

NEW COLLECTION RECORDS FOR SCALE INSECTS OF TENNESSEE

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ABSTRACT

An annotated list of Tennessee scale insect (Homoptera: Coccoidea) fauna and their hosts was compiled between 1 November 1974 and 31 December 1977. Collection records are given for 74 species, in 9 families, of which 26 species are new state records. Also, 142 new county records are presented.

INTRODUCTION

Scale insects are a group of sucking insects in the order Homoptera which also includes aphids and whiteflies. They are considered among the most difficult insect pests to control because of the production of a waxy protective test which may completely cover the body (Figure 1). Many species attack agricultural as well as

ornamental plants and trees. The economic importance of the group is usually underestimated because of isolated infestations in a region.

Species of scale insects cause damage to their hosts by pit formation (Figure 2), sap extraction, and production of honeydew. The honeydew serves as a substrate for sooty mold development which may turn foliage and bark black and interfere with plant photosynthesis. Ants, bees, and wasps attracted to the honeydew often become a nuisance (Figure 3). Economic loss is attributed primarily to premature leaf or fruit drop, loss of plant vigor, die-back, or unsightly appearance of infested ornamental shrubs and trees (Figure 4). Heavy populations for extended periods may cause death of the host.

Species identification by the non-specialist has been hampered by the lack of a single source of up-to-date data at the species level for Tennessee. Because the scale insect fauna is poorly known, this investigation was initiated to provide information on the species, their hosts, and distribution in the state.

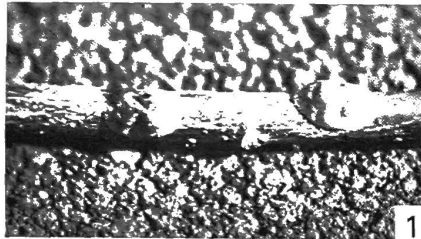


FIG. 1. Adult females of magnolia scale on host protected by waxy test.

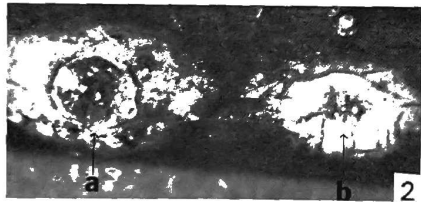


FIG. 2. Oak pit scale. a, adult female at apex of pit formation on host. b, adult female removed to reveal depression where scale insect fed.



FIG. 3. Ants tending adult females of tuliptree scale for honeydew.

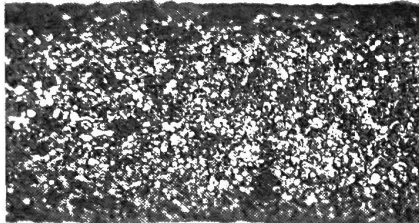


FIG. 4. Heavy population of obscure scale encrusting a limb of its host.

MATERIALS AND METHODS

Scale insect specimens and host samples were collected from roadsides, state and national parks, etc. throughout the state by the investigators from 1974 through 1977. Material sent by county agents as well as the general populace of Tennessee for identification was incorporated into the study. Infested portions of the host, 7 to 10 cm long, were placed in a cellophane bag and labeled. The cellophane bags provided the opportunity to obtain parasites in addition to first instars and adult male scales of several species. Some specimens were removed from the host and preserved in 70% ethanol.

Identification of most species required microscopic examination. To examine diagnostic morphological features, each specimen was processed through a series of chemicals to remove the test and body contents, stained, and mounted on a slide (Lambdin and Kosztarab, 1973). A Wild M20 phase-contrast microscope was used for species determinations.

Data on collected species were compared with U. S. Department of Agriculture and Tennessee Department of Plant Industries records. An asterisk following county names or species/common name indicates new county or state records.

RESULTS

ORTHEZIIDAE

Orthezia insignis Browne, 1887 (greenhouse orthezia). Collection records: on *Coleus* sp., Davidson Co., Nov. 1974.

MARGARODIIDAE

Matsucoccus gallicolus Morrison, 1939 (gall pine scale). Collection records: on *Pinus echinata* Mill. (shortleaf pine), Blount Co.,* 17 Aug. 1976; on *P. rigida* Mill. (pitch pine), Sevier Co.,* 9 Sept. 1976; on *P. virginiana* Mill. (Virginia pine), Blount Co., and Sevier Co., 19 Aug. 1976.

