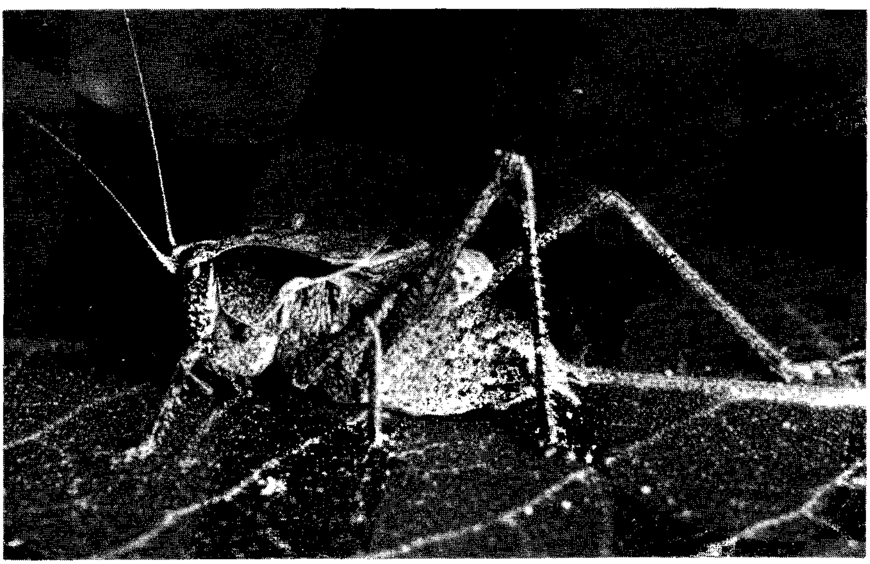
The

# GREAT LAKES ENTOMOLOGIST

MICHIGAN ENTOMOLOGICAL SOCIETY • 1954 •

Vol. 7, No. 3 Fall 1974



THE GREAT LAKES ENTOMOLOGIST

Published by the Michigan Entomological Society

Volume 7 1974 No. 3

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A male Short-legged Shield-bearer, *Atlanticus testaceus* (Scudder) (Orthoptera: Tettigoniidae: Decticinae). Photograph taken by Howard K. Wallace.

Vol. 7, No. 1 of *The Great Lakes Entomologist* was mailed on May 15, 1974.
Vol. 7, No. 2 of *The Great Lakes Entomologist* was mailed on July 1, 1974.

## THE MICHIGAN ENTOMOLOGICAL SOCIETY



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# NORTH AMERICAN SPECIES OF THE GENUS AXONOPSIS (ACARINA: ATURIDAE: AXONOPSINAE)[1]

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Members of the genus *Axonopsis* have a broad zoogeographic distribution but are unreported from the Australian region and South America south of Colombia. Species occur in permanent standing waters and streams (including interstitial water). Representatives of four subgenera, *Axonopsis* s. s., *Brachypodopsis, Paraxonopsis* and *Vicinaxonopsis,* have been collected in North America, and a species of the closely related genus *Erebaxonopsis* is also known from interstitial waters in California. The only anomalous aspects of the distributional patterns are the apparent absence of *Hexaxonopsis* (which has a relatively widespread Palearctic range) and the stream (and interstitial) habitat of the North American species of the typical subgenus. The European species occurs only in lakes.

There have been four species (plus an additional two subspecies) previously described by Herbert Habeeb from North America: *Axonopsis setonensis* (Habeeb, 1953); *rivophila, cullasaja* and *pallida* (Habeeb, 1957); *pallida cayuga* (Habeeb, 1961); *cullasaja boreosaja* (Habeeb, 1968). The type material on which these species were based has been privately retained and I have been unable to obtain the loan of specimens. Although both descriptions and illustrations are inadequate, either the collection of topotypic material or an unusual habitat type has made it possible to identify the four full species with a reasonable degree of certainty. I cannot recognize the two subspecies and only short discussions of them are included under the species to which they were assigned.

The concept of the genus *Axonopsis* and its included subgenera has been considerably modified during the last few years and the reader is referred to Cook (1974) for a more detailed discussion. In presenting measurements, those of the holotype and allotype are given first. If a series of specimens is available, the range of variation is given in parentheses following the measurements of the primary types. Holotypes and allotypes will be placed in the Field Museum of Natural History (Chicago).

Especially in the case of *Brachypodopsis,* there are many somewhat closely related species which are often distinguished by a combination of characters. For greater ease in identifying these species the following key is included. For the sake of completeness species in the other subgenera are also placed in the key.

## KEY TO THE NORTH AMERICAN SPECIES OF THE GENUS *AXONOPSIS*

1. Anchoral process of the capitulum very long (Fig. 82); P-V approximately same length as P-IV (Fig. 62) . . . . . . . . . . . . . . . Subgenus *Vicinaxonopsis* Cook [only known North American species . . . . . . . . . . . . . *A. californica* Cook]

1′. Anchoral process of the capitulum much shorter than remainder of capitulum; P-V much shorter than P-IV (Figs. 4, 85) . . . . . . . . . . . . . . . . . . . . . . 2

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3(2). Two pairs of glandularia (not counting a pair flanking the excretory pore) located in posterior half of the dorsal shield (Fig. 84) . . . *A. bimaculata* (Cook)

[1]Contribution No. 317 from the Department of Biology, Wayne State University. Supported by a grant (GB-12375) from the National Science Foundation.

3′. One pair of glandularia (not counting a pair flanking the excretory pore) located in posterior half of the dorsal shield (Fig. 78) . . . . . *A. sabulonis,* new species
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## Subgenus **AXONOPSIS** Piersig

### AXONOPSIS (AXONOPSIS) BIMACULATA (Cook)
(Figs. 79, 84)

*Pseudaxonopsis bimaculata* Cook, 1963. Amer. Midland Nat., 70:122.

*Male:* Dorsal and ventral shields broadly fused anteriorly; lateral eyes well developed; length of body 384μ, width 312μ; width of dorsal shield 273μ; dorsal shield bearing four pairs of glandularia, one pair of which flank the excretory pore at extreme posterior end (Fig. 84); two pairs of elongated glandularia platelets and a pair of small gland platelets lying in the integument between the posterior portions of the dorsal and ventral shields; dorsal shield without ridges; color pattern of dorsum indicated in Figure 84, pigment heavy; capitular bay deep; no glandularia located on the ventral shield between the anterior end of the genital field and the insertions of the fourth legs; structure of the venter, except for genital field, similar to that shown in Figure 80; structure of genital field similar to that of the following species (Fig. 83); width between outer edges of most lateral pair of acetabula 126μ; four pairs of acetabula; suture line between genital field and remainder of ventral shield moderately distinct.

Dorsal lengths of the palpal segments: P-I, 27μ; P-II, 48μ; P-III, 31μ; P-IV, 100μ; P-V, 29μ; Figure 79 illustrates the proportions and chaetotaxy of the palp; dorsal lengths of the distal segments of the first leg: I-Leg-4, 48μ; I-Leg-5, 62μ; I-Leg-6, 69μ; proximal end of I-Leg-5 lacks the pronounced ventral projection shown in Figure 81; swimming hairs present on all but the first pair of legs.

*Female:* Described in detail in the paper cited above. The female venter is similar to that illustrated in Figure 80 but the posterior two pairs of acetabula are not as large.

*Habitat and Distribution:* The female holotype was collected in a gravel bar in the King's River, Carrol County, Arkansas. The male specimen described above was collected on rocks in a stream near junctions of routes 73 and S278, Jackson County, Florida, November 9, 1970.

*Discussion:* In spite of habitat differences the male specimen seems to agree well with the expected morphology. However, until a longer series of specimens is available to provide a known range of variation, the identification should be regarded as tentative.

### AXONOPSIS (AXONOPSIS) SABULONIS, new species
(Figs. 78, 80, 81, 83, 85)

*Female:* Dorsal and ventral shields broadly fused anteriorly; lateral eyes moderately well developed; length of body 433μ (425μ-464μ), width 327μ (319μ-349μ); width of dorsal shield 293μ (293μ-319μ); dorsal shield bearing three pairs of glandularia, one pair of which flank the excretory pore at extreme posterior end (Fig. 78); two pairs of elongated glandularia platelets and a pair of small gland platelets lying in the integument between the posterior portions of the dorsal and ventral shields; dorsal shield without ridges; color pattern of dorsum consisting of light anterior and posterior pigment patches as shown in Figure 78, but some populations contain individuals in which the pigment has almost completely disappeared; capitular bay deep; no glandularia located on the ventral shield between the anterior end of the genital field and the insertions of the fourth legs; Figure 80 shows the morphology of the ventral shield; width between outer edges of most lateral pair of acetabula 155μ (155μ-169μ); four pairs of genital acetabula; suture line between genital field and remainder of ventral shield very distinct.

Dorsal lengths of the palpal segments: P-I, 38μ (36μ-38μ); P-II, 52μ (48μ-54μ); P-III, 38μ (38μ-39μ); P-IV, 110μ (110μ-116μ); P-V, 31μ (31μ-33μ); Figure 85 illustrates the proportions and chaetotaxy of the palp; dorsal lengths of the distal segments of the first leg: I-Leg-4, 55μ (55μ-58μ); I-Leg-5, 59μ (59μ-62μ); I-Leg-6, 71μ (69μ-72μ); proximal end of I-Leg 5 with a pronounced ventral projection; swimming hairs present on all but the first pair of legs.

*Male:* Similar to female except in structure of the genital field region (Fig. 83) and only measurements are given; length of body 418μ (418μ-456μ), width 319μ (311μ-349μ); width of dorsal shield 293μ (282μ-319μ); width between outer margins of most lateral pair of acetabula 138μ (138μ-145μ); dorsal lengths of the palpal segments: P-I, 37μ (37μ-39μ); P-II, 47μ (47μ-52μ); P-III, 34μ (34μ-38μ); P-IV, 100μ (100μ-116μ); P-V, 28μ (28μ-31μ); dorsal lengths of the distal segments of the first leg: I-Leg-4, 50μ (48μ-52μ); I-Leg-5, 64μ (63μ-66μ); I-Leg-6, 73μ (73μ-83μ); Figure 81 shows I-Leg-5 and 6.

*Holotype:* Adult female, taken in gravel deposits of a stream east of Griffen (two miles from the Warren County line), Hamilton County, New York, August 30, 1968.

*Allotype:* Adult male, same data as holotype.

*Paratypes:* 1 male, found in a gravel bar in a small stream near Limestone, Victoria County, New Brunswick, August 26, 1964; 1 male, 1 female, from a gravel bar in the North Branch of the Meduxnekeag River at Monticello, Aroostook County, Maine, August 28, 1964; 1 female, from bottom gravels in Wytopitlock Stream, Aroostook County, Maine, September 5, 1968; 1 male, taken in gravel deposits of a stream at Perry City, Schuyler County, New York, August 29, 1968; 2 females, found in gravel deposits in Flatbrook two miles south of Bevans, Sussex County, New Jersey, August 16, 1964; 1 female, from gravel deposits in the Cowpasture River five miles northwest of Millboro Springs, Bath County, Virginia, July 24, 1964; 1 male, from bottom gravels in Thompson Creek near McClung, Bath County, Virginia, September 9, 1968; 1 male, collected in a sand and gravel bar in Goose Creek, Russell County, Kentucky, July 14, 1964.

*Discussion:* This is an interstitial water species which seems to be confined to northeastern North America. Its known range extends from New Brunswick to Virginia and westward into southwestern Kentucky. The present species differs from *bimaculata* in being larger, possessing one less pair of glandularia on the dorsal shield and a proportionally longer P-I (compare Figures 79 and 85). Different populations exhibit varying degrees of integumental pigmentation loss. Some have lightly pigmented anterior and posterior patches as shown in Figure 78 but in others the color is almost absent.

## Subgenus **BRACHYPODOPSIS** Piersig

Most North American species of *Axonopsis* belong to this subgenus. Unfortunately, many of the species are rather similar and there is no pronounced sexual dimorphism to aid in separation. Species with both three and four pairs of acetabula are assigned to this subgenus. Those with four pairs of acetabula seem to be a polyphyletic group, having evolved from several unrelated triacetabulate ancestors, and therefore acetabula number cannot be used to further subdivide the subgenus. Important taxonomic characters for the North American species are acetabula number, size and number of ridges on the dorsal shield. The height of the ridges is somewhat variable but when used in conjunction with other characters is highly useful. Other important differences are number of glandularia on the dorsum, presence or absence of a projection on P-II and proportional sizes of the appendage segments. Habitat types and color patterns are very important supplementary characteristics. It is advisable to clear specimens during slide making with KOH in order to preserve these color patterns. The male genital field is more or less terminal and difficult to illustrate in a strict ventral view because of the foreshortening. Therefore, with rare exceptions, illustrations of the male genital field are posteroventral views. Figures 27 and 28 are posteroventral and ventral views respectively of the male genital field of *A. amnicola* and indicate the apparent differences caused by the variation in angle of view.

## AXONOPSIS (BRACHYPODOPSIS) PALLIDA Habeeb
(Figs. 1-3, 5, 6)

*Axonopsis pallida* Habeeb, 1957. Leaflets Acadian Biol., 15:8.

*Female:* Dorsal and ventral shields lightly fused at anterior end; lateral eyes well developed; length of dorsal shield 380μ-433μ, width 288μ-329μ; length of ventral shield 373μ-415μ, width 327μ-368μ; dorsal shield bearing three pairs of glandularia posterior to the postocularia; median and lateral ridges of dorsal shield well developed, lateral ridges extending nearly to anterior end of dorsal shield; Figure 1 shows the typical color pattern of the dorsum; two pairs of glandularia located very close together on their respective sides between genital field and insertions of fourth legs; Figure 3 shows the morphology of the ventral shield: lateral edges of ventral shield rounded or somewhat angled as shown in the illustration of a related species (Fig. 13); a well developed suture line (continuation of that between first and second coxae) joining at the midline (Fig. 3, arrow A); three pairs of genital acetabula; width between outer edges of most lateral pair of acetabula 121μ-162μ; gonopore 38μ-41μ in width.

Dorsal lengths of the palpal segments: P-I, 31μ-33μ; P-II, 43μ-49μ; P-III, 27μ-31μ; P-IV, 57μ-68μ; P-V, 23μ-24μ; Figure 5 shows the proportions and chaetotaxy of the palp; distoventral projection on P-II prominent but not always as well developed as illustrated; capitulum 79μ-89μ in length; dorsal lengths of the distal segments of the first leg: I-Leg-4, 48μ-55μ; I-Leg-5, 59μ-72μ; I-Leg-6, 61μ-72μ; Figure 2 shows I-Leg-5 and 6; swimming hairs present on all but the first pair of legs.

*Male:* Similar to female except in structure of the genital field region (Fig. 6) and only measurements are given; length of dorsal shield 364μ-395μ, width 282μ-304μ; length of ventral shield 357μ-388μ, width 319μ-332μ; width between outer edges of most lateral pair of acetabula 121μ-128μ; dorsal lengths of the palpal segments: P-I, 28μ-31μ; P-II, 43μ-45μ; P-III, 25μ-27μ; P-IV, 55μ-59μ; P-V, 21μ-23μ; capitulum 80μ in length; dorsal lengths of the distal segments of the first leg: I-Leg-4, 48μ-51μ; I-Leg-5, 59μ-61μ; I-Leg-6, 59μ-62μ.

*Habitat and Distribution:* The type was collected by Habeeb in Mill Creek near Highlands, Macon County, North Carolina in early May 1957. I have taken specimens from the following localities: 1 male, 1 female, collected from submerged sticks in the Cullasaja River one mile north of Highlands, Macon County, North Carolina, May 14, 1961 (the type locality is a tributary of the Cullasaja River); 1 female, taken in sand deposits of a small stream one mile north of Albion, Pushmataha County, Oklahoma, July 9, 1961; 1 female, from gravel deposits in Thompson Creek near McClung, Bath County, Virginia, September 9, 1968; 1 male, found on a submerged stick in the Perdido River, Escambia County, Florida, November 7, 1970; 7 females, collected in matted roots in a small tributary of the Waccasassa River approximately one mile south of Gulf Hammock, Levy County, Florida, November 11, 1970.

*Discussion:* Although two specimens were taken in collections in which interstitial mites predominated, it is felt this is primarily a reophilic species. It is not uncommon in streams with little vegetation for reophilic species to move into the uppermost bottom layer and be taken along with true interstitial species. The female specimens from the last collection had a much narrower genital field than those from outside Florida, but otherwise were similar. Genital field width of the Florida females varied from 121μ-131μ but varied from 155μ-162μ in specimens from outside Florida. The significance, if any, of these differences is presently not clear.

Habeeb (1961) described a female specimen from Lake Cayuga, Seneca County, New York as a subspecies, *A. pallida cayuga,* and stated it differed from *pallida* in lacking a complete suture line as shown in Figure 3, arrow A. If, as must be assumed from the original description, it has the three well developed ridges on the dorsal shield, this plus its lentic habitat should make it easy to identify. There is a strong possibility this taxon should be given full species ranking.

