDAE.

Quayle (1913) states that there are two or three species of syrphus-fly larvæ that eat red spiders. Ewing (1914) also records that he has seen them feeding on the mites in hop fields. However, we find no records of any of these having been reared or specifically identified.

At Batesburg syrphus flies are found in all stages in cotton fields from the last of May until the 1st of September, and are most abundant during July and August. They are incidental enemies of the red spider, and are more intent upon the capture of aphids and insects more conspicuous than mites. However, they are often seen crawling through red-spider colonies, and upon a few occasions have actually been seen to devour adult mites.

Baccha clavata Fab.—This dark-colored, wasplike syrphid was apparently the commonest species. The larvæ and the large, flesh-colored puparia could always be found through the midsummer on cotton infested with aphids and mites. A larva was seen to grasp and devour a female red spider in an interval of 2 or 3 seconds. Table XXI gives statistics on red-spider consumption gathered from tests with larvæ of *Baccha clavata* collected in the field in various stages of development.

TABLE XXI.—*Red-spider consumption by larvæ of Baccha clavata, Batesburg, S. C.*

Individual No.	Consumption of mites.[1]											
	1st day.	2d day.	3d day.	4th day.	5th day.	6th day.	7th day.	8th day.	9th day.	10th day.	Feeding days.	Total mites eaten.
1	19										1	19
2	70	[2] 56									2	126
3	60	33	47	2	26	13	21	27	20	4	10	253
4	20										1	20
5	13	10	9								3	32
Total											17	450

[1] Fed with adult mites but many mite eggs were also eaten. [2] Pupated.

It will be seen that 5 larvæ of *Baccha clavata* in 17 feeding days consumed 450 adult red spiders, which gives an average of 26.5 mites per day.

Allograpta obliqua Say.—This medium-sized syrphus-fly, with abdomen alternately banded with sulphur yellow and chocolate brown, probably ranks second in abundance among these flies. Its larvæ are seen commonly in fields during August.

Sphaerophoria cylindrica Say.—Although a trifle smaller, this syrphid (fig. 15) resembles the preceding species superficially. The small, parchment-like puparia are frequently observed on leaves supporting active or exterminated aphid and mite colonies. They become very common toward the end of August on tomato vines infested by mites, upon which they exert marked control.

Toxomerus duplicatus Wied.—This very small, yellowish species was occasionally taken on infested cotton leaves toward late summer. Its small size would indicate, possibly, that it is better qualified as an enemy of the red spider than the larger species. Its occurrence, however, is rather limited.

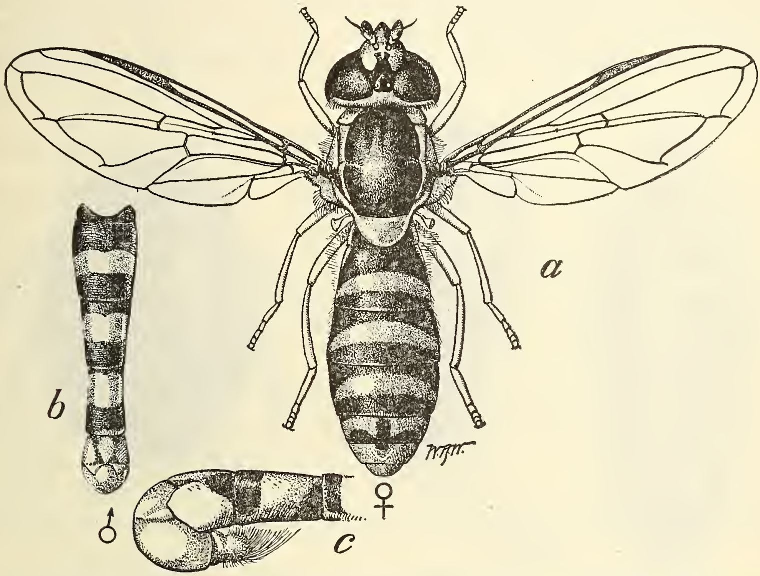


FIG. 15.—*Sphaerophoria cylindrica*, an enemy of the red spider: *a*, Female fly; *b*, dorsal view of abdomen of male; *c*, hypopygium of male, lateral view. Much enlarged. (Webster and Phillips.)

Like most of the other red-spider predators, the syrphids in turn have their enemies. In fact, they are usually well supplied with parasites, 7 species having been reared during the last few seasons. We are not in a position to furnish specific data connecting these parasites with their respective hosts, but will merely list them collectively as enemies of the four syrphid species. They are: *Chrysopophagus compressicornis* Ashm., *Pachyneuron allograptae* Ashm., *Pachyneuron* sp., *Syrphophagus mesograptae* Ashm., *Tetrastichus* sp., *Diplazon laetatorius* Fab., and a species belonging to the tribe Mirini.

COLEOPTERA.

Coccinellidae.