Xylococcus betulae (Pergande), 1898 (birch margarodid)*. Collection records: on *Aesculus oxiandra* Marsh. (yellow buckeye), Cocke Co., 31 Aug. 1977; on *Betula alleghaniensis* Brit. (yellow birch), Cocke Co., 31 Aug. 1977; Sevier Co., 6 Jun. 1976; on *Fagus grandifolia* Ehrh. (American beech), Cocke Co., 31 Aug. 1977; Sevier Co., 13 Sept. 1977.

PSEUDOCOCCIDAE

Ferrisia virgata (Cockerell), 1893 (striped mealybug)*. Collection records: on *Liquidambar styraciflua* L. (sweetgum), Shelby Co., 23 Jul. 1975; on *Magnolia* sp., Blount Co., 18 Sept. 1975.

Phenacoccus gossypii Townsend and Cockerell, 1898 (Mexican mealybug)*. Collection records: on *Geranium* sp., Carter Co., 6 Sept. 1977; on *Pilea repens* Lieb., Knox Co., 14 Dec. 1977.

Planococcus citri (Risso), 1813 (citrus mealybug). Collection records: on *Azalea* sp., *Coleus blumei* Benth. (pineapple beauty), *Euphorbia pulcherrima* Willd. (poinssetta), *Gardenia* sp., *Gossypium hirsutum* L. (cotton), *Haworthia* sp., *Hedera helix* L. (English ivy), *Hoya* sp. (Indian rope plant), *Ipomoea*

batatas (L.) (sweetpotato), *Kalanchoe* sp., *Lantana camara* L., *Liriodendron tulipifera* L. (yellow-poplar), *Lycopersicon esculentum* Mill. (tomato), *Oxalis* sp. (sorrel), *Philodendron cuspidatum* C. Koch and Bouche, *Pyraecanthia* sp. (firethorn), *Saintpaulia ionantha* Wendl. (African violet), *Schinus* sp. (Brazilian pepper tree), *Solanum tuberosum* L. (potato), *Stapelia* sp. (carrion flower), *Tolmiea menziesii* (Pursh.) (Stick-a-back), *Ulmus rubra* Muhl. (red elm), *Viburnum rhytidophyllum* Hensl. (leather leaf viburnum), Knox Co.,* 10-12 Sept. 1977 (all citrus mealybug specimens collected from greenhouse grown hosts).

Pseudococcus longispinus (Targioni-Tozzetti), 1867 (longtailed mealybug)*. Collection records: on *Crassula argentea* L. (jade plant), *Gardenia* sp., and *Musa* sp. (banana), Knox Co., 10 Dec. 1977; on *Neprolepis exaltata bostoniensis* Davenport. (Boston fern), Monroe Co., 10 Nov. 1977.

KERMESIDAE

Kermes galliformis Riley, 1881. Collection records: on *Quercus alba* L. (white oak), Blount Co.,* 19 Sept. 1976; on *Q. velutina* Lam. (black oak), Blount Co., 29 Jul. 1976.

Kermes pubescens Bogue, 1898. Collection records: on *Quercus stellata* Wangenh. (post oak), Blount Co.* and Knox Co.,* 25 Jun. 1975.

ERIOCOCCIDAE

Eriococcus azaleae Comstock, 1881 (azalea bark scale). Collection records: on *Azalea* sp., Decatur Co.,* 15 Aug. 1976.

Eriococcus coccineus Cockerell, 1894 (cactus eriococcin)*. Collection records: on *Mammillaria* sp. (pinchusion cactus), Knox Co., 22 Sept. 1977.

CEROCOCCIDAE

Cerococcus parrotii (Hunter), 1899 (pecan pit scale)*. Collection records: on *Carpinus caroliniana* Walt. (American hornbeam), Sevier Co., 5 Oct. 1977; on *Celtis occidentalis* L. (hackberry), Knox Co., May 1976; on *Cornus florida* L. (flowering dogwood), Sevier Co., 5 Oct. 1977.

ASTEROLECANIIDAE

Asterolecanium minus Lindinger, 1912 (Oak pit scale)*. Collection records: on *Quercus alba* L. (white oak), Knox Co., 10 Jul. 1976; Sevier Co., 6 Jun. 1976; on *Q. palustris* Muenchh. (pin oak), Knox Co., 27 May 1975; on *Q. prinus* L. (chestnut oak), Blount Co., 17 Aug. 1976.