## AXONOPSIS (BRACHYPODOPSIS) OCCIDENTALIS, new species
(Figs. 14, 17-20)

*Female:* Dorsal and ventral shields lightly fused at anterior end; lateral eyes well developed; length of dorsal shield 471μ (463μ-471μ), width 334μ (334μ-349μ); length of ventral shield 456μ (452μ-456μ), width 384μ (384μ-395μ); dorsal shield typically bearing three pairs of glandularia posterior to the postocularia; median and lateral ridges of dorsal shield poorly to moderately developed; lateral ridges not extending near anterior end of dorsal shield; edges of posterior half of dorsal shield more or less rounded; Figure 20 shows the color pattern in the holotype (the two patches joined by a narrow median bridge of pigment in one paratype); two pairs of glandularia located very close together on their respective sides between the genital field and insertions of the fourth legs; Figure 18 shows the morphology of the ventral shield; suture line between first and second coxae extending toward the midline but not as well developed as in the preceding species; three pairs of genital acetabula; width between outer margins of most lateral pair of acetabula 142μ (142μ-156μ); gonopore 46μ (45μ-48μ).

Dorsal lengths of the palpal segments: P-I, 32μ (32μ-34μ); P-II, 46μ (46μ-50μ); P-III, 30μ (30μ-31μ); P-IV, 67μ (67μ-69μ); P-V, 26μ (26μ-27μ); Figure 14 illustrates the proportions and chaetotaxy of the palp; no pronounced projection present on the ventral side of P-II; capitulum 90μ in length; dorsal lengths of the distal segments of the first leg: I-Leg-4, 55μ (55μ-58μ); I-Leg-5, 66μ (66μ-69μ); I-Leg-6, 69μ (68μ-69μ); Figure 19 shows I-Leg-5 and 6; swimming hairs present on all but the first pair of legs.

*Male:* Similar to female except in structure of the genital field region (Fig. 17) and only measurements are given; length of dorsal shield 445μ (425μ-445μ), width 319μ (312μ-319μ); length of ventral shield 434μ (418μ-434μ), width 364μ (358μ-364μ); width between outer edges of most lateral pair of acetabula 145μ (138μ-145μ); dorsal lengths of the palpal segments: P-I, 34μ (32μ-34μ); P-II, 49μ (49μ-50μ); P-III, 31μ; P-IV, 69μ (67μ-69μ); P-V, 24μ (24μ-26μ); capitulum 89μ in length; dorsal lengths of the distal segments of the first leg: I-Leg-4, 59μ; I-Leg-5, 72μ (72μ-75μ); I-Leg-6, 72μ (72μ-74μ).

*Holotype:* Adult female, collected in submerged mosses on rocks in the South Branch of the Umpqua River west of Milo, Douglas County, Oregon, August 11, 1961.

*Allotype:* Adult male, same data as holotype.

*Paratypes:* 1 female, collected in Moccasin Creek, Tuolumne County, California, October 26, 1970; 1 male, 1 female, from the Navarro River near Paul M. Dimmick State Recreation Area, Mendocino County, California, October 29, 1970.

*Discussion:* The new species is related to *A. pallida* but differs in being larger, having less well developed ridges on the dorsal shield and a smaller projection on the ventral side of P-II.

## AXONOPSIS (BRACHYPODOPSIS) LACUSTRIS, new species
(Figs. 11-13, 15, 16)

*Female:* Dorsal and ventral shields lightly fused at anterior end; lateral eyes well developed; length of dorsal shield 388μ, width 300μ; length of ventral shield 376μ, width 338μ; dorsal shield bearing three pairs of glandularia posterior to the postocularia; lateral ridges of dorsal shield slightly developed but median ridge absent; edges of posterior half of dorsal shield less rounded (more acutely angled) than in preceding species; Figure 11 shows the color pattern of the dorsum; two pairs of glandularia located very close together on their respective sides between the genital field and the insertions of the fourth legs; Figure 13 illustrates the ventral shield; suture line between the first and second coxae extending towards the midline and well developed (but not to the degree found in *pallida*); three pairs of genital acetabula; width between most lateral pair of acetabula 128μ; gonopore 46μ in width.

Dorsal lengths of the palpal segments: P-I, 31μ; P-II, 47μ; P-III, 33μ; P-IV, 62μ; P-V, 23μ; Figure 15 shows the proportions and chaetotaxy of the palp; no pronounced projection present on ventral side of P-II; capitulum 86μ in length; dorsal lengths of the distal segments of the first leg: I-Leg-4, 52μ; I-Leg-5, 66μ I-Leg-6, 64μ; Figure 12 shows I-Leg-5 and 6; swimming hairs present on all but the first pair of legs.

*Male:* Unknown.

*Holotype:* Adult female, collected in Lake Tsala Apopka within the city limits of Inverness, Citrus County, Florida, December 21, 1955.

*Discussion:* The present species seems closely related to *pallida* and *occidentalis*. It differs from *pallida* in its poorly developed ridges on the dorsal shield and lack of a large projection on P-II. The new species is much smaller than *occidentialis* and lacks a median ridge on the dorsal shield. There is also a difference in habitats. *A. lacustris* is a lake inhabitant, the other two are lotic species.

## AXONOPSIS (BRACHYPODOPSIS) DAPSILA, new species
(Figs. 4, 7-10)

*Female:* Dorsal and ventral shields fused lightly at anterior end; lateral eyes well developed; length of dorsal shield 380μ (364μ-395μ), width 288μ (274μ-297μ); length of ventral shield 369μ (355μ-380μ), width 316μ (304μ-319μ); dorsal shield bearing three pairs of glandularia posterior to the postocularia; lateral ridges of dorsal shield moderately developed, median ridge poorly developed; lateral ridges not extending near anterior end; Figure 10 shows the color pattern of the dorsum; color patches vary from light to almost colorless; two pairs of glandularia located very close together on their respective sides between the genital field and insertions of the fourth legs; Figure 8 shows the structure of the venter; suture line between first and second coxae extending towards the midline but not as well developed as in *pallida* (compare Figs. 3, arrow A and 8); three pairs of genital acetabula; width between outer edges of most lateral pair of acetabula 145μ (138μ-152μ); gonopore 38μ (34μ-38μ) in width.

Dorsal lengths of the palpal segments: P-I, 27μ (26μ-29μ); P-II, 38μ (38μ-44μ); P-III, 24μ (23μ-26μ); P-IV, 54μ (52μ-57μ); P-V, 20μ (18μ-22μ); palpal segments stocky; ventral side of P-II bulging, Figure 4 shows the proportions and chaetotaxy of the palp; capitulum 76μ (73μ-79μ) in length; dorsal lengths of the distal segments of the first leg: I–Leg-4, 44μ (43μ-47μ); I-Leg-5, 55μ (54μ-59μ); I-Leg 6, 55μ (55μ-59μ); Figure 9 shows I-Leg 5 and 6; swimming hairs present on all but the first pair of legs.

*Male:* Similar to female except in morphology of the genital field region (Fig. 7) and only measurements are given; length of dorsal shield 360μ (350μ-378μ), width 282μ (273μ-299μ); length of ventral shield 354μ (342μ-373μ), width 308μ (304μ-318μ); width between outer edges of most lateral pair of acetabula 132μ (131μ-142μ); dorsal lengths of the palpal segments: P-I, 28μ (25μ-31μ); P-II, 41μ (39μ-46μ); P-III, 24μ (22μ-26μ); P-IV, 54μ (52μ-59μ); P-V, 22μ (19μ-22μ); dorsal lengths of the distal segments of the first leg: I-Leg-4, 44μ (42μ-45μ); I-Leg-5, 55μ (52μ-58μ); I-Leg-6, 56μ (56μ-62μ).

*Holotype:* Adult female, taken in gravel deposits of a stream east of Griffen (two miles from the Warren County line), Hamilton County, New York, August 30, 1968.

*Allotype:* Adult male, same data as holotype.

*Paratypes:* 2 males, 1 female, same data as holotype; 5 males, 3 females, same area as holotype on August 19, 1964; 2 females, from bottom deposits in the Aroostook River near Ashland, Aroostook County, Maine, September 2, 1968; 1 male, 2 females, from gravel desposits in Wytopitlock Stream, Aroostook County, Maine, September 5, 1968; 1 female, taken in bottom gravels of the Saco River, Carroll County, New Hampshire, September 1, 1968; 1 female, taken in a gravel bar in Flatbrook two miles south of Bevans, Sussex County, New Jersey, August 16, 1964; 2 males, from bottom deposits in a small stream on Highway 678 six miles north of Millboro Springs, Bath County, Virginia, July 24, 1964; 3 males, 4 females, from sand bar in Little Back Creek on Highway 39 three miles from the West Virginia border, Bath County, Virginia, July 25, 1964; 1 male, 1 female, from a tributary of the Jackson River near Bacova, Bath County, Virginia, September 9, 1968; 1 female, from a gravel bar in Knapp's Creek near Minnehaha Springs, Pocahontas County, West Virginia, July 22, 1964.

*Discussion:* The present species is related to *pallida, occidentalis* and *lacustris* but differs most noticeably in its much stockier appendages. *A. dapsila* is definitely an interstitial water species which is in the process of losing integumental pigmentation. As is so often the case in ground water forms, there is a variation in degree of color loss. Even within the same population one finds variation from light color patches to an almost complete lack of pigmentation. The striations shown in Figures 4 and 9 are found in all members of the subgenus but are especially pronounced in the present species.

## AXONOPSIS (BRACHYPODOPSIS) RIVOPHILA Habeeb
(Figs. 21-24, 26)

*Axonopsis rivophila* Habeeb, 1957. Leaflets Acadian Biol., 15:6.

*Female:* Dorsal and ventral shields lightly fused at anterior end; lateral eyes well developed; length of dorsal shield 319μ-380μ, width 252μ-302μ; length of ventral shield 308μ-365μ, width 288μ-334μ; dorsal shield bearing four pairs of glandularia posterior to the postocularia; dorsal shield either without ridges or with a pair of short, ill-defined ridges posteriorly as shown in Figure 21; Color pattern of dorsum typically as shown in Figure 21 but in some specimens the narrow median bridge of pigment connecting the anterior and posterior patches is absent; posterior end of dorsal shield somewhat projecting; two pairs of glandularia located very close together on their respective sides between the genital field and the insertions of the first legs; Figure 23 illustrates the structure of the ventral shield; suture line between first and second coxae not extending close to midline; four pairs of genital acetabula, these arranged in an arc on their respective sides; second pair of acetabula located posterolateral to the first pair; width between most lateral pair of acetabula 124μ-218μ; gonopore 34μ-39μ.

Dorsal lengths of the palpal segments: P-I, 24μ-29μ; P-II, 39μ-45μ; P-III, 27μ-29μ; P-IV, 60μ-63μ; P-V, 23μ-24μ; ventral side of P-II without a projection; structure of palp similar to that illustrated for the male (Fig. 24); capitulum 83μ-87μ in length; dorsal lengths of the distal segments of the first leg: I-Leg-4, 42μ-46μ; I-Leg-5, 55μ-60μ; I-Leg-6, 62μ-65μ; structure of I-Leg-5 and 6 similar to that illustrated for the male (Fig. 22); swimming hairs present on all but the first pair of legs.

*Male:* Similar to female except in structure of genital field region (Fig. 26) and only measurements are given; dorsal shield 316μ-372μ in length, 251μ-304μ in width; length of ventral shield 304μ-364μ, width 289μ-330μ; width between outer edges of most lateral pair of acetabula 114μ-134μ; dorsal lengths of the palpal segments: P-I, 24μ-30μ; P-II, 37μ-43μ; P-III, 23μ-27μ; P-IV, 56μ-64μ; P-V, 23μ-25μ; capitulum 76μ-83μ; dorsal lengths of the distal segments of the first leg: I-Leg-4, 42μ-51μ; I-Leg-5, 58μ-66μ; I-Leg-6, 62μ-69μ.

*Habitat and Distribution:* The type was collected by Habeeb in the Cullasaja River near Highlands, Macon County, North Carolina in early May, 1957. This is a stream inhabiting species which occasionally wanders into the more superficial layers of the intersitial water habitat. I have recollected *rivophila* from the type locality and it was also present in the following collections: 1 female, from a stream in Cedar Falls State Park, Hocking County, Ohio, June 18, 1967; 1 male, from gravel deposits in Russell Creek near Russell Springs, Adair County, Kentucky, June 14, 1964; 1 male, from the North Fork of the Thornton River near Sperryville, Rappahannock County, Virginia, September 8, 1968; 1 male, collected in gravel deposits of Thompson Creek near McClung, Bath County, Virginia, September 9, 1968; 1 female, from a tributary of the Jackson River near Bacova, Bath County, Virginia, September 9, 1968; 1 male, collected in a stream in Caledonia State Park, Adams County, Pennsylvania, August 20, 1959; 1 male, 1 female, from a stream in Pine Grove Furnace State Park, Cumberland County, Pennsylvania, August 20, 1959; 1 male, 1 female, from a stream in Cowen's Gap State Park, Fulton County, Pennsylvania, May 21, 1961; 1 males, 5 females, from rocks in a small stream near junctions of highways 73 and S278, Jackson County, Florida, November 9, 1970.

## AXONOPSIS (BRACHYPODOPSIS) AMNICOLA, new species
(Figs. 25, 27-31)

*Female:* Dorsal and ventral shields lightly fused at anterior end; lateral eyes well developed; length of dorsal shield 410μ (388μ-432μ), width 297μ (289μ-323μ); length of ventral shield 399μ (380μ-418μ), width 334μ (327μ-368μ); dorsal shield bearing four pairs of glandularia posterior to the postocularia; dorsal shield without ridges; color pattern as indicated in Figure 31 with anterior and posterior patches joined by a broad middle bridge of pigment; posterior end of dorsal shield slightly projecting; two pairs of glandularia located very close together on their respective sides between the genital field and insertions of the fourth legs; Figure 29 shows the structure of the ventral shield; suture line between first and second coxae not extending to the midline; four pairs of genital acetabula, these arranged in an arc on their respective sides; second pair of acetabula tending to be located more or less lateral to the first pair in the female; width between outer edges of most lateral pair of acetabula 130μ (130μ-135μ); gonopore 45μ (42μ-46μ) in width.

Dorsal lengths of the palpal segments: P-I, 30μ (28μ-31μ); P-II, 44μ (41μ-45μ); P-III, 29μ (28μ-30μ); P-IV, 63μ (62μ-67μ); P-V, 24μ (24μ-26μ); ventral side of P-II without a projection; structure of palp similar to that illlustrated for the male (Fig. 25); capitulum 85μ (83μ-90μ) in length; dorsal lengths of the distal segments of the first leg: I-Leg-4, 49μ (48μ-52μ); I-Leg-5, 62μ (61μ-66μ); I-Leg-6, 69μ (66μ-69μ); structure of I-Leg-5 and 6 similar to that of male (Fig. 30); swimming hairs present on all but the first pair of legs.

*Male:* Similar to female except in structure of the genital field region (Figs. 27, 28) and only measurements are given; length of dorsal shield 410μ (395μ-425μ), width 304μ (289μ-304μ); length of ventral shield 399μ (399μ-414μ), width 79μ (76μ-80μ); width between outer edges of most lateral pair of acetabula 131μ (131μ-138μ); dorsal lengths of the palpal segments: P-I, 28μ (28μ-30μ); P-II, 43μ (43μ-45μ); P-III, 29μ (29μ-30μ); P-IV, 66μ (64μ-67μ); P-V, 26μ (24μ-26μ); capitulum 83μ (80μ-87μ) in length; dorsal lengths of the distal segments of the first leg: I-Leg-4, 55μ (53μ-55μ); I-Leg-5, 66μ (66μ-69μ); I-Leg-6, 72μ (71μ-73μ).

*Holotype:* Adult female, collected in the South Branch of the Umpqua River near Milo, Douglas County, Oregon, August 11, 1961.

*Allotype:* Adult male, same data as holotype.

*Paratypes:* 17 males, 22 females, same data as holotype; 1 female, taken in the Navarro River near Paul M. Dimmick State Recreation Area, Mendocino County, California, October 27, 1970; 1 female, collected in Clear Creek, Shasta County, California, July 30, 1966.

*Discussion:* The present species, along with *A. rivophila,* is unusual among North American species of the subgenus in that it bears four pairs of glandularia on the dorsal shield posterior to the postocularia (rather than three pairs). The new species is larger than *rivophila,* has a less projecting posterior end of the dorsal shield, more angular posterior end of the ventral shield and difference in color pattern (compare Figs. 21 and 31). *A. rivophila* is confined to streams in eastern North America and *A. amnicola* is presently known only from streams in California and Oregon.

**AXONOPSIS (BRACHYPODOPSIS) SETONENSIS** Habeeb
(Figs. 35, 37-40)

*Axonopsis setonensis* Habeeb, 1953. Leaflets Acadian Biol., 1:9.

*Female:* Dorsal and ventral shields lightly fused at anterior end; lateral eyes well developed; length of dorsal shield 456μ-471μ, width 349μ-365μ; length of ventral shield 445μ-458μ, width 395μ-410μ; dorsal shield bearing three pairs of glandularia posterior to the postocularia; dorsal shield with a pair of lateral ridges; Figure 38 shows the color pattern typically present on the dorsal shield; two pairs of glandularia located very close together on legs; second coxae decidedly angled (Fig. 40, arrow A) and in some specimens this projection is more pronounced than in the specimen illustrated; four pairs of genital acetabula, these arranged in an arc on their respective sides; width between outer edges of most lateral pair of acetabula 183μ-193μ; gonopore 43μ-48μ in width.