In 1893 Morgan recorded the predatory work of *Pentilia* sp., which was very effective against mites at Baton Rouge, La. Titus states that several lady-beetles were observed by him in 1905 feeding on the red spider. In 1906, at Washington, D. C., Chittenden (1909) found (*Scymnus*) *Stethorus punctum* an active enemy of the red spider on Gymnocladus. *Stethorus punctum* was also recorded in 1909 by Weldon as one of the principal red-spider enemies in Colorado. Worsham (1910) states that *Stethorus punctum* was the only predacious species observed in Georgia in the case of the cotton red spider. In the Sacramento Valley of California, Parker (1913) found *Stethorus nanus*, *S. marginicollis*, and *Pentilia* sp. present in small numbers

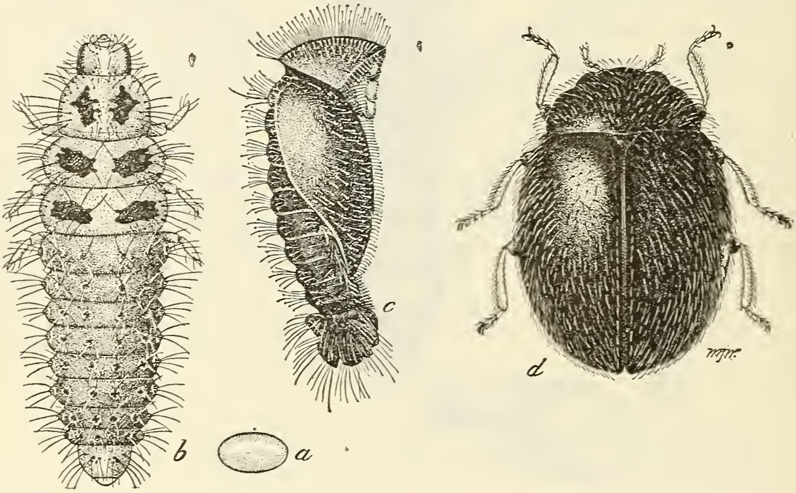


Fig. 16.—*Stethorus punctum*, an enemy of the red spider: *a*, Egg; *b*, larva; *c*, pupa; *d*, adult. All greatly enlarged. *a*, *b*, *c*, redrawn after Weldon; *d*, Webster.

in mite colonies. Ewing (1914) found the larvæ of *Stethorus punctum* in the Willamette Valley, Oregon, where he says they were voracious red-spider enemies. These coccinellids have been known as red-spider enemies for some time, and occur over a large part of the United States.

Stethorus punctum Le Conte (fig. 16).—This is probably the most effectual coccinellid enemy of the red spider. We have seen it so extremely abundant on infested jack beans and jump-vine leaves that the red spider was quickly exterminated. On these host plants as many as a dozen larvæ and a dozen pupæ have been seen on a single leaf. This is the same species as that observed by J. C. Duffey (1891) to exterminate vast colonies of the red spider on Manihot, Ficus, Morus, Tilia, and Ipomœa at St. Louis in 1891. Such striking demonstrations of the economic value of the species have been seen in the field that it holds a position of greatest importance as an enemy of the red spider. Duffey records chrysopid larvæ as predacious on the pupæ of this form, and we also have observed lace-wing-fly larvæ devouring the immature stages.

Stethorus utilis Horn.—This little brownish species has been observed in red-spider colonies on cotton. It is second in importance only to the preceding ladybird, and is most in evidence during July and August. An individual of this species (in the third instar) was observed to eat 3 mite eggs in 7, 7$\frac{3}{5}$, and 8 seconds. This is the fastest rate of egg destruction noted for any predator. Another individual (in the fourth instar) sucked 4 mite eggs in 28, 72, 46, and 77 seconds. Two larvæ were isolated and kept supplied with red spider eggs. One escaped, but the other was reared through to adult. Table XXII gives the life-history record of this individual.

TABLE XXII.—*Life cycle of Stethorus utilis, Batesburg, S. C. (Individual No. 1.)*

Eggs collected	July 25	Length of incubation	4 days (?)
Eggs hatched	July 29	Length of first instar	3 days
First molt	Aug. 1, 9 a. m.	Length of second instar	1$\frac{1}{10}$ days
Second molt	Aug. 2, 11.30 a. m.	Length of third instar	2$\frac{1}{6}$ days
Third molt	Aug. 4, 3 p. m.	Length of fourth instar	4$\frac{3}{4}$ days
Pupated	Aug. 9, 9 a. m.	Pupal period	4 days
Adult issued	Aug. 13, 9 a. m.	Deposition to adult	19 days (?)

Since the conditions surrounding this individual were as nearly normal as possible, it is probable that the foregoing record represents fairly the life cycle of the species.

Table XXIII contains statistics covering the entire feeding capacity of one individual of this species from hatching until adult.

TABLE XXIII.—*Consumption of red-spider eggs by Stethorus utilis.*

Hatched	July 29.	Eggs eaten—Continued.	
Eggs eaten:		Tenth day [1]	116
First day	10	Total	385
Second day	14		
Third day	7	Feeding days	10
Fourth day	32	Average daily consumption	38. 5
Fifth day	38	Eggs eaten:	
Sixth day	17	During first instar	31
Seventh day	38	During second instar	32
Eighth day	73	During third instar	55
Ninth day	40	During fourth instar	267

[1] Was found pupated on eleventh day.