COCCIDAE

Ceroplastes ceriferus (Fabricius), 1798 (Japanese wax scale)*. Collection records: on *Eunonymus* sp., Shelby Co., 26 Jun. 1975; on *Ilex opaca* Ait. (American holly), Dyer Co., 11 Oct. 1976; on *Ilex* sp., Shelby Co., 10 Jul. 1975; on *Podocarpus macrophyllum maki* D. Don (Chinese podocarpus), Knox Co., 19 Jan. 1976.

Ceroplastes floridensis Comstock, 1881 (Florida wax scale)*. Collection records: on *Cornus florida* L. (flowering dogwood), Shelby Co., 26 Jun. 1976; on *Ilex* sp. (holly), Davidson Co., Nov. 1975.

Coccus hesperidum L., 1758 (brown soft scale). Collection records: on *Asparagus densiflorus* (Kun.) (Sprenger's fern), Knox Co., 7 Jul. 1977; on *Chlorophyllum comosum* Bak. (spider plant), Anderson Co.,* 9 Nov. 1977; Knox Co., 27 Jan. 1975; on *Citrus limon* Burm. (ornamental lemon), Sequatchie Co.,* 29 Jul. 1977; on *Ficus benjamina* L. (weeping fig), Knox Co., 4 Apr. 1975; on *Nephelium litchi* Camb. (Litchi nut tree), Anderson Co., 9 Nov. 1977; on *Neprolepis exaltata bostoniensis* Davenport. (Boston fern), Anderson Co., 9 Nov. 1977; Knox Co., 18 May 1977; on *Pilea repens* Lieb., Anderson Co., 9 Nov. 1977; on *Plectranthus parviflorus* Willd. (Swedish ivy), Knox Co., 13 Feb. 1977; Monroe Co.,* 26 Oct. 1976; on *Solanum tuberosum* L. (potato), Knox Co., 2 May 1975.

Lecanium corni Bouche, 1844 (European fruit lecanium). Collection records: on *Acer negundo* L. (boxelder), Sevier Co.,* 10 Jul. 1976; on *A. rubrum* L. (red maple), Blount Co.,* 17 Aug. 1976; Knox Co., 17 Jun. 1975; on *A. saccharinum* L. (silver maple), Sullivan Co.,* 9 Jun. 1977; on *Buxus sempervirens* L. (common box), Sevier Co., 10 Jul. 1976; on *Carpinus caroliniana* Walt. (American hornbeam), Blount Co., 5 Aug. 1976; on *Carya illinoensis* (Koch) (pecan), Tipton Co.,* 30 May 1977; on *C. tomentosa* Nutt. (mockernut hickory), Blount Co., 17 Aug. 1976; on *Celtis occidentalis* L. (hackberry), Knox

Co., 2 Jul. 1976; Sevier Co., 2 Aug. 1977; on *Cornus florida* L. (flowering dogwood), Knox Co., 13 March 1977; on *Fraxinus americana* L. (white ash), Knox Co., 5 May 1977; on *Liquidambar styraciflua* L. (sweetgum), Blount Co., 22 Jul. 1976; on *Liriodendron tulipifera* L. (yellow-poplar), Blount Co., 3 Aug. 1977; Cocke Co.,* 31 Aug. 1977; Shelby Co.,* 26 Jun. 1976; on *Nyssa sylvatica* Marsh. (blackgum), Cocke Co., 24 Aug. 1977; on *Pyraecanthia* sp. (firethorn), Knox Co., 25 Aug. 1977; on *Salix nigra* Marsh. (black willow), Sevier Co., 1 May 1977; on *Tilia americana* L. (American basswood), Knox Co., 5 May 1977; on *Ulmus americana* L. (American elm), Knox Co., 5 May 1977; Shelby Co., 9 Aug. 1977; on *U. parvifolia* Jacq. (Chinese elm), Sevier Co., 2 Aug. 1977; on *U. thomasi* Sarg. (rock elm), Knox Co., 5 May 1977.

Lecanium fletcheri Cockerell, 1893 (Fletcher scale). Collection records: on *Juniperus virginiana* L. (eastern redcedar), Sevier Co.,* 20 Jul. 1977.

Lecanium nigrofasciatum Pergande, 1898 (terrapiin scale). Collection records: on *Platanus occidentalis* L. (sycamore), Blount Co.,* 21 Oct. 1977.

Lecanium persicae (Fabricius), 1776 (European peach scale)*. Collection records: on *Pracantha* sp. (firethorn) Cocke Co., 24 Aug. 1977.