Dorsal lengths of the palpal segments: P-I, 33μ-35μ; P-II, 50μ-53μ; P-III, 30μ-33μ; P-IV, 66μ-69μ; P-V, 25μ-27μ; distoventral portion of P-II with a well developed projection (Fig. 35); capitulum 97μ-100μ in length; dorsal lengths of the distal segments of the first leg: I-Leg-4, 58μ-60μ; I-Leg-5, 73μ-78μ; I-Leg-6, 66μ-69μ; Figure 39 illustrates I-Leg-5 and 6; swimming hairs present on all but the first pair of legs.

*Male:* Similar to female except in structure of the genital field region (Fig. 37) and only measurements are given; length of dorsal shield 456μ, width 350μ; length of ventral shield 438μ, width 395μ; width between outer edges of most lateral pair of acetabula 166μ; numerous short setae on the genital field; dorsal lengths of the palpal segments: P-I, 35μ; P-II, 52μ; P-III, 31μ; P-IV, 71μ; P-V, 26μ; capitulum 100μ in length; dorsal lengths of the distal segments of the first leg: I-Leg-4, 62μ; I-Leg-5, 83μ; I-Leg-6, 80μ.

*Habitat and Distribution:* This species is an inhabitant of lakes and ponds. The type was collected by Habeeb in a pond near Millburn, Essex County, New Jersey. I have taken it in the following localities in Michigan: 1 female, collected in Head Lake, Barry County, Michigan, July 12, 1967; 2 females, same area on August 19, 1967; 1 female, from Wall Lake, Barry County, Michigan, June 6, 1951; 1 male, collected in the Hook Point area of Douglas Lake, Cheboygan County, Michigan, July 1, 1952.

*Discussion:* It is suspected that this species may be more abundant that these few collection records would indicate. Collections in lakes are normally made with a net in which the mesh size is large enough to permit most of the specimens to pass through. I have not seen the type and have no specimens from the type locality or other area in eastern North America. However, the specimens from Michigan agree well with the measurements of the type and any characters illustrated or described by Habeeb. When one also considers the habitat similarity, it is probable they are conspecific. The combination of habitat type, projection on P-II, four pairs of acetabula and widely separated color patches on the dorsal shield are diagnostic.

**AXONOPSIS (BRACHYPODOPSIS) OZARKENSIS,** new species
(Figs. 50-52, 55)

*Female:* Dorsal and ventral shields lightly fused at anterior end; lateral eyes well developed; length of dorsal shield 440μ (418μ-440μ); width 314μ (314μ-319μ); length of ventral shield 424μ (400μ-424μ), width 364μ (364μ-373μ); dorsal shield with three pairs of glandularia posterior to the postocularia; dorsal shield with a pair of lateral ridges; Figure 52 shows the color pattern of the dorsal shield; anterior and posterior dark patches connected by a wide median bridge of lighter pigment; two pairs of glandularia located very close together on their respective sides between the genital field and insertions of the fourth legs; second coxae more or less rounded in the holotype (Fig. 50, arrow A), but more angular (similar to that in Figure 40, arrow A) in one of the paratypes; four pairs of genital acetabula, these arranged in an arc on their respective sides; width between outer edges of most lateral pair of acetabula 162μ (162μ-173μ); gonopore 43μ (43μ-49μ) in width.

Dorsal lengths of the palpal segments: P-I, 35μ (31μ-35μ); P-II, 52μ (50μ-52μ); P-III, 31μ (28μ-31μ); P-IV, 66μ (66μ-67μ); P-V, 25μ (24μ-25μ); distoventral portion of P-II with a well developed projection (Fig. 55); capitulum 97μ (92μ-97μ) in length; dorsal lengths of the distal segments of the first leg: I-Leg-4, 55μ (54μ-55μ); I-Leg-5, 72μ (72μ-74μ); I-Leg-6, 67μ (65μ-67μ); Figure 51 shows I-Leg-5 and 6; long swimming hairs present on all but the first pair of legs.

*Male:* Unknown.

*Holotype:* Adult female, collected in matted plant roots in a small stream seven miles north of Cave City, Sharp County, Arkansas, June 27, 1961.

*Paratypes:* 2 females, same data as holotype.

*Discussion:* The present species seems most closely related to *A. setonensis.* It differs in being smaller, having a different dorsal color pattern (compare Figures 38, 52) and in the tendency for the second coxae to be more rounded (compare Figures 40, 50, arrow A). However, in one paratype of the present species the second coxae are also projecting. There is also a habitat difference. *A. setonensis* is a lentic species, *ozarkensis* is a stream inhabitant.

## AXONOPSIS (BRACHYPODOPSIS) OHIOENSIS Cook
(Figs. 44, 46-49)

*Axonopsis ohioensis* Cook, 1967. Ohio Jour. Sci., 67:220.

*Female:* Dorsal and ventral shields lightly fused at anterior end; lateral eyes well developed; length of dorsal shield 410μ, width 319μ; length of ventral shield 406μ, width 365μ; dorsal shield bearing three pairs of glandularia posterior to the postocularia; dorsal shield without prominent ridges; Figure 47 illustrates the color pattern of the dorsum; two pairs of glandularia located very close together on their respective sides between genital field and insertions of the fourth legs; four pairs of genital acetabula; the first three pairs of acetabula forming a straight line or concave arc on their respective sides (Fig. 49); width between outer edges of most lateral pair of acetabula 155μ, gonopore 45μ in width.

Dorsal lengths of the Palpal segments: P-I, 34μ; P-II, 52μ; P-III, 31μ; P-IV, 70μ; P-V, 25μ; ventral side of P-II without a projection (Fig. 44); capitulum 97μ in length; dorsal lengths of the distal segments of the first leg: I-Leg-4, 60μ; I-Leg-5, 76μ; I-Leg-6, 69μ; Figure 48 shows I-Leg-5 and 6; swimming hairs present on all but the first pair of legs.

*Male:* Similar to female except in structure of the genital field region (Fig. 46) and only measurements are given; length of dorsal shield 403μ-425μ, width 304μ-334μ; length of ventral shield 395μ-426μ, width 350μ-388μ; width between outer edges of most lateral pair of acetabula 149μ-169μ; first three pairs of acetabula forming a straight line or a concave arc on their respective sides (Fig. 46); dorsal lengths of the palpal segments: P-I, 34μ-37μ; P-II, 53μ-55μ; P-III, 31μ; P-IV, 69μ-72μ; P-V, 26μ-28μ; dorsal lengths of the distal segments of the first leg: I-Leg-4, 62μ; I-Leg-5, 79μ; I-Leg-6, 76μ.

*Habitat and Distribution:* Apparently this is a small lake or pond inhabiting species. The holotype was collected by Dr. Andrew Weaver in Shreve Lake, Wayne County, Ohio on November 30, 1962. I have taken a female specimen in Winter's Pond in Pine Hills Scenic Drive, Union County, Illinois, June 20, 1967 and a male specimen from the same locality on March 31, 1970.

*Discussion:* In the original description it was stated that there was no dorsal color pattern. It now appears the color pattern had been destroyed during the initial slide making. Also, as the type locality was a small lake recently formed by the damming of a stream, there was uncertainty as to whether *ohioensis* was a lentic or lotic species. It now seems certain that standing waters are its typical habitat.

## AXONOPSIS (BRACHYPODOPSIS) BELTISTA, new species
(Figs. 32-34, 36, 54)

*Male:* Dorsal and ventral shields lightly fused at anterior end; lateral eyes well developed; length of dorsal shield 384μ, width 315μ; length of ventral shield 388μ, width

364μ; dorsal shield bearing three pairs of glandularia posterior to the postocularia; dorsal shield with a pair of well developed lateral ridges and a well developed median ridge near posterior end; Figure 34 illustrates the color pattern and ridges of the dorsum; two pairs of glandularia located very close together on their respective sides between the genital field and insertions of the fourth legs; four pairs of genital acetabula; first three pairs of acetabula forming a concave arc on their respective sides (Fig. 54); genital acetabula relatively small; width between outer edges of most lateral pair of acetabula 130μ.

Dorsal lengths of the palpal segments: P-I, 33μ; P-II, 53μ; P-III, 32μ; P-IV, 70μ; P-V, 26μ; distoventral portion of P-II somewhat bulging but without a distinct projection (Fig. 36); dorsal lengths of the distal segments of the first leg: I-Leg-4, 59μ; I-Leg-5, 80μ; I-Leg-6, 73μ; Figure 33 illustrates I-Leg-5 and 6; swimming hairs present on all but the first pair of legs.

*Female:* Unknown.

*Holotype:* Adult male, collected from rocks in the Hillsborough River at Hillsborough River State Park, Hillsborough County, Florida, November 12, 1970.

*Discussion:* The combination of four pairs of acetabula in which the first three pairs are arranged in a concave arc (Fig. 54) and the unusual arrangement of the ridges of the dorsal shield (Fig. 34) are diagnostic.

## AXONOPSIS (BRACHYPODOPSIS) ARPEDA, New species
(Figs. 53, 56-58)

*Female:* Dorsal and ventral shields lightly fused at anterior end; lateral eyes well developed; length of dorsal shield 373μ (373μ-392μ), width 274μ (274μ-282μ); length of ventral shield 346μ (346μ-358μ), width 319μ (319μ-342μ); dorsal shield bearing three pairs of glandularia posterior to the postocularia; dorsal shield without ridges; dorsal shield projecting well beyond the ventral shield posteriorly producing the wide area illustrated in Figure 56, arrow A; two pairs of glandularia located very close together on their respective sides between genital field and insertions of the fourth legs; four pairs of genital acetabula, these arranged in an arc on their respective sides; width between outer edges of most lateral pair of acetabula 143μ (143μ-145μ); gonopore 36μ (35μ-36μ) in width.

Dorsal lengths of the palpal segments: P-I, 29μ (28μ-29μ); P-II, 43μ (41μ-43μ); P-III, 26μ (26μ-28μ); P-IV, 63μ (63μ-66μ); P-V, 26μ (26μ-28μ); ventral side of P-II without a ventral projection (Fig. 53); capitulum 87μ (87μ-89μ) in length; dorsal lengths of the distal segments of the first leg: I-Leg-4, 48μ (48μ-50μ); I-Leg-5, 58μ (58μ-61μ); I-Leg-6, 64μ (62μ-64μ); Figure 57 illustrates I-Leg-5 and 6; swimming hairs present on all but the first pair of legs.

*Male:* Unknown.

*Holotype:* Adult female, collected in a gravel bar in the Meramec River at Cook Station, Crawford County, Missouri, July 23, 1960.

*Paratypes:* 1 female, same data as holotype; 1 newly metamorphosed female, taken from mosses on rocks in a small stream on Highway 143 near State Camp "Sam A. Baker", Wayne County, Missouri, July 8, 1960.

*Discussion:* The combination of no dorsal ridges plus the wide marginal area at posterior end of the dorsal shield (Fig. 56, arrow A) are diagnostic.

## AXONOPSIS (BRACHYPODOPSIS) GENNADA, new species
(Figs. 68-71)

*Female:* Dorsal and ventral shields lightly fused at anterior end; lateral eyes well developed; length of dorsal shield 350μ (342μ-350μ), width 273μ (266μ-273μ); length of ventral shield 334μ (327μ-334μ), width 304μ (293μ-304μ); dorsal shield bearing three pairs of glandularia posterior to the postocularia; lateral ridges of the dorsal shield well developed, these coalescing posteriorly as shown in Figure 70; a solid central area of pigment present on the dorsal shield; dorsal shield somewhat projecting at posterior end; two pairs of glandularia located very close together on their respective sides between the genital field and insertions of the fourth legs; four pairs of genital acetabula, these arranged in an arc on their respective sides; width between outer edges of most lateral pair of acetabula 109μ (109μ-113μ); gonopore 39μ (39μ-40μ) in width.

Dorsal lengths of the palpal segments: P-I, 26μ (26μ-28μ); P-II, 42μ (41μ-42μ); P-III, 27μ (26μ-27μ); P-IV, 57μ (57μ-59μ); P-V, 23μ (22μ-23μ); ventral side of P-II without a projection (Fig. 71); capitulum 80μ (76μ-82μ) in length; dorsal lengths of the distal segments of the first leg: I-Leg-4, 47μ (47μ-49μ); I-Leg-5, 59μ (59μ-61μ); I-Leg-6, 62μ (62μ-63μ); Figure 69 shows the proportions and chaetotaxy of I-Leg-5 and 6; swimming hairs present on all but the first pair of legs.

*Male:* Unknown.

*Holotype:* Adult female, collected in matted plant roots in a small stream (tributary of the Waccasassa River) one mile south of Gulf Hammock, Levy County, Florida, November 11, 1970.

*Paratypes:* 2 females, same data as holotype.

*Discussion:* The unusual arrangement of the ridges of the dorsal shield, with the lateral ridges coalescing posteriorly and continuing as a short median ridge (Fig. 70) is diagnostic.

## **AXONOPSIS (BRACHYPODOPSIS) EREMITA,** new species
(Figs. 41-43, 45)

*Female:* Dorsal and ventral shields lightly fused at anterior end; lateral eyes well developed; length of dorsal shield 425μ (425μ-441μ), width 327μ (327μ-334μ); length of ventral shield 418μ (418μ-426μ), width 380μ (380μ-382μ); dorsal shield bearing three pairs of glandularia posterior to the postocularia; posterior pair of dorsal glandularia shifted relatively far posteriorly (considerably posterior to the muscle scars–Figure 43, arrow A); a pair of prominent ridges present on the dorsal shield; two pairs of glandularia located relatively close together on their respective sides between the genital field and insertions of the fourth legs; four pairs of genital acetabula, these arranged in an arc on their respective sides; width between outer edges of most lateral pair of acetabula 145μ (145μ-159μ); gonopore 42μ (42μ-43μ) in width.

Dorsal lengths of the palpal segments: P-I, 35μ; P-II, 55μ (52μ-55μ); P-III, 33μ (33μ-34μ); P-IV, 75μ (75μ-76μ); P-V, 27μ; ventral side of P-II without a projection (Fig. 45); capitulum 103μ (97μ-103μ) in length; dorsal lengths of the distal segments of the first leg: I-Leg-4, 58μ (58μ-59μ); I-Leg-5, 73μ (73μ-76μ); I-Leg-6, 69μ (69μ-73μ); Figure 42 shows I-Leg-5 and 6; swimming hairs present on all but the first pair of legs.

*Male:* Unknown.

*Holotype:* Adult female, collected in the Withlacoochee River on Route 84 (near the Brooks County border), Lowndes County, Georgia, September 13, 1968.

*Paratype:* 1 female, taken in the Yellow River, Okaloosa County, Florida, November 8, 1970.

*Discussion:* This species was taken by panning rocks in the deeply stained, sandy bottomed streams of northern Florida and southern Georgia. It is characterized by the following combination of characters: Lateral ridges on dorsum and posterior shifting of the posterior pair of glandularia of the dorsal shield, four pairs of acetabula and lack of a projection on the ventral side of P-II.

## **AXONOPSIS (BRACHYPODOPSIS) CULLASAJA** Habeeb
(Figs. 60, 63, 65, 67)

*Axonopsis cullasaja* Habeeb, 1957. Leaflets Acadian Biol., 15:6.

*Female:* Dorsal and ventral shields lightly fused at anterior end; lateral eyes well developed; length of dorsal shield 369μ-380μ, width 304μ-307μ; length of ventral shield

361μ-380μ, width 342μ-349μ; dorsal shield bearing three pairs of glandularia posterior to the postocularia, the most posterior pair located more or less in a line with the posterior muscle scars (Fig. 65, arrow A); a pair of prominent lateral ridges present on dorsal shield; posterior color patch of dorsal shield extending farthest anteriorly in region of midline (Fig. 65); two pairs of glandularia located very close together on their respective sides between the genital field and insertions of the fourth legs; four pairs of genital acetabula, these arranged in an arc on their respective sides (Fig. 67); width between outer edges of most lateral pair of acetabula 138μ-145μ; gonopore 43μ-45μ in width.

Dorsal lengths of the palpal segments: P-I, 27μ-28μ; P-II, 43μ-45μ; P-III, 29μ-31μ; P-IV, 62μ; P-V, 22μ-24μ; ventral side of P-II without a ventral projection (Fig. 63); capitulum 82μ-83μ in length; dorsal lengths of the distal segments of the first leg; I-Leg-4, 48μ-51μ; I-Leg-5, 64μ-66μ; I-Leg-6, 72μ-73μ; structure of these segments shown in Figure 60; swimming hairs present on all but the first pair of legs.

*Male:* Similar to female except in structure of the genital field region and only measurements are given; length of dorsal shield 365μ, width 296μ; length of ventral shield 358μ, width 327μ; width between outer edges of most lateral pair of acetabula 138μ; dorsal lengths of the palpal segments: P-I, 26μ; P-II, 42μ; P-III, 27μ; P-IV, 62μ; P-V, 23μ; dorsal lengths of the distal segments of the first leg: I-Leg-4, 48μ; I-Leg-5, 64μ; I-Leg-6, 72μ; genital field similar to that of the following species (Fig. 64).