It will be seen that the above individual in 10 feeding days ate 385 red-spider eggs, or 38.5 eggs per day. Although this coccinellid has frequently been seen eating mites in outdoor locations, the experimental individual was confined to an exclusive egg diet, in order to ascertain if the species would develop to maturity on eggs alone. Quayle (1913) has stated that *S. picipes* larvæ ate about 7 mites per day during April in California, but that rate of feeding would doubtless become accelerated under such temperature conditions as obtained during the tests at Batesburg.

Stethorus nanus Le Conte.—This small black species has been identified from individuals collected while actively feeding in red-spider colonies. Tests have not been conducted with this coccinellid.

Scymnus collaris Melsheimer.—This species has been taken on several occasions from the midst of red-spider colonies in which they were feeding, but no data relative to its mite-feeding capacity have been secured.

Microweisea misella Le Conte.—This minute member of the lady-beetle group was collected from June to October on elderberry, phlox, and tomato, all of which were infested with the red spider. Only individuals in the adult stage were seen, but these were very

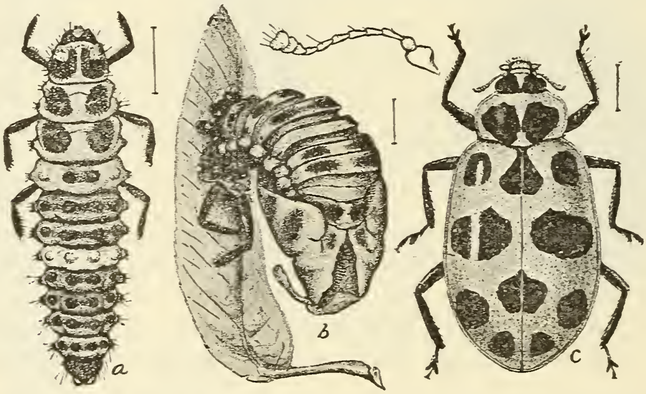


FIG. 17.—The spotted lady-beetle (*Megilla maculata*), an enemy of the red spider: *a*, Larva; *b*, empty pupa skin; *c*, adult. Much enlarged. (Chittenden.)

active within the mite colonies. Owing to the minute size of this species, it is probable that its control capacity is rather limited.

Megilla maculata De Geer.—A few eggs of this coccinellid (fig 17) were collected September 10, 1914, and hatched under control. One individual was reared to adult on a diet of adult mites and was identified as this species. Table XXIV contains our data relative to the life history of this lady-beetle.

TABLE XXIV.—*Life cycle of Megilla maculata, Batesburg, S. C.*

Eggs collected 1914	Sept. 10	Length of first instar	7 days
Eggs hatched	Sept. 11	Length of second instar	3 days
First molt	Sept. 18	Length of third instar	4 days
Second molt	Sept. 21	Length of fourth instar	10 days
Third molt	Sept. 25	Pupal period	6 days
Fourth molt	Oct. 5	Hatched to adult	30 days
Egg period	1 + day		

There is a larval period of 24 days, requiring 4 instars of 7, 3, 4. and 10 days, respectively, and a pupal period of 6 days, altogether embracing an interval of 30 days from hatching to the issuance of the adult.

TABLE XXV.—*Feeding capacity of Megilla maculata for red-spider adults, Batesburg. S. C. (Eggs hatched Sept. 11, 1914.)*

	Mites.		*Mites.*		*Mites.*
1st day	7	11th day	80	20th day	218
2d day	7	12th day	100	21st day	206
3d day	9	13th day	96	22d day	224
4th day	17	14th day (molted)	76	23d day	125
5th day	22	15th day	83	24th day (pupated).	
6th day	25	16th day	97		
7th day (molted)	31	17th day	111	Total consumption	2,011
8th day	48	18th day	135	Average daily consumption	87.4
9th day	63	19th day	156		
10th day (molted)	75				

From Table XXV it may be seen that 1 individual in 23 feeding days ate 2,011 adult mites, thus averaging 87.4 mites per day. There are probably 3 or 4 generations of this coccinellid in a season in the Southeast.

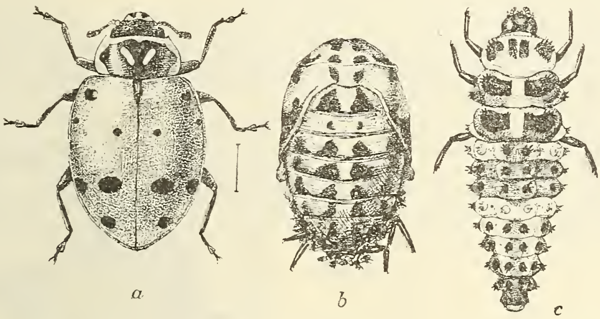


FIG. 18.—The convergent lady-beetle (*Hippodamia convergens*), an enemy of the red spider: *a*, Adult; *b*, pupa; *c*, larva. Much enlarged. (Chittenden.)