Lecanium quercifex Fitch, 1859 (oak lecanium)*. Collection records: on *Quercus alba* L. (white oak), Blount Co., 10 Sept. 1976; Cocke Co., 1 Sept. 1977; Sevier Co., 19 Aug. 1976; on *Q. nigra* L. (water oak), Knox Co., 1 Jun. 1976; Shelby Co., 27 Apr. 1977; on *Q. palustris* Muenchh. (pin oak), Knox Co., 26 Jun. 1975; Shelby Co., 26 Jun. 1975; on *Q. phellos* L. (willow oak), Shelby Co., 26 Jun. 1975; on *Q. prinus* L. (chestnut oak), Blount Co., 24 Aug. 1977; on *Q. rubra* L. (northern red oak), Blount Co., 28 Jul. 1977; Knox Co., 1 Jun. 1976; Sevier Co., 16 Sept. 1976; on *Q. stellata* Wangenh. (post oak), Blount Co., 17 Aug. 1976; on *Q. velutina* Lam. (black oak), Blount Co., 25 Jul. 1976.

Neolecanium cornuparvum (Thro), 1903 (magnolia scale)*. Collection records: on *Magnolia tripetala* L. (umbrella magnolia), Cocke Co., 1 Sept. 1977.

Pulvinaria acericola (Walsh and Riley), 1868 (cottony maple leaf scale). Collection records: on *Acer negundo* L. (boxelder), Hancock Co.* and Sevier Co.,* 10 Jul. 1976; on *A. rubrum* L. (red maple), Blount Co.,* 8 Jul. 1976; Knox Co., 6 Jun. 1976; on *A. saccharum* Marsh. (sugar maple), Knox Co., 5 May 1977; on *Cornus florida* L. (flowering dogwood), Sullivan Co.,* 9 Jun. 1977.

Pulvinaria innumerebilis (Rathvon), 1854 (cottony maple scale). Collection records: on *Acer negundo* L. (boxelder), Sevier Co.,* 10 Jul. 1976; on *A. rubrum* L. (red maple), Blount Co.,* 17 Aug. 1976; Knox Co., 17 Jun. 1975; on *A. saccharinum* L. (silver maple), Sullivan Co., 9 Jun. 1977; on *Carpinus caroliniana* Walt. (American hornbeam), Blount Co., 23 Jun. 1976; Sevier Co., 9 Jun. 1977; on *Cornus florida* L. (flowering dogwood), Knox Co., 13 Mar. 1977; on *Quercus palustris* Muenchh. (pin oak), Shelby Co.,* 26 Jun. 1975; on *Ulmus thomasi* Sarg. (rock elm), Knox Co., 5 May 1977.

Saissetia coffeae (Walker), 1852 (hemispherical scale). Collection records: on *Chlorophyllum comosum* Bak. (spider plant), Hamilton Co.,* 12 Jul. 1977; Knox Co.,* 12 Sept. 1977.

Saissetia miranda (Cockerell and Parrott), 1899 (Mexican black scale)*. Collection records: on *Cornus florida* L. (flowering dogwood), Knox Co., 6 Oct. 1975; on *Ficus benjamina* L. (weeping fig), Knox Co., 23 Apr. 1975.

Toumeyella liriodendri (Gmelin), 1789 (tuliptree scale). Collection records: on *Liriodendron tulipifera* L. (yellow-poplar), Bedford Co.,* 14 Oct. 1975; Blount Co.,* 21 Sept. 1977; Knox Co., 18 Feb. 1975; Shelby Co., 26 Jun. 1975; Sullivan Co.,* 11 Jul. 1975; Sumner Co.,* 20 Aug. 1976.

Toumeyella parvicornis (Cockerell), 1897 (pine tortoise scale). Collection records: on *Pinus taeda* L. (loblolly pine), Knox Co.,* 12 Feb. 1977.

Toumeyella pini (King), 1901 (striped pine scale). Collection records: on *Pinus rigida* Mill. (pitch pine), Blount Co.,* 6 Sept. 1976.

DIASPIDIDAE

Aburataspis comstocki (Johnson), 1896 (Comstock scale). Collection records: on *Acer pensylvanicum* L. (striped maple), Sevier Co.,* 19 Aug. 1976.