*Habitat and Distribution:* This is a stream inhabiting species which was originally described from material collected in the Cullasaja River and one of its tributaries (Mill Creek) near Highlands, Macon County, North Carolina in early May 1957. I have taken a male and a female from the type locality (Cullasaja River), May 14, 1961 and a female individual from the North Fork of the Thornton River near Sperryville, Rappahannock County, Virginia, September 8, 1968.

*Discussion:* Habeeb (1968) described *A. cullasaja boreosaja* from specimens collected in New York (West Branch of Onondaga River, Onondaga County and Dutch Hollow Brook, Cayuga County) stating it differed from the typical form in having the epimera (coxae) longer and narrower and that certain leg segments had an extra swimming hair. This latter character is somewhat variable, with even opposite sides of the same individual having a different number of swimming hairs, and so is a poor taxonomic character. The status of this taxon will remain uncertain until additional material has been taken.

## AXONOPSIS (BRACHYPODOPSIS) FLORIDENSIS, new species
(Figs. 61, 64, 66)

*Female:* Dorsal and ventral shields lightly fused at anterior end; lateral eyes well developed; length of dorsal shield 349μ (342μ-373μ), width 289μ (278μ-297μ); length of ventral shield 246μ (342μ-348μ), width 323μ (304μ-334μ); dorsal shield bearing three pairs of glandularia posterior to the postocularia, the posterior pair of which are located very close to the posterior muscle scars; a pair of prominent lateral ridges present on the dorsal shield; posterior color patch of dorsal shield extending farthest anteriorly in region of lateral edges (Fig. 61); two pairs of glandularia located very close together on their respective sides between genital field and insertions of fourth legs; four pairs of genital acetabula, these arranged in an arc on their respective sides; width between outer edges of most lateral pair of acetabula 128μ (113μ-128μ), gonopore 41μ (39μ-43μ) in width; ventral shield similar to that illustrated for *A. cullasaja* (Fig. 67).

Dorsal lengths of the palpal segments: P-I, 27μ (27μ-28μ); P-II, 43μ (41μ-43μ); P-III, 29μ (28μ-29μ); P-IV, 62μ (60μ-65μ); P-V, 24μ (23μ-24μ); palp similar to that described and illustrated for *A. cullasaja;* capitulum 83μ (80μ-86μ) in length; dorsal lengths of the distal segments of the first leg: I-Leg-4, 48μ (48μ-51μ); I-Leg-5, 60μ (60μ-65μ); I-Leg-6, 64μ (64μ-67μ); Figure 66 illustrates the proportions and chaetotaxy of these segments; swimming hairs present on all but the first pair of legs.

*Male:* Similar to female except in morphology of the genital field region (Fig. 64) and only measurements are given; length of dorsal shield 334μ (330μ-349μ), width 277μ (270μ-281μ); length of ventral shield 327μ (321μ-327μ), width 304μ (304μ-318μ); width between outer edges of most lateral pair of acetabula 121μ (117μ-125μ); dorsal lengths of the palpal segments: P-I, 27μ (27μ-28μ); P-II, 39μ (39μ-42μ); P-III, 28μ (26μ-28μ); P-IV, 57μ (57μ-62μ); P-V, 23μ (21μ-24μ); dorsal lengths of the distal segments of the first leg: I-Leg-4, 48μ (48μ-50μ); I-Leg-5, 63μ (62μ-66μ); I-Leg-6, 62μ (62μ-69μ).

*Holotype:* Adult female, collected in a small stream (tributary of the Waccasassa River) one mile south of Gulf Hammock, Levy County, Florida, November 11, 1970.

*Allotype:* Adult male, same data as holotype.

*Paratypes:* 20 males, 34 females, same data as holotype; 3 males, 17 females, from rocks in a stream near junction of highways 73 and S278 (approximately 10 miles from Calhoun County line), Jackson Country Florida, November 9, 1970.

*Discussion: A. floridensis* is closely related to *A. cullasaja* but differs most noticeably in the color pattern of the dorsal shield (compare Figures 61 and 65).

## Subgenus **PARAXONOPSIS** Motas and Tanasachi

### **AXONOPSIS (PARAXONOPSIS) PUMILA,** new species

(Figs. 72-77)

*Female:* Dorsal and ventral shields broadly fused at anterior end; lateral eye pigment greatly reduced; length of dorsal shield 358μ (293μ-364μ), width 258μ (228μ-258μ); length of the ventral shield 358μ (304μ-364μ), width 273μ (247μ-276μ); dorsal shield bearing two pairs of small glandularia posterior to the postocularia, these flanked by a pair of lateral ridges (Fig. 75); integumental pigmentation absent; one pair of small glandularia present between genital field and insertions of fourth legs; three pairs of genital acetabula; width between outer edges of most lateral pair of acetabula 121μ (104μ-121μ); gonopore 33μ (28μ-34μ) in width; Figure 78 illustrates the morphology of the ventral shield.

Dorsal lengths of the palpal segments: P-I, 24μ (21μ-24μ); P-II, 40μ (35μ-40μ); P-III, 24μ (21μ-24μ); P-IV, 48μ (44μ-48μ); P-V, 21μ (20μ-21μ); structure of palp similar to that shown for the male (Fig. 76); capitulum 76μ (73μ-76μ) in length; dorsal lengths of the distal segments of the first leg: I-Leg-4, 38μ (35μ-38μ); I-Leg-5, 42μ (40μ-44μ); I-Leg-6, 56μ (52μ-56μ); swimming hairs absent.

*Male:* Similar to female except in morphology of the genital field region and for the most part only measurements are given; male genital field located on a short cauda; Figure 72 shows a ventral view of the cauda, Figure 74 gives a posteroventral view of cauda; length of dorsal shield 304μ (289μ-338μ), width 228μ (228μ-255μ); length of ventral shield 308μ (304μ-356μ), width 247μ (243μ-273μ); width between outer edges of most lateral pair of acetabula 104μ (104μ-121μ); dorsal lengths of the palpal segments: P-I, 19μ (19μ-23μ); P-II, 34μ (34μ-38μ); P-III, 23μ (22μ-24μ); P-IV, 48μ (46μ-49μ); P-V, 20μ (20μ-22μ); Figure 76 illustrates the proportions and chaetotaxy of the palp; dorsal lengths of the distal segments of the first leg: I-Leg-4, 35μ (35μ-37μ); I-Leg-5, 44μ (42μ-45μ); I-Leg-6, 52μ (52μ-54μ); Figure 73 shows I-Leg-5 and 6.

*Holotype:* Adult female, taken in interstitial waters of a gravel bar in Salmon Creek, Monterey County, California, July 23, 1966.

*Allotype:* Adult male, same data as holotype.

*Paratypes:* 6 males, 6 females, same data as holotype; 1 male, 1 female, from a gravel bar in the South Fork of the Trinity River near Forest Glen State Park, Trinity County, California, July 30, 1966; 4 males, 6 females, from a gravel bar in the Van Duzen River on Highway 36 approximately 16 miles east of Bridgeville, Humboldt County, California, July 30, 1966.

*Discussion:* This is the only member of its subgenus presently known from the New World. It does not seem closely related to any of the previously described species.

Subgenus **VICINAXONOPSIS** Cook

**AXONOPSIS (VICINAXONOPSIS) CALIFORNICA** Cook
(Figs. 59, 62, 82, 86)

*Axonopsis (Vicinaxonopsis) californica* Cook, 1974. Mem. Amer. Entomol. Inst., 21:459.

Not redescribed here. The extremely long capitular apodemes (anchoral process) and long pointed P-V (Figs. 62, 82) will easily distinguish it from all other species of *Axonopsis* known from the New World. A closely related species has been taken in Japan. This is an interstitial water species which is presently known from streams in Monterey and Humboldt Counties, California.

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————. 1961. Walter Vincent Powers, Noble Fellow, 1895-1954. Leaflets Acadian Biol., 22:1 6.

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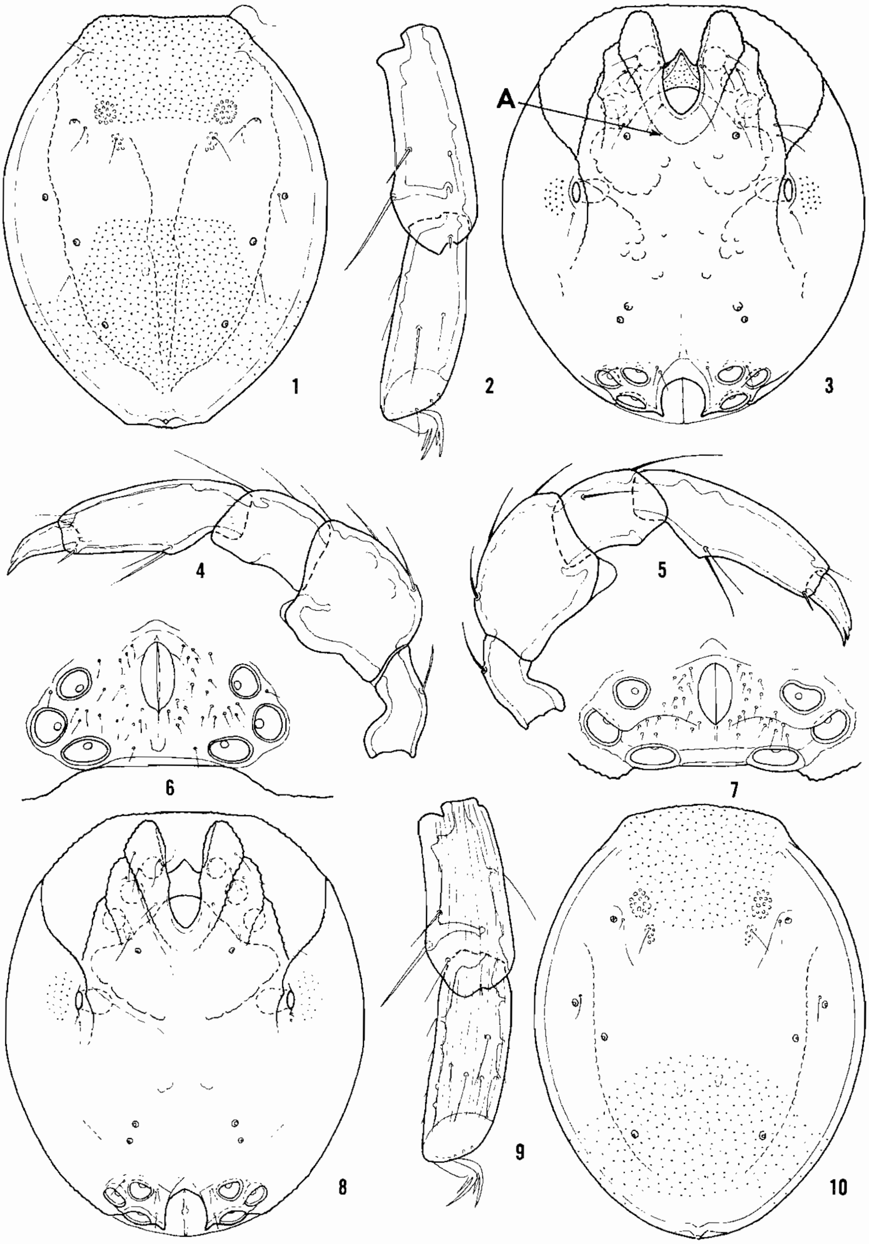
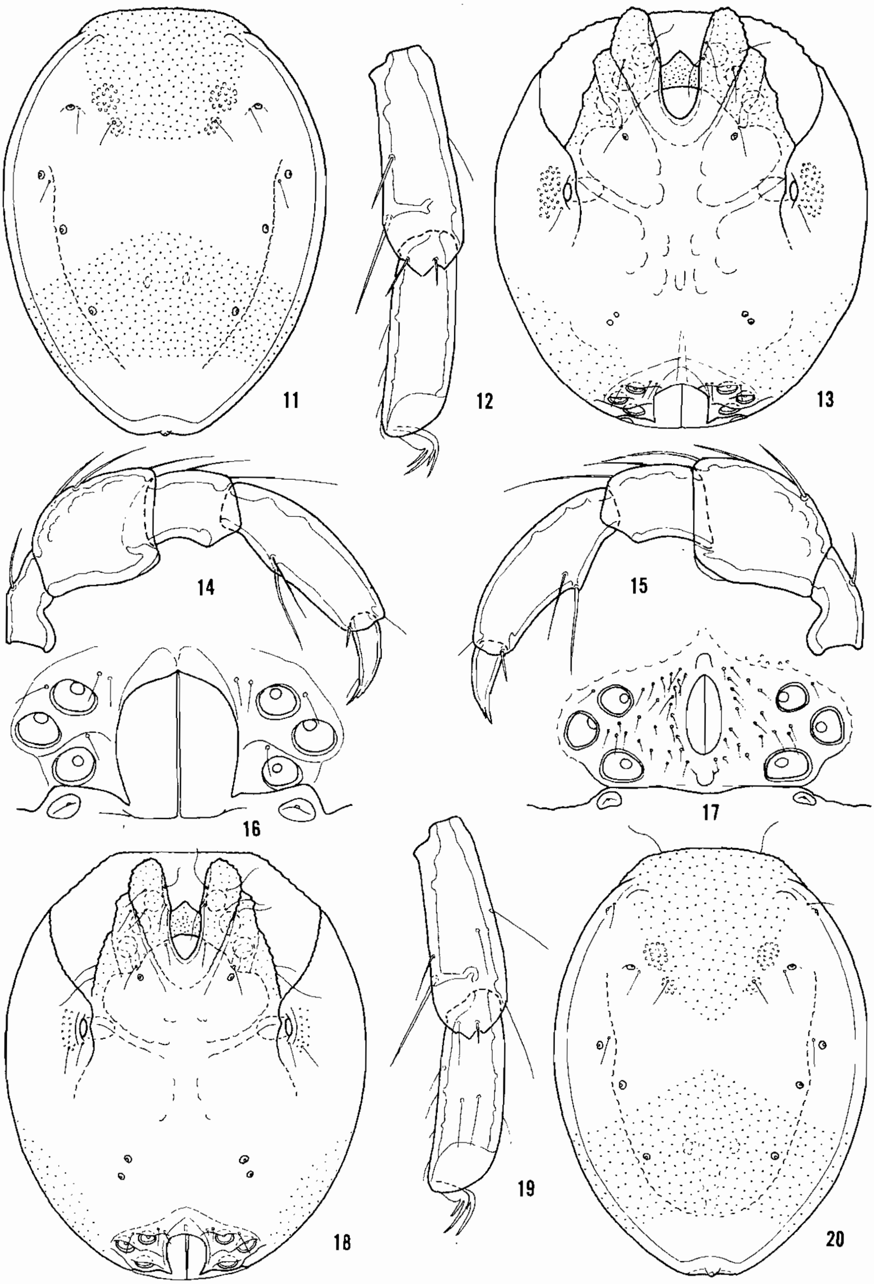


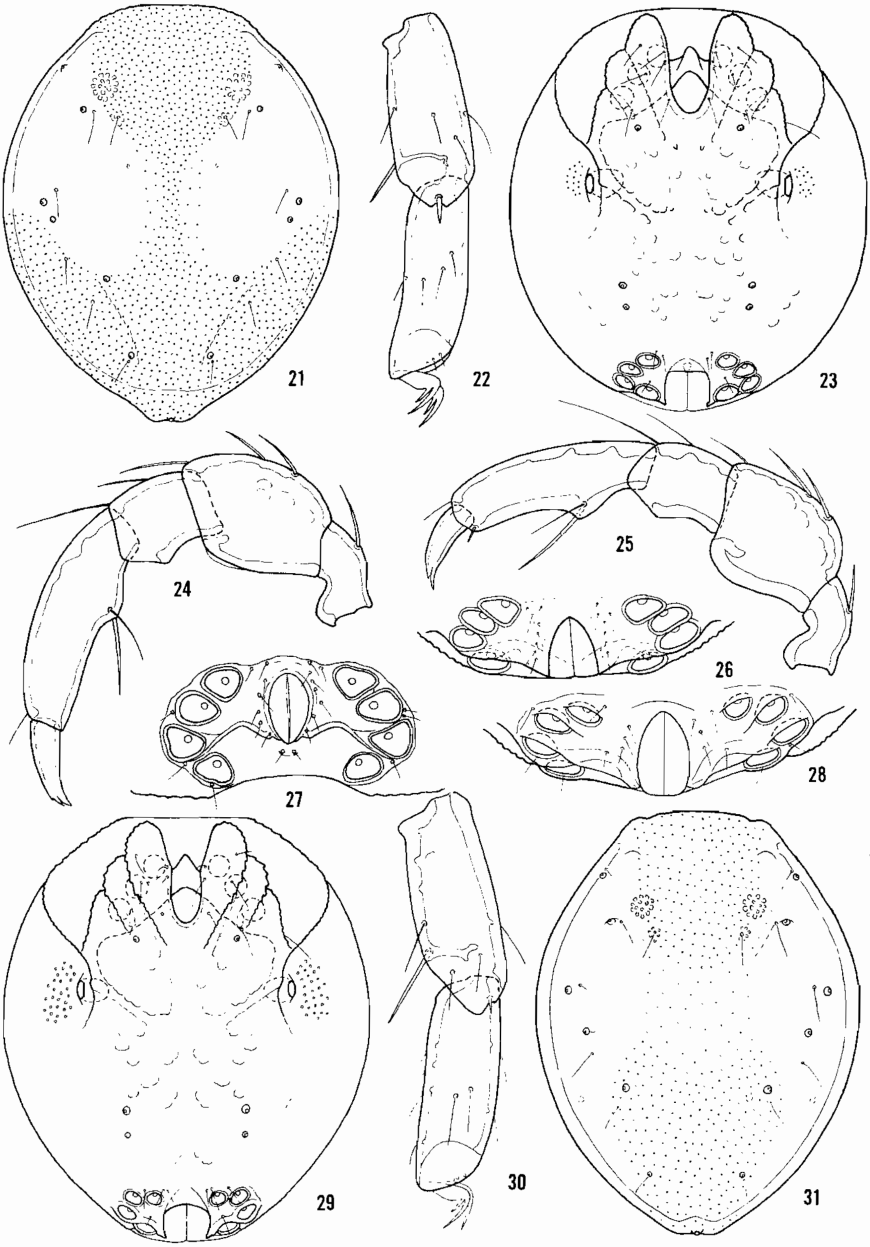

*Axonopsis pallida* Habeeb. Fig. 1, dorsal shield, female; Fig. 2, I-Leg-5 and 6, female; Fig. 3, ventral shield, female; Fig. 5, palp, female; Fig. 6, posteroventral view of genital field, male.