Hippodamia convergens Guérin.—This species (fig. 18) is perhaps the commonest of the ladybirds in the Southeast. We have seen it on a few occasions busily engaged in consuming the members of mite colonies. We have conducted no special tests with this beetle, either for life history or control efficiency, since we do not consider that it normally spends much of its time in the quest of red spiders. A new-born larva of this species on one occasion ate 27 adult mites in 24 hours. As compared with Miss Palmer's (1914) life-history records for this species, we obtained 3 days in 2 cases for the egg period and 7 and 8 days in 2 cases for the pupal stage, as against 3 days and 4 or 5 days, respectively, for her experiments. The fact that the summer adults of the larger lady-beetles live from 2 to 4 months (as established by Miss Palmer, 1914) makes each individual potentially of much greater economic importance. This species deposits about 400 eggs.

Coccinella novemnotata Herbst.—Next to the preceding species the

9-spotted lady-beetle (fig. 19) is probably most abundant. Its seasonal occurrence doubtless corresponds very closely with that of *H. convergens*, although our records of the latter have usually been somewhat earlier.

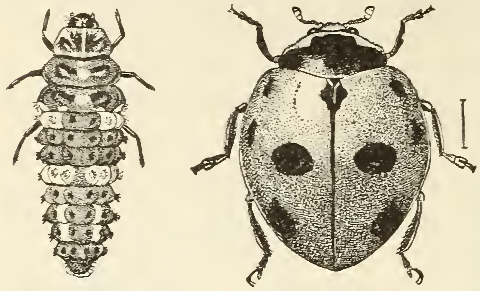


FIG. 19.—The nine-spotted lady-beetle (*Coccinella novemnotata*), an enemy of the red spider: Larva at left, adult at right. Much enlarged. (Chittenden.)

One adult individual from infested cotton ate 31 adult red spiders in 24 hours. Occasional observations have been recorded of this coccinellid feeding on red spiders in the field. At Batesburg the one record for incubation was 3 days (in August) and for the pupal period the solitary record occupied the last 10 days of August.

LEPIDOPTERA.

NOCTUIDAE.

Alabama argillacea Hübn.—When the cotton leafworm caterpillars become abundant, usually in late September or early October, they devour every vestige of the cotton foliage, excepting the stalks, branches, and petioles. Consequently myriads of red spiders which are harbored on the leaves at the time of defoliation are eaten along with the leaf tissue. In this way the leafworm acts most effectively as a remedial agency against the mites. There is an additional consideration in this connection, namely, that those mites which are not actually devoured at the time of the defoliation are compelled to seek new hosts through migration.

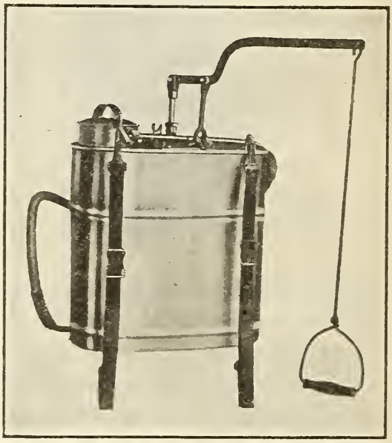


FIG. 20.—Knapsack sprayer suitable for spraying low-growing plants. (Quaintance.)

APICAL SWARMING.

At times of continued drought and heat the lower and earlier infested leaves of many plants become dry and unattractive to the red spiders, which travel upward or outward, seeking the apical leaves, that normally remain green longer. If the plant is heavily infested, a swarming horde of mites is often witnessed converging toward and concentrating at the apices of the branchlets. Upon reaching the tip of the branch or leaf they fairly overrun one another and become ensnared in the web spun by the later arrivals. In the case of the perennial pea (*Lathyrus latifolius*), the swarming continued until fully half of the area of the terminal leaflets was enveloped. A typical terminal leaflet was carefully examined and measured. The swarm was found to be built out to a thickness of 0.25 inch beyond the surface of the leaf, and all mites within the mass were dead. One such swarm was found to contain about 15,000 mites. Innumerable thousands of red spiders are eliminated in this manner.

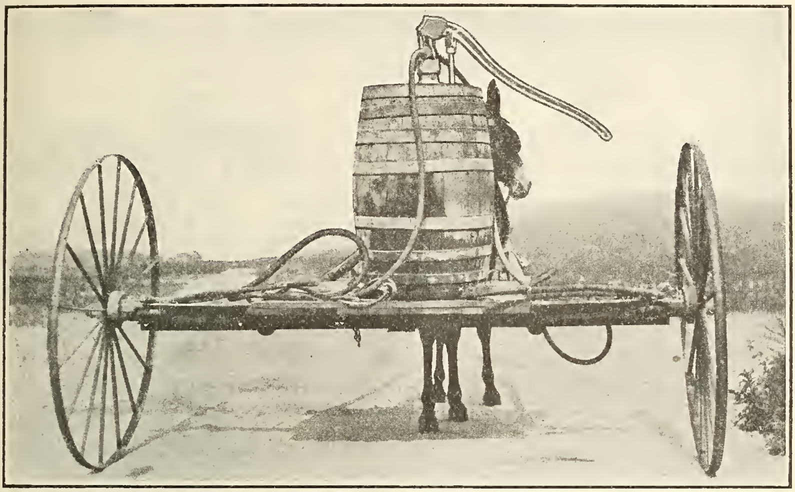


FIG. 21.—Ideal outfit for spraying cotton fields: Barrel pump with double lead of hose mounted on dismantled hayrake. (Original.)

REMEDIAL MEASURES.

PREVENTIVE.

Titus, in 1905, was the first investigator to advocate the application of cultural methods as a means of controlling the red spider. He suggested the rotation of crops, elimination of all plant, weed, and grass growth near fields during the winter and early spring, and fall or winter plowing to turn under all vegetation. Worsham (1910) also strongly recommended the destruction of all winter food plants in proximity to infested cotton fields.

We have already shown that red spiders readily establish themselves on several of the native and dooryard plants. These hosts serve as sources of dispersion. By destroying, during the winter and early spring, pokeweed, Jerusalem oak, Jamestown weed, wild blackberry, wild geranium, and other plants which breed the pest, much good will be done. This plan has been tested by the writer in several instances and has given complete immunity the following season. Ewing (1914) states that this idea was tried in hop fields in Oregon, with the result that the part of the field that was well cleared of foreign vegetation remained free of red spiders, while the neglected portion developed serious infestation. Too much emphasis can not be placed on the importance of ridding all field borders, ditch banks, terraces, etc., of all vegetation so far as possible. Pokeweed and other persistent perennials should be grubbed out.

The destruction of weeds by spraying with sodium arsenite at the rate of 1 pound to 20 gallons of water is very effective.

Many cases of infestation in urban localities can be traced back to borders of cultivated violets growing in near-by house yards. (Pl. VII.) In several instances of past severe annual infestation violets adjoining fields have been thoroughly sprayed, with the result that no red spiders appeared in these fields. The objection to this treatment is the failure on the part of the average person to persevere with the spraying until the mites have been entirely exterminated. The most satisfactory procedure consists in the removal and destruction of the violets.

Early in the investigation it appeared possible that there might be a variation in the degree of susceptibility of cotton varieties to the red spider, for in 1903 Watt and Mann stated that there was a marked difference in the susceptibility of tea (Thea) varieties in India to the Indian red spider, *Tetranychus bioculatus* Green.

During 1912, 1913, and 1914 many varieties of cotton have been planted in exposed fields and records have been made of the percentage of infestation developing in each. Paralleling these experiments data have also been gathered from many cases of infestation in South Carolina and North Carolina. In Table XXVII, which represents the relative degree of infestation of the varieties tested at Batesburg, the position of each variety is obtained by averaging the infestation percentage as exhibited by it during the several years; thus, variety No. 1 was the heaviest infested and No. 37 was the lightest.

TABLE XXVI.—*List of standard varieties of cotton, tested for susceptibility to red-spider injury, Batesburg, S. C.*

1. Lone Star.
2. Keenan.
3. Christopher.
4. Bank Account.
5. Rublee.
6. Money Maker.
7. Cook's Improved.
8. Simpkins.
9. Uncle Sam.
10. Broadwell.
11. Stone's.
12. Toole.
13. Covington-Toole.
14. Hawkins.
15. Mebane Triumph.
16. Lowe.
17. Culpepper.
18. Peterkin.
19. Excelsior.
20. Dixie.
21. Cleveland.
22. World's Wonder.
23. Russell Big Boll.
24. Hite's Prolific.
25. Bostwick.
26. King.
27. Columbia L. S.
28. Poor Land.
29. Bates.
30. Rowden.
31. Truitt.
32. Trice.
33. Shine's Early.
34. Sea Island.
35. Wade's Triumph.
36. Dongola.
37. Summerour's Half and Half.

We feel that we can say that among the cotton strains the old Peterkin group is probably most susceptible.

An experiment was conducted in testing the value of thickly broadcasting cotton at the boundary of a field as a trap crop for red spiders. The cotton was sowed between the cotton field proper and a large, heavily infested border of violets. The broadcasted cotton became infested and was plowed in before there was danger of a second migration to the crop proper. As a result the field remained free from mites. Although we do not recommend the broadcasting measures as an important method of prevention, still the success of this experiment would indicate strongly that the cotton trap crop is practicable as an auxiliary expedient to be used in controlling this pest.

It has been surmised that wide spacing of the stalks, thus preventing the interlacing of branches, would prevent the spread of the red spider through a field. Experiments at Batesburg have shown that the red spider disperses through a cotton field commonly both by means of the ground and the interlacing branches. While this shows the futility of the wide spacing as a complete preventive, it seems reasonable to suppose that the movement of the red spider will be somewhat impeded; in fact, we can corroborate this supposition to some extent in that infestation was observed to spread very slowly in certain checked fields.

Since the movements of nearly all insects, when crawling over the ground, are retarded by pulverized soil, it appeared that by maintaining a dust mulch in exposed cotton fields the progress of the migrating mites would be checked. In the case of the "check" cotton fields, it was possible to maintain continually a thoroughly pulverized soil surface. It was observed that the infestation in these fields progressed very slowly and failed to become at all threatening. In fields cultivated in checks it is easy to see that leaf-to-leaf dispersion will be greatly restricted and, at the same time, ground travel somewhat retarded. Thus, by combining these two measures—spacing the plants and maintaining a surface mulch—much good will doubtless result. In the cultural experiments conducted, both the ordinary sweep and the spring-tooth adjustable cultivator have been employed. The latter implement creates a much better surface mulch than does the old-type sweep.