*Axonopsis dapsila* n. sp. Fig. 4, palp, female; Fig. 7, posteroventral view of genital field, male; Fig. 8, ventral view, female; Fig. 9, I-Leg-5 and 6, female; Fig. 10, dorsal shield, female.



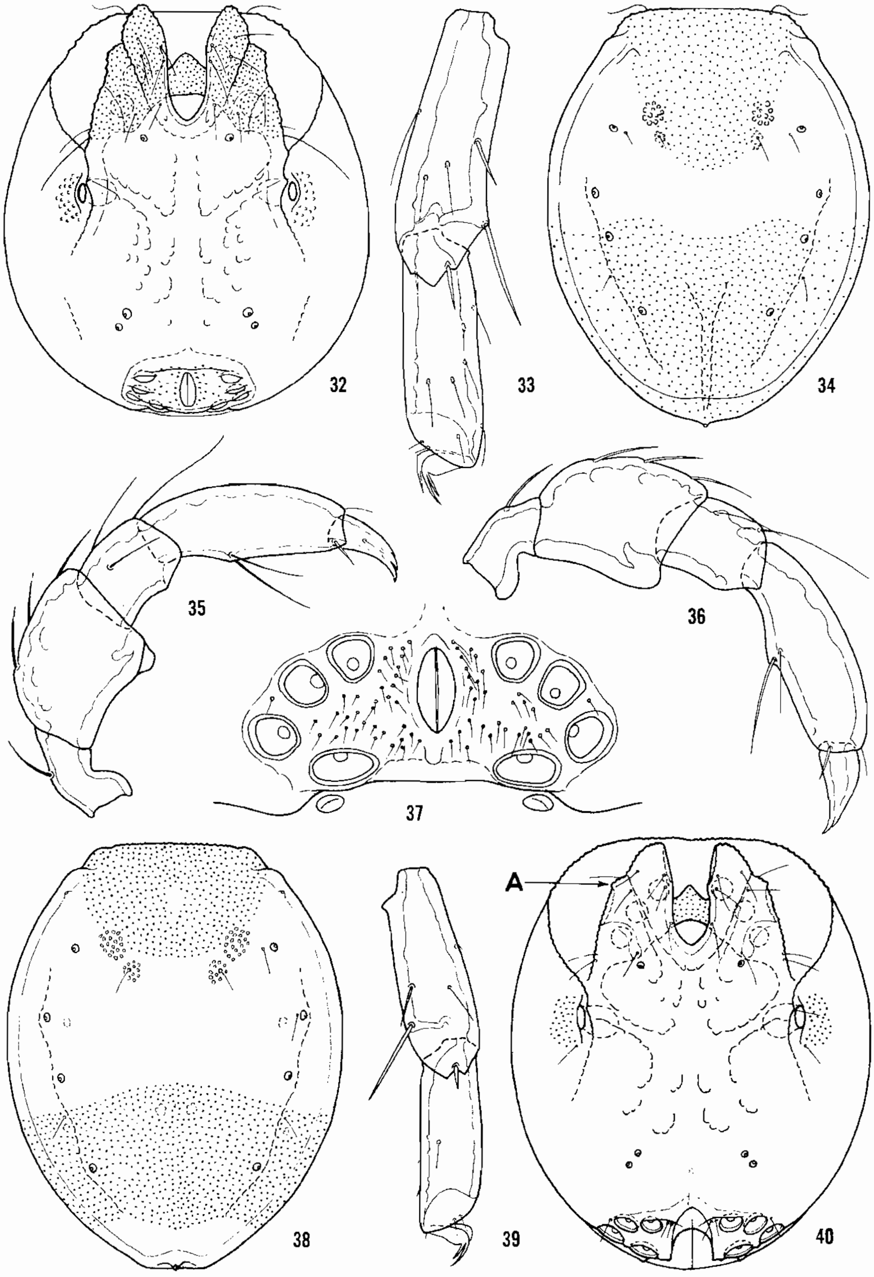

*Axonopsis lacustris* n. sp. Fig. 11, dorsal shield, female; Fig. 12, I-Leg-5 and 6, female; Fig. 13, ventral shield, female; Fig. 15, palp, female; Fig. 16, posteroventral view of genital field, female.

*Axonopsis occidentalis* n. sp. Fig. 14, palp, female; Fig. 17, posteroventral view of genital field, male; Fig. 18, ventral shield, female; Fig. 19, I-Leg-5 and 6, female; Fig. 20, dorsal shield, female.



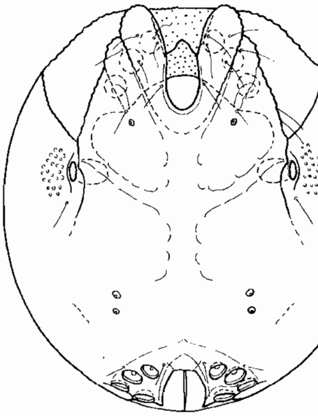

*Axonopsis rivophila* Habeeb. Fig. 21, dorsal shield, female; Fig. 22, I-Leg-5 and 6, male; Fig. 23, ventral shield, female; Fig. 24, palp, male; Fig. 26, ventral view of genital field, male.

*Axonopsis amnicola* n. sp. Fig. 25, palp, male; Fig. 27, posteroventral view of genital field, male; Fig. 28, ventral view of genital field, male; Fig. 29, ventral shield, female; Fig. 30, I-Leg-5 and 6, male; Fig. 31, dorsal shield, female.




*Axonopsis beltista* n. sp. Fig. 32, ventral shield, male; Fig. 33, I-Leg-5 and 6, male; Fig. 34, dorsal shield, male; Fig. 36, palp, male.

*Axonopsis setonensis* Habeeb. Fig. 35, palp, female; Fig. 37, posteroventral view of genital field, male; Fig. 38, dorsal shield, female; Fig. 39, I-Leg-5 and 6, female; Fig. 40, ventral shield, female.



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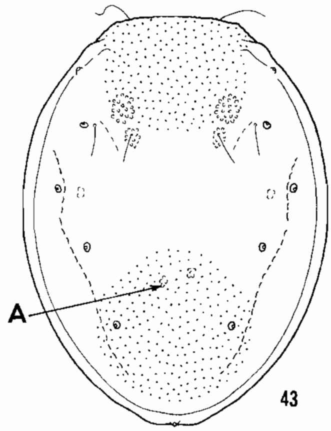


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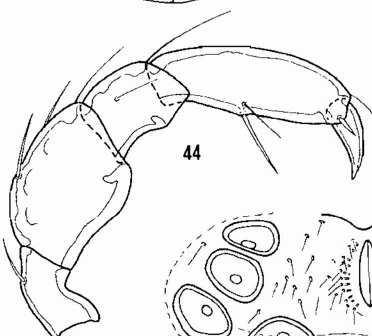

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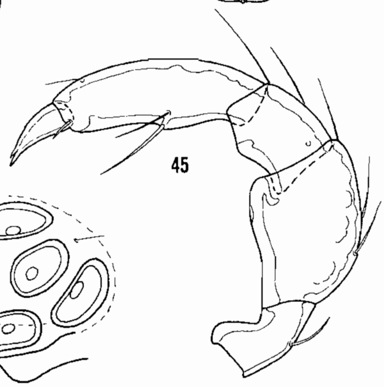

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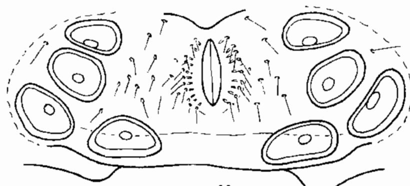

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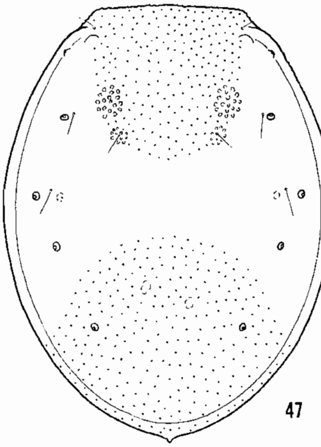

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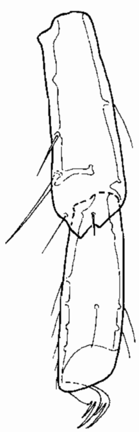

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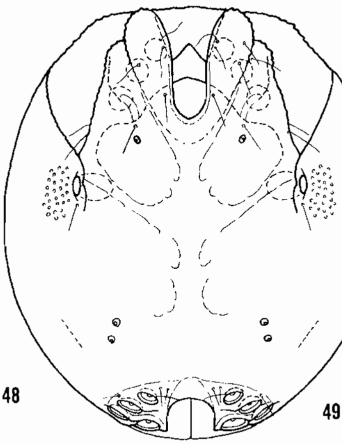

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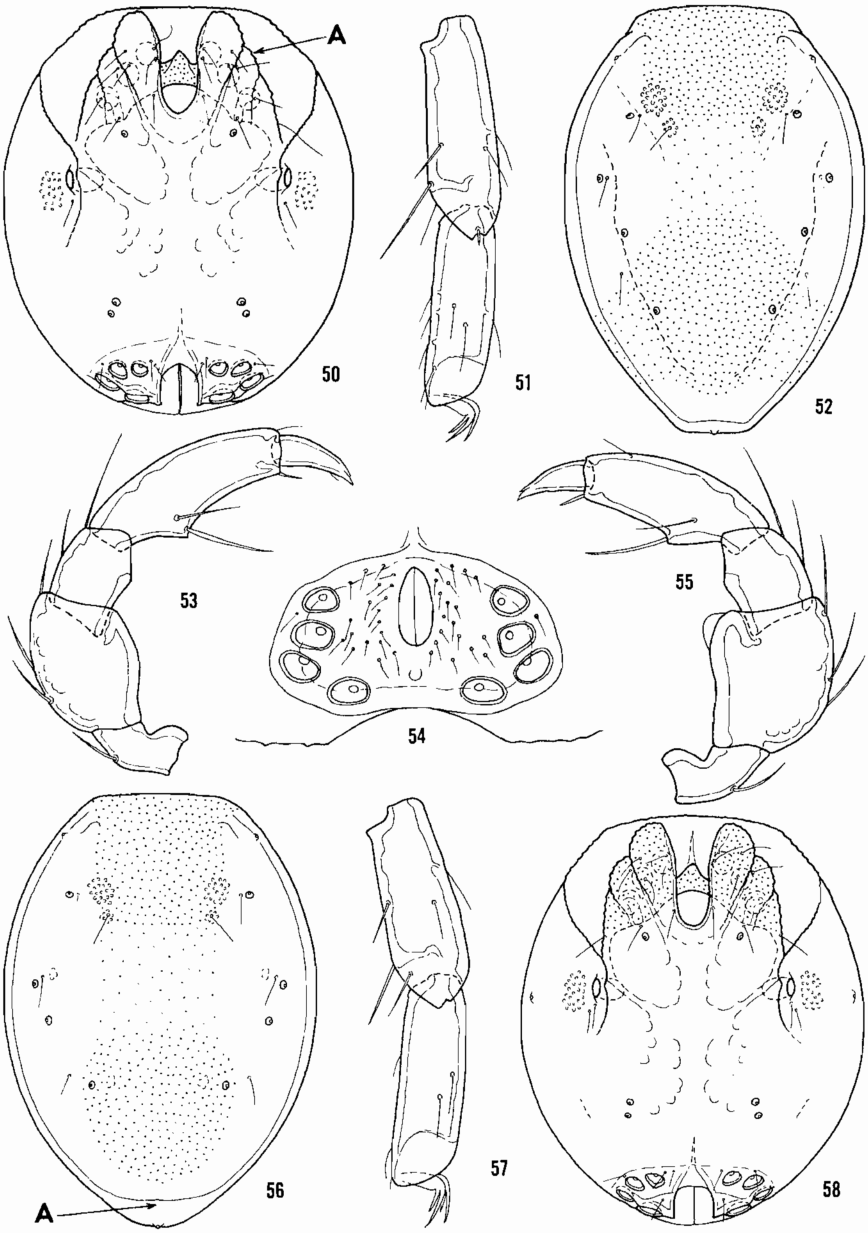
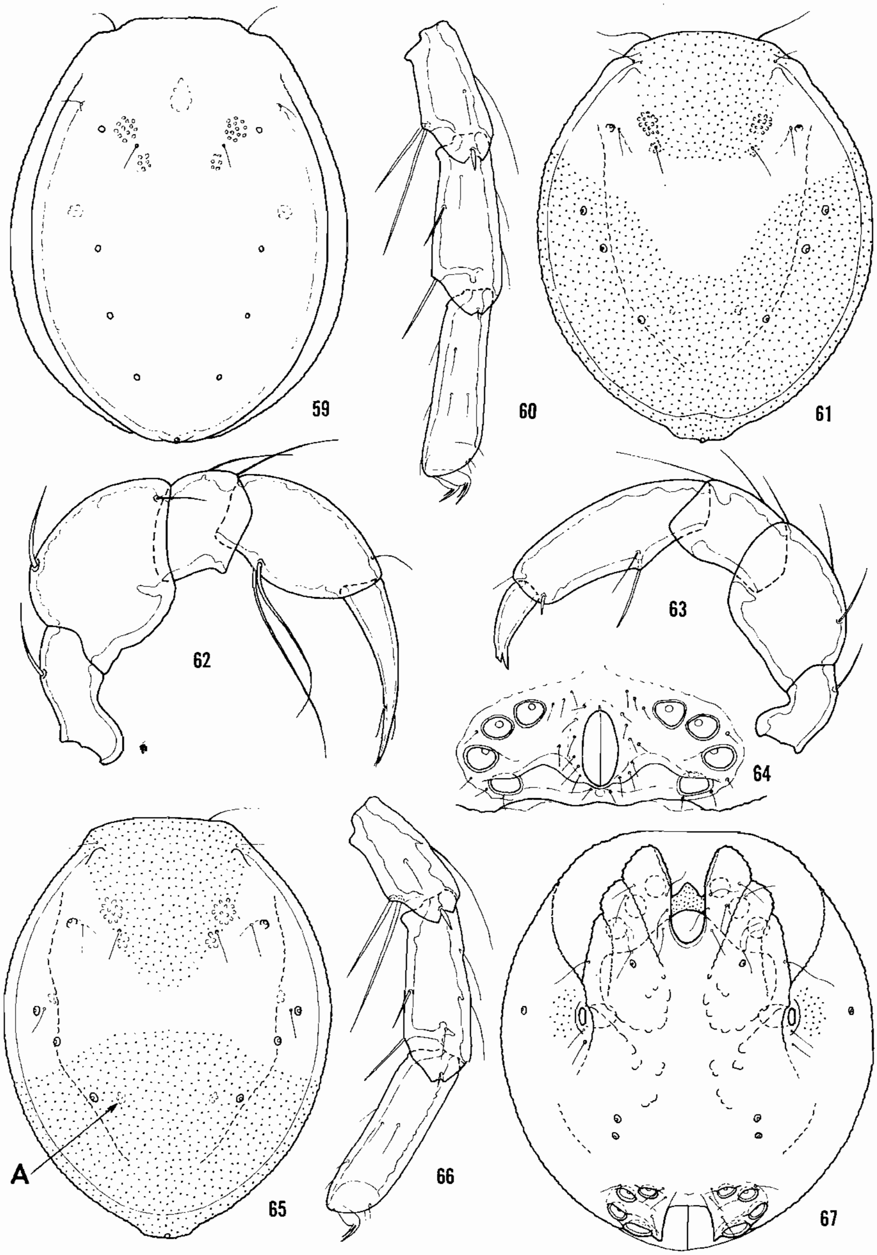
*Axonopsis eremita* n. sp. Fig. 41, ventral shield, female; Fig. 42, I-Leg-5 and 6, female; Fig. 43, Dorsal shield, female; Fig. 45, palp, female.