Early planting permits the plants to develop a maximum growth of foliage and fruit by the time mites appear in large numbers, which is important, inasmuch as plants of considerable size are rarely killed by the pest, nor are well-advanced bolls commonly shed from red-spider infestation. Early planted cotton ages and soon toughens, making it untempting to the red spider at a time when later cotton offers ideal feeding conditions. Late cotton is almost always objectionable to the farmer, since in ordinary seasons it results in a reduction of the yield, and because of the fact that it suffers heavily in the event of the appearance in the late summer of the bollworm, or the leafworm, or of the boll weevil in western sections.

We have made an effort to establish the rotational value of the common crop plants, garden plants, and field plants, both by planting them in or near infested fields and by making frequent examinations of a great many of these plants which happened to be planted by others in infested localities. Besides cotton, we have found red spiders commonly upon the following field crops: Cowpeas, vetch, red and white clover, alfalfa, corn, hops, beets, and watermelon. They also have been found frequently upon the following garden crops: Pea, bean, onion, tomato, pepper, Irish potato, sweet potato, lettuce, okra, turnip, mustard, radish, cabbage, squash, beet, celery, strawberry, and several others. Our host list also included many of the common bush fruits, tree fruits, and dooryard plants. Rather acute cases have been seen on corn, cowpeas, and sweet potatoes. The only plants which have appeared largely immune are the grasses and the small grains. Owing probably to the lack of shelter, which the foliage of the grasses exhibits, the mites are unable to maintain themselves under severe weather conditions. The planting of grains on land normally heavily infested is therefore a measure which should be considered by the farmer.

REPRESSIVE.

That it is possible to eradicate the pest from infested fields has been demonstrated, but in many cases the task is so tedious that only the most determined farmers will resort to the necessary measures.

The experiment has been tested frequently of pulling up and destroying the first few plants which show infestation. In applying this measure the farmer must maintain a constant surveillance of suspected fields, so that the earliest affected stalks may be detected. In such cases the operation will probably have to be repeated several times, owing to the fact that certain plants are overlooked during the first examination because the colonies on them are too young to have revealed their presence. Great care should be observed in locating every plant which shows the characteristic red spots, and these must be carefully taken from the field and burned. This must be done before infestation has reached the point where there is danger of a secondary dissemination, and before there is liability of the dropping of infested leaves.

If infestation has spread until a considerable area has become involved, more drastic steps will have to be taken. It is sometimes advisable, where a continuous area of infestation occurs in a large field, to plow up all the affected portion in order to save the balance of the field. The stalks should be piled up quickly and burned with the assistance of straw or light trash. Such a severe measure, however, should be resorted to only in extreme cases, and the planter concerned must be the judge of its advisability.

Since we have established by experimentation that red spiders are unable to liberate themselves when buried 1 inch or more in soil, the importance of plowing affected areas thoroughly is evident.

INSECTICIDES.

In the course of experiments with red-spider sprays 74 different spray combinations have been tested.

Table XXVII.—*List of red-spider sprays employed with favorable results, Batesburg, S. C.*

1. Potassium sulphid.	6. A water-soluble oil.
2. Kerosene emulsion.	7. Resin wash.
3. Lime sulphur (home-made).	8. Nicotine sulphate and miscible oil.
4. Lime sulphur (manufactured).	9. Nicotine sulphate and fish-oil soap.
5. A miscible oil.	10. Fish-oil soap solution.

In addition to these successful sprays, special mention should be made of potassium permanganate. In a 2 per cent solution this is an excellent spray, but its cost is prohibitive, except in cases where only a few plants are to be treated.

Sulphur Preparations.

Finely resublimed sulphur, both unadulterated and mixed with dehydrated lime, was thoroughly tested on infested violets, dahlias, roses, and cotton. It was applied with a dust gun during very warm weather. Heavy infestation on prostrate violets was eradicated by the sulphur dust; 60 per cent of the red spiders on dahlias were killed; 25 per cent of those on roses were destroyed; and from 1 to 15 per cent mortality occurred on 4-foot cotton. Suspecting that this variation in mortality came about through the agency of surface radiation, the following test was made: A small area of ground surface was thoroughly dusted with resublimed sulphur, and a heavily infested potted violet plant was set into the center of this area, so that no leaves touched the ground. The foliage, which had not been treated, was about 6 inches from the soil surface. Examination after 8 hours' exposure on a very hot day showed that over 99 per cent of the mites had been killed. When elevated a distance of 18 inches above the sulphured ground practically no mortality occurred to infested violets. This indicates that the heat radiated from the ground (acting on the sulphur immediately at hand) is the chief factor which determines the mortality resulting from the use of sulphur dust. We can state that this treatment (except for such very prostrate plants as violets) is not at all effective in the Southeast.

Sulphur mixed with water was sprayed on infested cotton. Examination showed that the red spiders were in no way affected. When soft soap was added to this same spray, however, the resulting mortality was from 50 to 99 per cent, depending on the thoroughness with which the preparation was kept mixed.

Potassium sulphid has been tested at strengths of from 4 ounces to 3 gallons of water to 1 ounce to 4 gallons of water on cotton, sweet peas, hollyhock, beans, and violet. The former concentration slightly damaged the foliage and a mixture of 1 ounce to 2 gallons of water was found to be ideal. This spray commends itself from every viewpoint—cheapness, simplicity of preparation, ability to kill quickly, and safety to foliage.

Both homemade and commercial lime-sulphur sprays were carefully tested on cotton, beans, and sweet peas. The mortality on cotton and beans was practically complete, but the results on infested sweet peas were invariably unsatisfactory. With the addition of neither flour paste nor gelatin was this substance effective on sweet-pea foliage. This is quite in agreement with Parker's results, and is explainable through the fact that the pubescent surface of the sweet-pea leaf prevents the even spreading of the insecticide. On cotton, beans, and several other hosts lime-sulphur is a perfect red-spider spray.

Sodium sulphid was tried repeatedly on infested cotton and beans. The greatest mortality obtained against red spiders on beans, a host well adapted to red-spider spraying, was 58 per cent, and the preparation was so strong as to damage the leaves somewhat. The addition of fish glue resulted in a mortality of 95 per cent, but in this case it is believed that much of the destruction was caused by the mechanical action of the glue.

Nicotine Preparations.

Nicotine sulphate and fish-oil soap or miscible oil.—Nicotine sulphate used by itself is very unsatisfactory as a red-spider spray. This preparation was tested at strengths of from 1: 400 to 1: 800 against red spiders on cotton, beans, sweet peas, and violets. The best results were secured on infested cotton, using the extract 1: 640, a mortality of 70 per cent being obtained. When combined with fish-oil soap (one-half ounce nicotine sulphate, one-fourth pound fish-oil soap, 2 gallons water) its effectiveness was perfect.

The mixture of nicotine sulphate (1 to 500) and a miscible oil (1 to 40) also gave complete mortality. The addition of flour paste had almost no noticeable effect in increasing the percentage of mortality. We believe, in the case of the excellent results obtained from the use of combined nicotine sulphate and fish-oil soap, and of combined nicotine sulphate and a miscible oil, that the efficacy was derived principally from the soap and the oil rather than from the nicotine ingredient. The nicotine sulphate applied by itself dries on the foliage in little beads so that the mites in the interstices are not affected.

Oils.

A commercial miscible oil preparation was tested against red spiders on cotton. It was found that a strength of 1 to 20, and even as weak as 1 to 30, sufficed to kill all red spiders, and no injury to foliage resulted. The spray is easily prepared and spreads fairly well over the infested leaves.

An oil that is easily miscible with water is more caustic than the foregoing composition and should not be employed stronger than a dilution of 1 to 32. This miscible oil induced complete mortality to red spiders on cotton, beans, and sweet peas. When one considers the almost invariable failures that have attended the attempts to destroy mites on sweet-pea foliage, an idea of the effectiveness of this preparation may be gained. Its spreading qualities are excellent.

When not less than 2 gallons of kerosene were used to 12 gallons of water in making kerosene emulsion the mortality of mites on cotton and beans was complete. The spreading property of this spray is excellent. The only possible arguments against its employment are the labor of preparation and the slight injury that occasionally occurs to delicate foliage. A weak solution of kerosene emulsion, when fortified with a small amount of a miscible oil, did not give satisfactory results.

Adhesive Sprays.

In 1903 Volck experimented with flour paste as a spreader for lime-sulphur solution. The success of this additional ingredient, perhaps, may have suggested to Cook and Horne the value of paste alone, for in 1908 they recommended the latter against the red spider. Again, in 1913, Parker determined that a flour paste (cooked), consisting of 1 pound of flour to 1 gallon of water, when diluted at the rate of 1 part paste to 9 parts water, produced complete mortality to red spiders on hops in California. At Batesburg the flour-paste solution, prepared according to Parker's formula, has been carefully tested on sweet peas, violets, beans, hollyhock, and cotton. On sweet peas, violets, and beans the results were unsatisfactory, while on hollyhock and cotton the mortality did not fall below 98 per cent and averaged nearly 100 per cent.

Thinking to utilize only the effective part of the flour, and to simplify the paste-cooking operation, a mucilaginous spray was made by converting laundry starch into paste and diluting it with water. This was applied to heavily infested cotton, and all mites that were hit by the preparation were killed. Since the making of this spray requires less time and care than is the case with flour paste, and since its efficacy appears to be just as good, it would appear thatthis simple mixture should be given further consideration.

Resin Wash.

An insecticide containing, resin 2 pounds, caustic soda one-half pound, fish oil one-fourth pint, and water 10 gallons was given a thorough test on heavily infested beans and cotton. In both cases all red spiders were killed. This preparation possesses the valuable quality of spreading, and is an excellent red-spider spray. The only objection to its general use is the fact that it is not quickly or easily prepared.

Soap Solutions.

A common brand of fish-oil soap, at the rate of one-fourth pound to 2 gallons of water, was applied to mites on beans and cotton. The mortality was complete and the spreading quality of the insecticide was ideal. Other strengths of this solution were tried, and combinations of the fish-oil soap with other substances were tested, but nothing seemed to be added to the efficiency of the soap through these modifications.