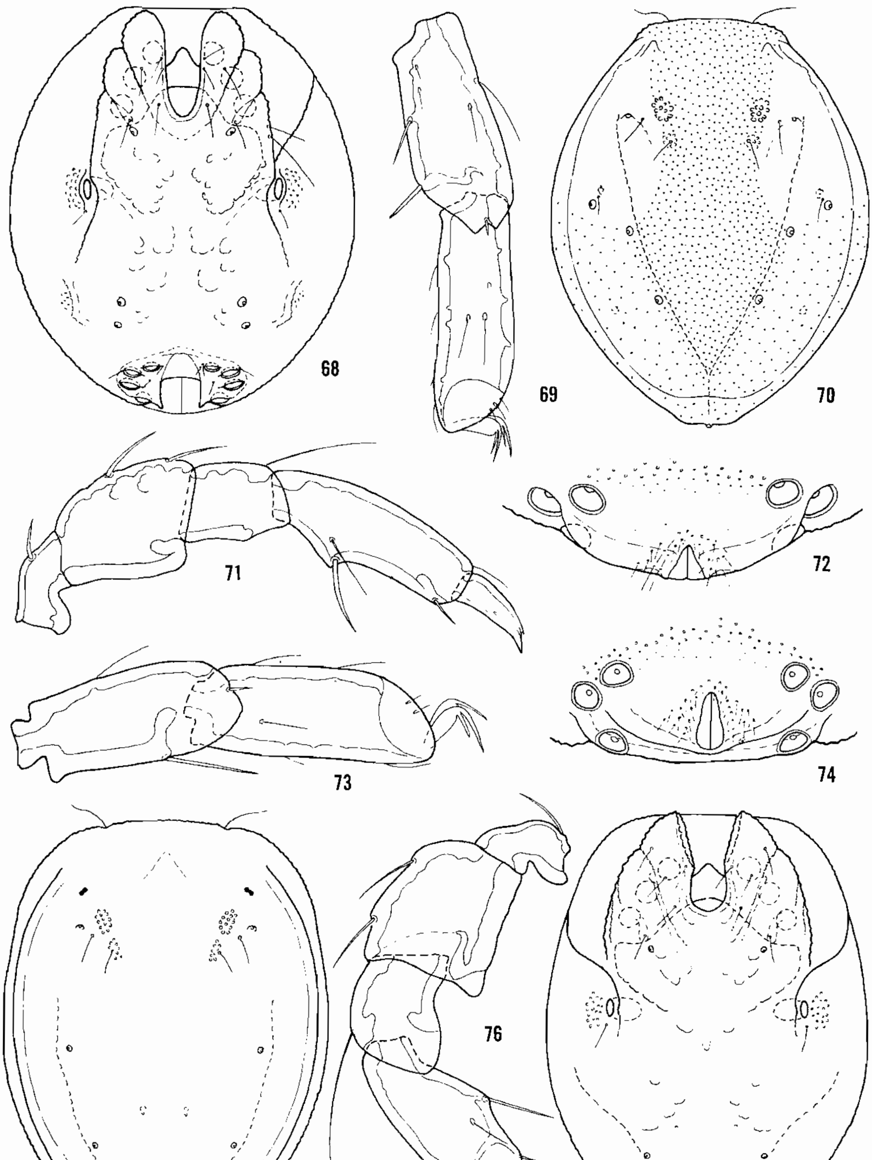
*Axonopsis ohioensis* Cook. Fig. 44, palp, female; Fig. 46, posteroventral view of genital field, male; Fig. 47, dorsal shield, female; Fig. 48, I-Leg-5 and 6, female; Fig. 49, ventral shield, female.




*Axonopsis ozarkensis* n. sp. Fig. 50, ventral shield, female; Fig. 51, I-Leg-5 and 6, female; Fig. 52, dorsal shield, female; Fig. 55, palp, female.
*Axonopsis beltista* n. sp. Fig. 54, posteroventral view of genital field, male.
*Axonopsis arpeda* n. sp. Fig. 53, palp, female; Fig. 56, dorsal shield, female; Fig. 57, I-Leg-5 and 6, female; Fig. 58, ventral shield, female.

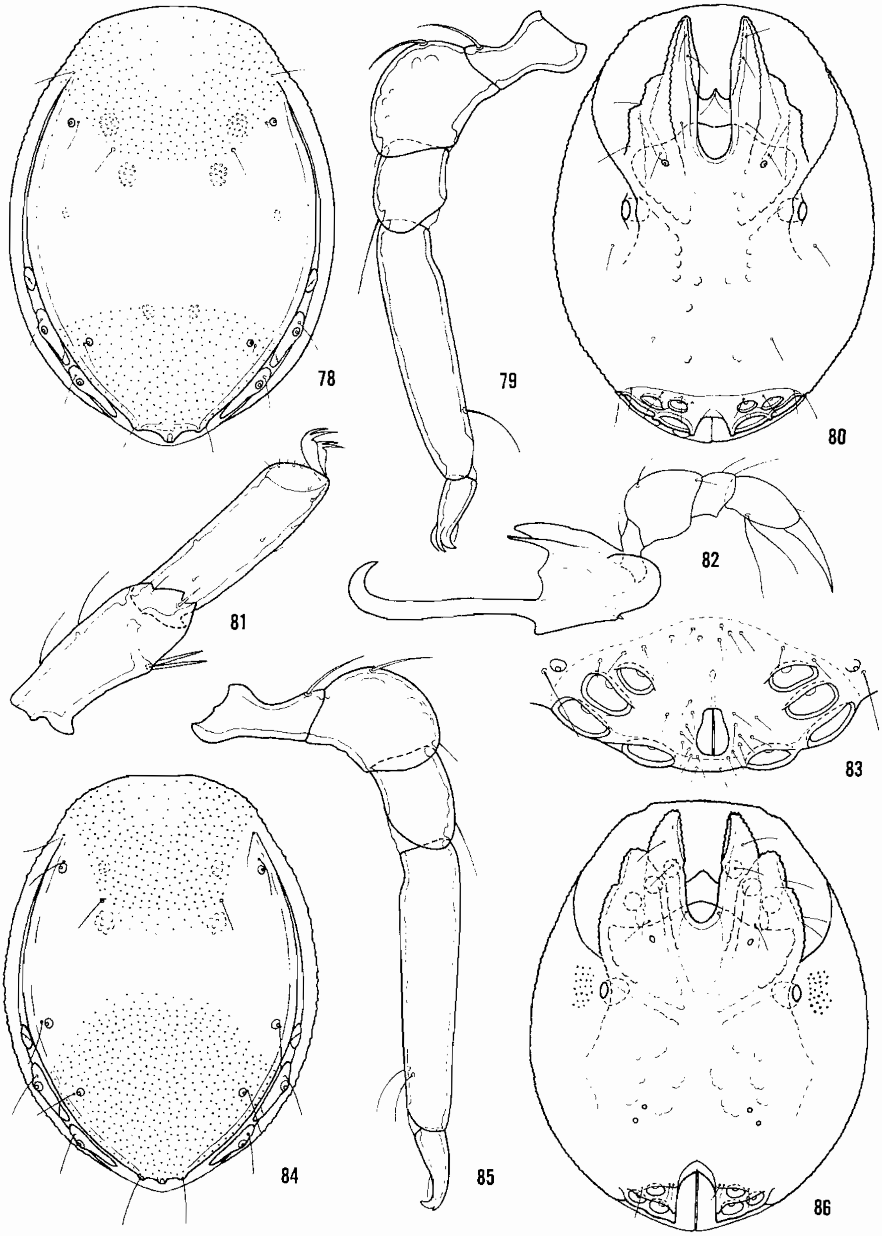



*Axonopsis californica* Cook. Fig. 59, dorsal view, female; Fig. 62, palp, male.
*Axonopsis cullasaja* Habeeb. Fig. 60, I-Leg-4, 5 and 6, female; Fig. 63, palp, female; Fig. 65, dorsal shield, female; Fig. 67, ventral shield, female.
*Axonopsis floridensis* n. sp. Fig. 61, dorsal shield, female; Fig. 64, posteroventral view of genital field, male; Fig. 66, I-Leg-4, 5 and 6, female.




*Axonopsis gennada* n. sp. Fig. 68, ventral shield, female; Fig. 69, I-Leg-5 and 6, female; Fig. 70, dorsal shield, female; Fig. 71, palp, female.

*Axonopsis pumila* n. sp. Fig. 72, ventral view of genital field, male; Fig. 73, I-Leg-5 and 6, male; Fig. 74, posteroventral view of genital field, male; Fig. 75, dorsal view, female; Fig. 76, palp, male; Fig. 77, ventral shield, female.




*Axonopsis sabulonis* n. sp. Fig. 78, dorsal view, female; Fig. 80, ventral shield, female; Fig. 81, I-Leg-5 and 6, male; Fig. 83, posteroventral view of genital field, male; Fig. 85, palp, female.

*Axonopsis bimaculata* Cook. Fig. 79, palp, male; Fig. 84, dorsal shield, male.

*Axonopsis californica* Cook. Fig. 82, lateral view of palp and capitulum, female; Fig. 86, ventral shield, female.

## BOOK REVIEW

SCABIES. Kenneth Mellamby. Second Edition, E. W. Classey Limited, London, 1972. vi, 81 p. $3.50 paperback. Distributed in North America by Entomological Reprint Specialists, P.O. Box 77971, Dockweiler Station, Los Angeles, California 90007.

This pocket-sized book was first published in 1943 as one of a series of Oxford War Manuals which dealt with medical problems of importance at that time. This second edition is virtually unchanged from the original which contained the results of extensive research on human volunteers and was a definitive compendium on human scabies at the time of its publication. Subsequent to World War II scabies became a medical rarity and since that time has evoked little research effort. Within the last few years, however, there has been a marked increase in the incidence of scabies so the current re-issue of this publication again makes available a useful and concise reference source for dermatologists, physicians and medical zoologists, few of whom have had extensive experience with this disease.

The information concerning *Sarcoptes scabiei* is still current and accurate but the sections on treatment and the Trombicula portion of the chapter dealing with other mites of medical and veterinary importance are outdated. The materials recommended for treatment were in common use at the time the first edition was written and while they are still effective in eliminating mites, it is probable that most medical practitioners will prefer to utilize more recently developed proprietary drugs. The therapeutic agents now available for the irritation and secondary infections associated with scabies are much more effective than those suggested in the text, and this is mentioned in the preface to this edition.

The excellent descriptive narration in this text, together with its convenient size and modest price should make it an attractive addition to the libraries of physicians and the medical and paramedical professionals concerned with human ectoparasites.

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# INJURY TO ALDRIN-TREATED AND UNTREATED RED PINE BY WHITE GRUBS (COLEOPTERA: SCARABAEIDAE) AND OTHER AGENTS DURING FIRST FIVE YEARS AFTER PLANTING

Richard F. Fowler[1] and Louis F. Wilson[2]

Freshly planted red pine (*Pinus resinosa* Ait.) seedlings are vulnerable to injury by several agents. White grubs–the larvae of May beetles (*Phyllophaga* spp.)–are among these agents and sometimes must be controlled in areas scheduled for pine planting. A study was begun in 1967 to evaluate the effectiveness of applying three levels of aldrin for controlling white grubs in the Upper Peninsula of Michigan. After two years white grubs were satisfactorily suppressed by the three treatments tested (Fowler and Wilson 1971a). Reported here is a continuation of that study for five years following planting. We wanted to learn the effect of the aldrin treatments on the subsequent growth and survival of young red pine trees and to what extent white grubs and other agents injured or killed the red pine during the five years after treatment.

## METHODS

Five white grub-infested areas were selected for planting and aldrin tests in the Hiawatha National Forest in Upper Michigan. These areas were machine-planted in the spring of 1967 with bed-run 3-0 red pine seedlings or 2-1 red pine transplants. Four of the research areas were suitable for red pine growth based on soil types and pH levels (Fowells, 1965). They also satisfied the requirements for white grubs in terms of soil types (Graham, 1958), soil pH (Hammond, 1948), and availability of adult and larval host vegetation (Graham, 1958). These four areas, designated Raco, Townhall, Townline Lake, and Bird, were observed for a five year period; the fifth area was abandoned because of low grub populations.

A randomized complete block design, replicated five times in each test planting, was used to evaluate the aldrin treatments. Each of the four treatments in a block included 15 trees in six adjacent rows or 90 trees per block (Fig. 1). The treatments were as follows:

Treatment 1–Aldrin solution applied with a dispenser attached to the planting machine (aldrin-machine).

Treatment 2–Aldrin solution applied with a backpack pump and wand (aldrin-pump).

Treatment 3–Granular aldrin applied with a dispenser attached to the planting machine (aldrin-granular).

Treatment 4–Check plots (untreated).

Each seedling was spot treated. Details of the equipment and application methods have been reported by Fowler and Wilson (1971a). Liquid aldrin concentrations varied from 0.3 to 1.2% and the dosage rates from 8.8 to 11.3 ml. per seedling. Granular aldrin was applied at 9.3 gm. per seedling (Table 1).

The plots were examined in the autumn of 1967 and 1968 and each spring (late May and early June) from 1968 to 1972. All dead seedlings were excavated and examined for white grub root feeding and other causes of death. In the autumn of 1967 and again in 1968, eight to ten living seedlings per plot were randomly selected, dug, roots examined,

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[2]North Central Forest Experiment Station, U.S. Department of Agriculture, East Lansing, Michigan 48823 (office maintained in coopreation with Michigan State University).

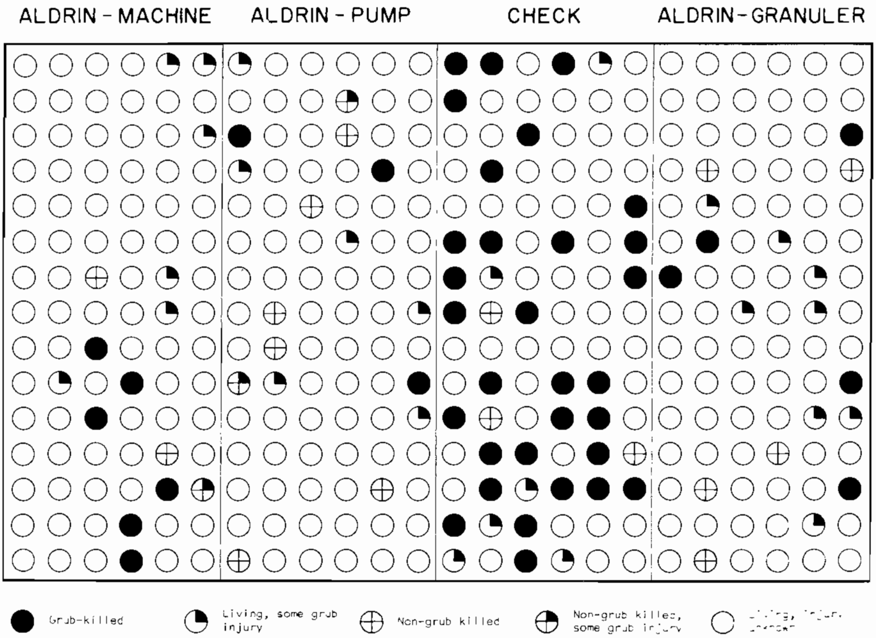


Fig. 1. Schematic diagram of typical plots showing location of seedlings with injury from white grubs and other causes. Data presented from Block II at Townline Lake plantation 5 years after planting. (Irregularities in planting and spaces are omitted.)

Table 1. Dosage rate of aldrin applied per seedling per plantation, based on 1% solutions and 20% granulars.*

| Study area | Liquid | | Granular |
|---|---|---|---|
| | Machine | Pump | |
| | *ml.* | *ml.* | *gm.* |
| Raco | 13.7 | 10.6 | 9.3 |
| Townhall | 13.7 | 10.6 | 9.3 |
| Townline Lake | 5.8 | 4.6 | 9.3 |
| Bird | 5.8 | 3.7 | 9.3 |

*From Fowler and Wilson (1971a).

Table 2. White grub (*Phyllophaga* spp.) populations and feeding indexes for all research study areas.

| Study area | 1968 | | 1971 | |
|---|---|---|---|---|
| | Number grubs | Feeding index | Number grubs | Feeding index |
| Raco | 11 | 70 | 3 | 16 |
| Townhall | 36 | 122 | 16 | 116 |
| Townline Lake | 40 | 218 | 26 | 155 |
| Bird | 7 | 26 | 2 | 16 |

and inspected for other potential causes of mortality. The root damage from grubs was visually scored one to five, depending on the degree of injury. Scoring criteria have been defined by Fowler and Wilson (1971b). Seriously damaged seedlings dug alive were considered as dead in analysis. Most of these were off-color or stunted or both. Past experience indicated such unhealthy trees would soon die.

Terminal shoot growth was measured after the first, second, and fifth growing seasons and tree height after the fifth growing season (spring 1972) on living seedlings as an indicator of sublethal injury.

White grub populations were sampled by examining thirty 1-cubic-foot soil samples in each research area as described by Fowler and Wilson (1971b). Larval instars were determined, and feeding indexes computed by the formula: $FI = (N_1 + 2N_2 + 4N_3 + 8N_4)$ where FI is the feeding index and $N_1$, $N_2$, etc., are the numbers of larvae in instars 1, 2, etc.

## MORTALITY FROM WHITE GRUBS

The highest seedling mortality from white grubs occurred in the period between the first and second years–from May 1968 to June 1969 in all of the test plantings (Fig. 2). Mortality occurred in most aldrin treated plots but was highest in the untreated plots. After the third year, mortality leveled off in all plots. Few seedlings were killed after three years, even though the grub populations and feeding indexes (Table 2) were high enough to cause serious damage (Fowler and Wilson, 1971b).

In the aldrin-treated plots, white grubs killed some seedlings, but in general significant control was accomplished early in the study and remained effective throughout the five year period. We thought the seedlings might become more susceptible to attack in the year following treatment as the roots grew out of the chemically treated zone, but this was not the case. The aldrin-treated plots lost 6% or less of their seedlings to white grubs after five years, the only exceptions were the machine-treated plots at the Townline Lake and Bird Areas, which suffered losses of 16 and 13%, respectively. These higher mortalities were expected because these plots received less than one-half the amount of aldrin that the machine-treated plots in the other two areas received due to misformulation and miscalibration of the dosages (Fowler and Wilson, 1971a). Even so, the untreated Townline Lake and Bird Area plots had considerably more grub-caused mortality than the treated ones–an average of 25% for the four areas during the five year period.

## MORTALITY FROM OTHER CAUSES

Several agents other than white grubs killed seedlings during the five year study period. Definitive nongrub mortality occurred each year at all locations (Fig. 3); by the end of the fifth year it varied from 11 to about 18% per area. Out of 7,200 seedlings in all plots and areas, 967 or 13% died strictly from nongrub causes. Most mortality occurred between the first and second years, the same period when grub-caused mortality occurred.

Seedling mortality was not always a clear-cut grub-caused or nongrub-caused situation. Of the 1,206 dead seedlings examined, 20% were clearly grub killed and 53% were clearly killed from other agents. But, the remaining 27% had grub-injured roots and injury from other agents simultaneously, either of which were capable of causing mortality (Fig. 3).

Agents other than white grubs causing mortality are listed in Table 3. Scleroderris canker (*Scleroderris lagerbergii* Gremmen) was the most important disease observed. It destroyed about 7% of the seedlings by 1972, mostly in the Raco Area. This diesase was identified by the characteristic yellow-green discoloration beneath the bark. Specimens examined by a forest pathologist indicated that our field identification was more than 95% accurate.

Canker-like damage was observed on 6% of the dead seedlings, especially on the 3-0 stock. Because no fungus was observed it could possibly have been mechanical injury from handling the seedlings. Most of this mortality occurred the year after planting. This canker was also found on some living seedlings.

Armillaria root rot (*Armillaria mellea* (Vahl ex Fr.) Kummer) killed 2% of the seedlings, mostly at Townline Lake where hardwoods were abundant. We identified this disease by its distinctive white mycelial mat under the bark at the ground line.

About 2% of the dead seedlings at three locations had a fine, irregular, discolored line completely encircling the stem just above the ground line. This "cambial ring" was usually blue, but a few were pink or brown. Forest pathologists could not identify it as a pathogen, but suggested it may be due to high temperature near the soil surface.

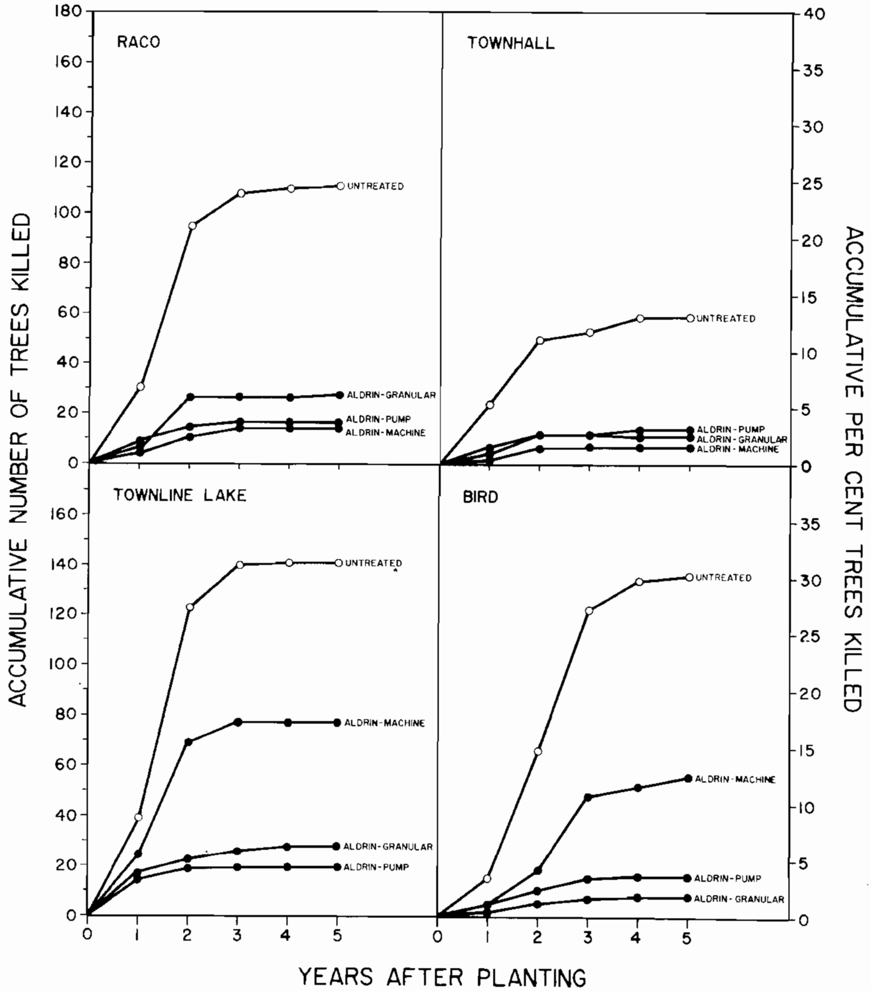


Fig. 2. Red pine mortality from white grubs for aldrin-treated and untreated plots for all research areas.

During the first and second winters, snow breakage of the main stem occurred on 3% of the seedlings. After the second year some branch breakage occurred from snow, but it caused little seedling mortality.

J-rooting caused by inadequately excavating a hole for the tree when it was planted was found on nearly 33% of the seedlings that died, and of these 66% showed no other evidence of injury. Most J-rooting of 3-0 stock occurred in the field at planting; however, serious J-rooting of 2-1 stock occurred both in the nursery and during field planting. Seedlings planted deep, i.e., root collar buried 1 or more inches below the soil surface, were frequently J-rooted because their roots were forced into a horizontal position on the bottom of the trench during planting. Although deep planting has been shown to be beneficial to red pine survival (Mullin, 1964), white grubs killed more J-rooted seedlings than those with roots spread out, because the rootlets are readily accessible to the insect.

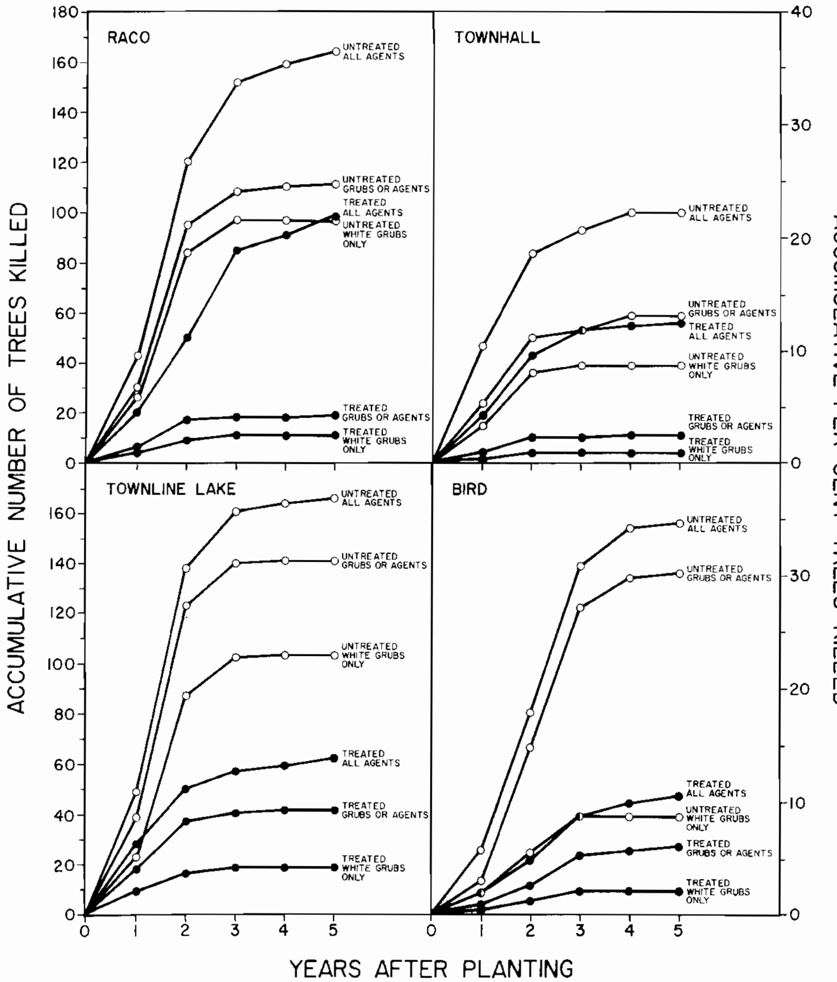


Fig. 3. Red pine mortality from white grubs and other agents for aldrin-treated and untreated plots for all research areas. *All agents* refers to mortality from all causes including white grubs; *grubs or agents* refers to seedlings having white grubs and another agent simultaneously—either of which, were capable of mortality; and *white grubs only* refers to mortality from just *Phyllophaga.*

A few seedlings also apparently died from shallow planting.

Of the mortality not caused by grubs, 40% was due to other, mostly unknown, causes (Table 3). Animals, especially deer, severed a few seedlings in the Townline Lake and Bird Areas shortly after planting. Seedlings sometimes vanished from the plots between examination periods, and deer may have nipped these, too. Trees that were smaller than those usually recommended for planting size often died for undetermined reasons. Some seedlings apparently died from competition; weeds choked out a few while others became sodbound when the lay of the furrow fell back against the seedlings at planting time. Other seedlings died from no apparent causes.

Table 3. Red pine mortality from agents other than white grubs 1967-1972.

| Agent | Dead Trees at: | | | | Total | |
|---|---|---|---|---|---|---|
| | Raco | Townhall | Townline Lake | Bird | | |
| | *Number* | | | | | *Percent* |
| Scleroderris canker | 59 | 7 | 1 | 5 | 72 | 7 |
| Unknown canker | 24 | 19 | 13 | 4 | 60 | 6 |
| Armillaria root rot | 2 | 1 | 13 | 1 | 17 | 2 |
| Cambial ring | 4 | 6 | 5 | 3 | 18 | 2 |
| Snowbreak | 8 | 9 | 4 | 11 | 32 | 3 |
| J-root | 83 | 51 | 38 | 142 | 314 | 33 |
| Planting depth | 24 | 19 | 15 | 6 | 64 | 7 |
| Other* | 126 | 103 | 104 | 57 | 390 | 40 |
| TOTAL | 330 | 215 | 193 | 229 | 967 | 100 |

*Includes trees missing, animal nip, competition, sub-standard planting size, and unknown causes.

Stem aphids were observed on a few seedlings in all but the Townhall Area. These aphids were as common in treated as in untreated plots. At Raco, however, root aphids were observed only in the untreated plots; those in the treated plots were probably killed by aldrin. No seedling mortality was ascribed to aphids.

## SEEDLING GROWTH

Aldrin-treated seedlings were significantly taller and had longer terminals ($P > 0.05$) than untreated seedlings 5 years after planting (Table 4). The treated seedlings averaged 3

Table 4. Seedling height and terminal length in 1972 for all treatments and research study areas.

| Study area | Treatment | | | |
|---|---|---|---|---|
| | Aldrin-machine | Aldrin-pump | Aldrin-granular | Untreated |
| | Height in feet | | | |
| Raco | 1.9 | 1.8 | 1.8* | 1.5 |
| Townhall | 2.5 | 2.4 | 2.8* | 2.0 |
| Townline Lake | 2.4* | 2.2 | 2.3 | 1.9 |
| Bird | 2.0* | 2.1* | 2.2* | 1.8* |
| Mean | 2.2 | 2.1 | 2.5 | 1.8 |
| | Terminal Length in inches | | | |
| Raco | 5.8 | 5.4 | 6.3* | 3.8 |
| Townhall | 7.9 | 7.3 | 9.8* | 6.1 |
| Townline Lake | 8.3* | 7.5 | 8.1 | 6.0 |
| Bird | 7.5* | 8.3* | 9.6* | 6.2* |
| Mean | 7.4 | 7.1 | 8.5 | 5.5 |

*2-1 stock. All other stock is 3-0. 2-1 stock averaged 0.5 foot and 3-0 stock averaged 0.7 foot at time of planting.

to 7 inches taller than the untreated ones, an increase of nearly 25%. The treated 2-1 transplants averaged slightly greater height and longer terminals than treated 3-0 stock in all cases except for the seedlings at Raco. In the Bird Area, where all 2-1 stock was used, seedlings treated with granular aldrin were taller and had longer terminals than those treated with liquid aldrin.

We thought that aldrin may have stimulated growth. Simkover and Shenefelt (1952) showed that chlordane (up to 50 pounds per acre) benefited growth by causing root elongation. Shenefelt *et al.* (1961) used liquid aldrin (e.c.), and suggested it may also act as a root simulant for red pine, eventually increasing vigor and height growth. However, Lane and Shearin (1972) applied granular aldrin around loblolly pine seedlings and found no increase in height growth. We are not able to tell if aldrin stimulated growth in this study, and thus have assumed for the most part that differences in height between aldrin-treated seedlings and the untreated ones have been due to injury by white grubs.

## DISCUSSION

White grubs are often blamed for pine seedling mortality following planting in old fields. White grubs do cause significant mortality and loss of vigor, but diseases, planting practices, and other agents accounted for more than half of the seedling mortality especially during the first three years after planting. Also seedling mortality is not just a white grub-caused versus nongrub-caused situation. Some seedlings that were severely grub injured showed evidence of damage by other agents which in the absence of grubs would have died anyway. Nevertheless the three aldrin treatments tested, which were equally effective in alleviating mortality by white grubs (Fowler and Wilson, 1971a), reduced white grub-caused mortality by 83% and surviving seedlings attained greater vigor than untreated seedlings. Whether this increased vigor, measured as a growth differential, is biologically significant must yet be determined. Perhaps differences will be more evident at thinning or harvesting time. It is certain, however, that some of the untreated seedlings still living at the end of the test will never reach merchantable size as they had not grown appreciably since they were planted. Many were seriously root damaged from white grubs, and for all practical purposes should be considered dead.

Aldrin had no obvious effect on the nongrub agents in this study because mortality from other causes was as great or greater in the aldrin-treated plots as in the untreated plots. Also, there was no evidence of a phytotoxic effect of aldrin on the red pine seedlings. This is not surprising because Simkover and Shenefelt (1952) reported no phytotoxic symptoms on red pine at a dosage rate of ten pounds of aldrin per tree.

Scleroderris canker and J-rooting were the predominant nongrub agents injurious to the seedlings. Although the trees outgrew most of the problem agents after three years, Scleroderris remains a potential threat because it readily attacks young saplings and most likely would cause additional mortality in the future. However, J-rooting might be lessened in future plantings by modifying existing planting practices.

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# WITHIN-TREE DISTRIBUTION OF THE JACK PINE TIP BEETLE, *CONOPHTHORUS BANKSIANAE* MCPHERSON, ON JACK PINE[1]

David J. Hall[2] and Louis F. Wilson[3]

The jack pine tip beetle (*Conophthorus banksianae* McPherson) attacks the shoot tips of jack pine (*Pinus banksiana* Lamb.) and other pines, killing the apical one inch of the shoot and thus causing crooks and forks in the branches and main stem. Several recent studies on this insect have presented the bionomics, host relations, and mortality (McPherson, Wilson, and Stehr, 1970; McPherson, Stehr, and Wilson, 1970; Hall and Wilson, 1974), as part of a project to learn its importance to the forest resource and to seek potential control methods. In the part of the study reported here we wanted to know the vertical distribution of attacked tips on the host in order to more readily understand the insects' injury to a stand of pine. Casual observation indicated that the attacked tips appeared to be aggregated in the tops of the crowns and were especially abundant on taller trees. Therefore we examined vertical distribution of attacks in relation to tree height, degree of exposure of the attack site to the sky (celestial hemisphere), and shoot tip size.