In addition to the tests discussed in the foregoing paragraphs, we have conducted several large-scale demonstrations in affected cotton fields. The sprays used in these operations were either potassium sulphid or lime-sulphur, and a barrel pump mounted on some type of horse-drawn vehicle was used for applying the material.

It should be noted that all tests with sprays were conducted during hot, sunny days in the South. This is important to consider in relation to results, since it is becoming known that similar sprays often yield very different results when applied under diverse climatic conditions.

SPRAYING OUTFITS.

The sort of outfit to be used for red-spider spraying[1] depends mainly upon the extent of the occurrence. Many prefer to use a 75-cent tin atomizer when only a score or so of plants are to be treated. This instrument is very economical of liquid and throws a fine, vapory spray which penetrates and blows to all accessible parts, but it is not economical of time, and should be employed only where a quart or two of spray material will complete the job. The bucket pump and knapsack pump (fig. 20, p. 58) come into use in cases of considerable scattered infestation or for treatment of a few plants in tall cotton where the platform pump would be impractical. The most economical outfit for a severe case involving several acres consists of a barrel

[1] Our recommendations regarding spraying methods apply primarily to cotton.

pump carried through the field on a wagon or on a specially constructed vehicle of some sort. Figure 21, page 59, is from a photograph of a portable outfit devised by a progressive planter at Laurinburg, N. C., from suggestions supplied by the writers. It consists of a platform built upon the axle and shafts of a dismantled hayrake. The two wheels are large, bringing the axle well above the ground, so that injury of the plants is avoided to a great extent. A barrel pump with a capacity of 50 gallons is mounted on the platform. A boy drives, one man pumps, and one handles each sprayer, of which preferably there should be two. Thorough treatment of 3 or 4 acres a day was readily obtained with this device. For safe work the attempt should not be made to use this device in cotton of tall growth, since the passing wagon will injure high plants, but it is ideal in fields of average height or less.

Some dissatisfaction has been experienced among certain of those who have undertaken to check the ravages of the red spider by spraying. This can be understood on account of the extreme care which must be exercised in order to secure effective results. From the fact that the mite as a rule passes its entire existence upon the underside of a single leaf, it becomes plainly necessary in spraying to *hit the entire underside of every leaf* of an infested plant. Furthermore, since we have shown that no safe insecticide is known which will destroy red spider eggs, it is clear that a second spraying is necessary to kill the individuals which were eggs at the time of the first spraying.

SUMMARY AND RECOMMENDATIONS.

The common red spider occurs throughout the United States, but is known as a serious pest in only three regions, namely: In that portion of the cotton belt including North Carolina, South Carolina, Georgia, Florida, Alabama, and Mississippi, where it is primarily a pest of cotton; in north-central and western Colorado as a pest of fruit trees; and in central California, where the species is a rather serious pest of hop fields.

It is estimated that during a season of severe red-spider occurrence the loss to the cotton planters of the Southeast amounts approximately to $2,000,000.

From the records of the present investigation the common red spider is known to maintain itself successfully on 183 species of wild and cultivated plants, weeds, vines, bushes, and trees. A small number of these hosts show special attractiveness for the pest and infestation upon them reaches a more acute degree. These favorite species may be grouped as winter hosts and summer hosts, the former supporting the pest through the cold, inactive period of the year, and the latter furnishing food throughout the spring and summer.

Weeds growing in borders, terraces, etc., and dooryard plants (in the case of fields near dwellings) constitute the sources from which red spiders are able to enter cotton fields. The invasion of fields is accomplished either (1) by travel upon the ground, (2) by travel from leaf to leaf, (3) by the wind, (4) by rain and surface water, or (5) by accidental transportation by farm hands, farm animals, or large insects.

The control of the red spider is possible either by preventive or by repressive measures. Great expenditures of time, labor, and material, however, are necessary when the latter operation is undertaken. Measures of prevention are far more economical and practical.

Clean culture, or the extermination of weeds and plants which breed the pest, is by far the most vital means of prevention that can be applied in the case of field and truck crops.

In cases where cotton is grown within 100 yards of dooryards containing violets and other ornamental plants a careful watch of these plants should be maintained in order that they may be sprayed or destroyed.

By the persistent maintenance of a finely pulverized surface mulch in fields the progress of migrating mites is somewhat retarded and the development of infestation correspondingly discouraged.

Although the fertilization of cotton land in no way interferes with the status of the red spider, and exerts no direct controlling effect on infestation, yet the judicious use of fertilizers assists the plants to overcome injury.

Trap crops, rotation, favorable planting time, irrigation, etc., are either of only slight or of negative value.

Dispersion may be prevented by eliminating the plants in a field which harbor the initial infestation. This may be accomplished by pulling the first few plants which show infestation, or, in case the pest has secured a good foothold, the elimination will be accomplished only by means of plowing up all the affected portion of the field. In either case the stalks should be quickly piled and burned with the help of a little straw or light trash.

Spraying for red spiders is effective if it is done with extreme care. There are a few sprays which will give complete mortality when properly applied, but *a second spraying is necessary to kill the individuals that were eggs at the time of the first spraying.* A contact insecticide is absolutely necessary, and it is vital that every leaf on an infested plant should be reached by the spray.

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