## METHODS AND RESULTS

Nine jack pines were sampled four times each in a young plantation in Wexford County, Michigan, in 1971. Data taken were: (1) tree height, (2) number of attacked tips, (3) vertical distance of attack from the top of the tree, (4) diameter of attacked tip and nearest neighboring tip (measured 3/8 in. below the base of bud), and (5) percent of the celestial hemisphere to which attacked tip was exposed (estimated visually). Data were collected on July 2, July 9, July 27, and August 10 in 1971, which covered the major attack and oviposition period.

During the first two weeks of the attack period, the top five inches of the crown received the most attacks even though it contained far fewer tips than the lower crown sections (Fig. 1). Later on, the next lower five inches surpassed the top five. The rate of attack slowed after July 27 and ceased by August 10.

The percent of attacks is high in the upper levels and decreases through the lower levels. Nearly 50% of the attacks are in the top ten inches of the crown and over 95% in the top three feet, even on trees that are over 11 feet tall (Table 1).

Incidence of attack was directly related to tree height at the 80% level of significance ($n = 9$, $r^2 = 0.32$). This trend is not surprising as taller trees have proportionately more susceptible shoot tips to attack. The jack pines are even-aged, plantation trees and differ only about three feet in height. A higher correlation would likely occur if a wider range of tree sizes was available.

The distribution of attacked tips is clearly shifted to the higher exposure classes. Tips well exposed to the sky are most likely to be attacked (Fig. 2). T-test showed curves differed significantly at 0.001 level. A few tips 60% exposed or less were attacked, indicating that the adult is not limited to highly exposed tips, but avoids them below 40% exposure. Also there were many unattacked tips in the classes above 70% indicating

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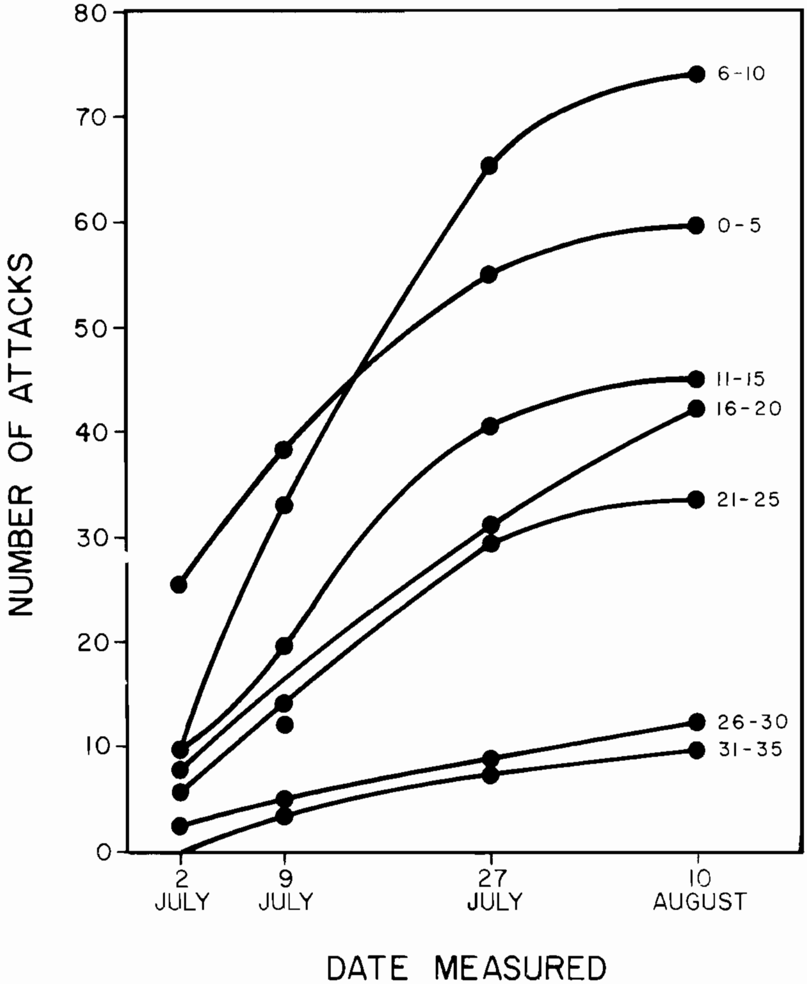


Fig. 1. The vertical distribution of *Conophthorus* attacks accumulated through the oviposition period. Numbers assigned to curves refer to the distance (inches) interval from the top of the tree. (The 16 to 20 inch class interval above was drawn disregarding the datum point for July 9.)

that the adults were not driven to the shaded tips due to lack of exposed tips. On the last measurement date, more than half of the unattacked tips were exposed to 61% sky or more.

Large diameter tips appeared to be preferred for attack (Fig. 3). T-test showed curves differed significantly at 0.001. There were only ten attacked tips with diameters less than 3.0 mm, while there were well over 100 available unattacked. Also, there were very few tips in the two largest diameter classes left unattacked.

Table 1. Vertical distribution of jack pine tip beetle attacks on nine jack pine trees in a plantation (autumn 1971).

| Attack location (inches below top of tree) | Attacks | | |
|---|---|---|---|
| | Number | Percent | Accumulated percent |
| 0 - 5 | 59 | 21 | 21 |
| 6 - 10 | 76 | 26 | 47 |
| 11 - 15 | 44 | 15 | 62 |
| 16 - 20 | 42 | 15 | 76 |
| 21 - 25 | 33 | 12 | 88 |
| 26 - 30 | 12 | 4 | 93 |
| 31 - 35 | 9 | 3 | 96 |
| 36+ | 12 | 4 | 100 |
| TOTAL | 287 | 100 | |

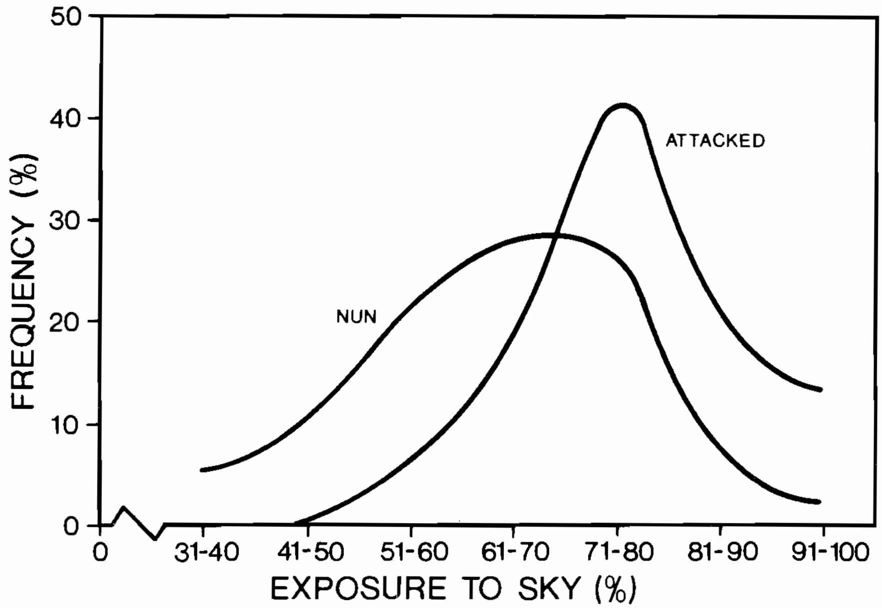


Fig. 2. Frequency distribution of attacked and unattacked shoot tips relative to percent exposure to the sky (percent of celestial hemisphere). Curves are significantly different at the 0.001 level (t-test).

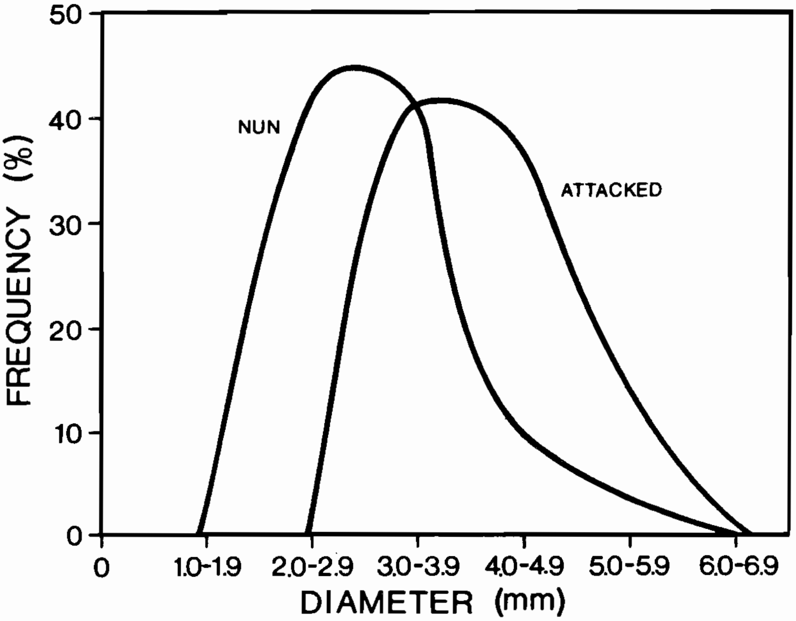


Fig. 3. Frequency distribution of the diameters of attacked and adjacent unattacked shoot tips. Curves are significantly different at the 0.001 level (t-test).

## DISCUSSION

Tree height, degree of exposure of the shoot tip to the celestial hemisphere, and shoot tip size all appear to effect the vertical distribution of the jack pine tip beetle attacks on jack pine. More attacks might be expected on larger trees because larger trees have more shoots than smaller trees of the same age. Exposed shoots are attacked more readily than shaded shoots regardless of their location in the tree. The beetles discriminate by showing a preference for the largest shoots, thus attacks are more prevalent on the top of the tree because most of the larger exposed shoots occur there. Early in the attack period the first five inches of treetop is the preferred attack site. Later on, the zone six to ten inches from the treetop becomes more heavily attacked, presumably because the upper five inches becomes saturated with attacks. On the rest of the tree the attacks are related inversely to distance from the top, but rarely occur below three feet from the top, at least on the closed-crown trees in the sample. Some attacks may occur lower on the crown of open-grown trees. Shoots 3.0 to 4.0 mm in diameter are preferred to attack and most shoots smaller than 3.0 mm are rejected by the adults regardless of their exposure.

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# DAILY ECLOSION PATTERN OF THE SARATOGA SPITTLEBUG, *APHROPHORA SARATOGENSIS* (FITCH) (HOMOPTERA: CERCOPIDAE)

Louis F. Wilson[1] and Patrick C. Kennedy[2]

The Saratoga spittlebug, *Aphrophora saratogensis* (Fitch), is a destructive pest of young planted pines in the Lake States. The adults injure the pines by feeding on the sap of branches. However, nymphs feed on the sap of alternate host plants, which include many herbs and woody plants on the forest floor. Our studies show that the time of eclosion and shortly thereafter is one of the most vulnerable periods in the insect's life cycle. During this period the nymphs must free themselves from the eggs that are on pine buds, vacate the pines, search out suitable host plants on the forest floor, initiate feeding, and cover themselves with masses of spittle. And they must do this before they desiccate (Ewan, 1961), starve, or are captured by predators.

As part of a survival study we wanted to observe the nymphs at eclosion because their emergence and behavior pattern at that time would certainly affect their survival. In the Lake States area eclosion occurs from early April to late May, a period when weather varies greatly from cool and wet to warm and dry. Reported is the nymphal eclosion pattern during the peak of the eclosion periods in 1969 and 1970.

## METHODS AND MATERIALS

Observations were taken in two young red pine (*Pinus resinosa* Ait.) plantations in Michigan, one in Alcona County in 1969 and one in Wexford County in 1970. Sticky traps and windowpane traps were used to detect the nymphs vacating the trees following eclosion. The sticky traps were flat boards (1 $ft.^2$) mounted at their center on short stakes and covered with cardboard sprayed with tanglefoot. Ten traps were placed in each plantation under several eight-foot tall trees containing spittlebug eggs. Four windowpane traps (see Wilson, 1969 for details) were placed five to ten foot out from the trees to catch windborne specimens. The trees were examined throughout most of the day for emerging nymphs, and nymphs caught on the traps were recorded hourly. Observations were made during several periods for two or three consecutive days in each area during the peak of the eclosion period from May 5 to 14 each year.

## RESULTS AND DISCUSSION

Nymphal eclosion occurred on all days of the test. Eclosion always began after 0600 hrs., peaked between 0800 and 0900 hrs., and then declined the rest of the day culminating before 1600 hrs. (Fig. 1). Nymphs never emerged between 1600 and 0600 hrs. About 33% eclosion occurred during the peak hour (0800-0900 hrs.); 85% occurred between 0700 and 1100 hrs.

Eclosion began at a different time each day depending upon morning temperature. The earliest was just after 0600 hrs. and the latest just after 0830 hrs. Cool, cloudy, or misty days prolonged the emergence period, extending it occasionally into mid-afternoon. Hot and sunny mornings abbreviated the emergence period; on such days it seldom lasted

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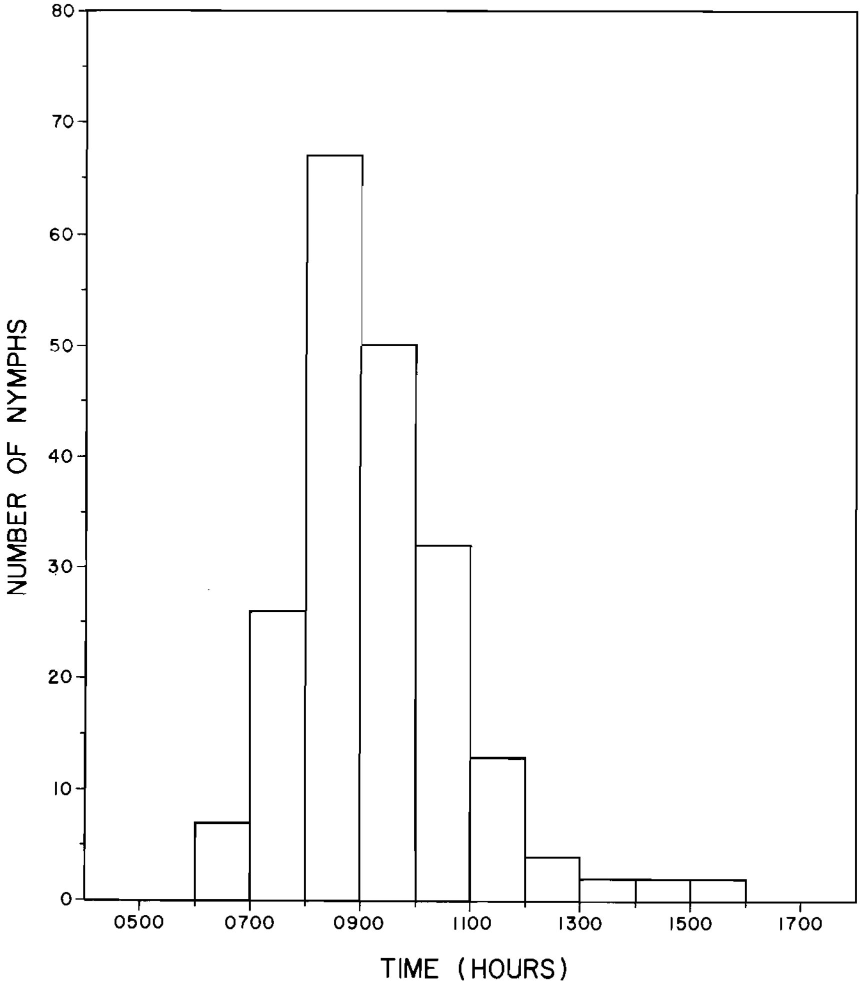


Fig. 1. Frequency of spittlebug nymphal eclosion per hour (EST).

beyond three hrs. However, on the average, about the same number of nymphs emerged on any two consecutive days that differed greatly in weather conditions.

The nymphs usually freed themselves from the egg in less than one min. They did not pause to dry out their exoskeleton, as some other insects do, but rather immediately began wandering over the surface of the bud or up and down nearby needles. They spent several minutes on the bud and needles if the humidity was high or if the sky was overcast, and less time when the day was sunny and warm. Most nymphs "dropped off" the tree, but a few were blown off by gusts of wind, as our windowpane traps attested.

Once on the ground the nymphs' immediate survival depends upon the proximity of suitable hosts and the humidity. The humidity in the morning near the ground, especially under the tree, is higher than on the tree, and the speed of their searching behavior normally can bring them to a host within a few minutes. Ewan (1961) has shown that they can travel a long distance in a few minutes. Of course, the nymphs are also vulnerable to spiders and other predators at this time, especially if the hosts are scarce.

Morning would be a logical time for major eclosion activity for insects such as young spittlebugs that are subject to relatively quick desiccation. Temperature and moisture probably interact to bring about eclosion under the best survival conditions. A rise in temperature in the morning may trigger the hatching sequence, and this is a time of day when the humidity is normally the highest. Moisture certainly is important but it appears not to be the only factor because the R.H. often reaches 100% at night and also on rainy afternoons, periods when the insects do not normally eclose. Temperature may also squelch eclosion later in the day.

In conclusion, it appears that the time of day eclosion occurs, the subsequent nymphal behavior, and perhaps the long six to seven weeks eclosion period all aid in the survival of this insect.

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