Aburataspis howardi (Cockerell), 1895 (Howard scale). Collection records: on *Cornus florida* L. (flowering dogwood),

- Blount Co.,* 3 Aug. 1977; on *Liquidambar styraciflua* L. (sweetgum), Blount Co., 21 Sept. 1977; on *Robinia pseudoacacia* L. (black locust), Cocke Co.,* 23 Aug. 1977.
- Abgrallaspis ithacae* (Ferris), 1938 (hemlock scale). Collection records: on *Tsuga canadensis* (L.) (eastern hemlock), Blount Co.,* 8 Jul. 1976; Cocke Co.,* 23 Aug. 1977; Knox Co.,* 30 Oct. 1977; Sevier Co.,* 10 Jul. 1976.
- Abgrallaspis townsendi* (Cockerell), 1896 (Townsend scale)*. Collection records: on *Cornus florida* L. (flowering dogwood), Blount Co., 3 Aug. 1977.
- Acutaspis morrisonorum* Kosztarab, 1963 (round conifer scale)*. Collection records: on *Tsuga canadensis* (L.) (eastern hemlock), Sevier Co., 2 Aug. 1977.
- Acutaspis perseae* (Comstock), 1881 (red bay scale)*. Collection records: on unknown host, Maury Co., 18 Nov. 1975.
- Aspidiotus nerii* Bouche, 1833 (oleander scale). Collection records: on *Aucuba japonica variegata* Donbr. (golddust tree), Overton Co.,* 24 Feb. 1976; on *Howea belmoreana* Becc. (belmore sentry palm), Blount Co.,* 3 Aug. 1977.
- Aulacaspis rosae* (Bouche), 1833 (rose scale). Collection records: on *Rosa* sp., Knox., 9 Sept. 1977.
- Carulaspis juniperi* (Bouche), 1851 (juniper scale). Collection records: on *Juniperus virginiana* L. (eastern redcedar), Blount Co.,* 2 Aug. 1977; Cocke Co.,* 23 Aug. 1977; Knox Co., 30 Oct. 1977; Sevier Co.,* 26 Jul. 1977; on *Thuja occidentalis* L. (eastern arborvitae), Knox Co., 8 Jul. 1977.
- Carulaspis minima* (Targioni-Tozzetti), 1869 (minute cypress scale)*. Collection records: on *Juniperus virginiana* L. (eastern redcedar), Knox Co., 12 Jul. 1977.
- Chionaspis americana* Johnson, 1896 (elm scurfy scale). Collection records: on *Carpinus caroliniana* Walt. (American hornbeam), Blount Co.,* 20 Aug. 1977; Sevier Co.,* 5 Oct. 1977; on *Ulmus americana* L. (American elm), Knox Co., 18 Aug. 1977; on *U. rubra* Muhl. (red elm), Blount Co., 31 Jul. 1977.
- Chionaspis furfura* (Fitch), 1857 (scurfy scale). Collection records: on *Malus angustifolia* (Ait.) (Southern crab apple), Cocke Co.,* 23 Apr. 1977.
- Chionaspis gleditsiae* Sanders, 1903 (honeylocust scale). Collection records: on *Gleditsia triacanthos* L. (honeylocust), Knox Co., 16 Jul. 1975.
- Chionaspis heterophyllae* Cooley, 1897 (pine scale)*. Collection records: on *Pinus virginiana* Mill. (Virginia pine), Blount Co., 17 Aug. 1976; Cocke Co., 24 Aug. 1977; Grainger Co., 21 Jul. 1975; Knox Co., 15 Aug. 1976; Sevier Co., 19 Aug. 1976.
- Chionaspis kosztarabi* Takagi and Kawai, 1967 (Kosztarab scale)*. Collection records: on *Fraxinus americana* L. (white ash), Knox Co., 18 Apr. 1975. *C. near kosztarabi* (leaf form), on *Carpinus caroliniana* Walt. (American hornbeam), Blount Co., 29 Jul. 1976; Sevier Co., 5 Oct. 1977.
- Chionaspis nyssae* Comstock, 1881 (sour gum scale)*. Collection records: on *Nyssa sylvatica* Marsh. (blackgum), Blount Co., 22 Jul. 1976; Cocke Co., 31 Aug. 1977; Knox Co., Jul. 1976; Sevier Co., 19 Aug. 1976.
- Chionaspis pinifoliae* (Fitch), 1856 (pine needle scale). Collection records: on *Juniperus virginiana* L. (eastern redcedar), Knox Co.,* Jul. 1977; on *Picea rubens* Sarg. (red spruce), Knox Co., 19 Jul. 1976; on *Pinus* sp., Knox Co., 13 Jul. 1976; Shelby Co.,* 25 Jul. 1975; on *Pinus strobus* L. (eastern white pine), Blount Co.,* 15 Jul. 1976; Cocke Co.,* Aug. 1977, Knox Co., 3 Oct. 1976; Shelby Co., 24 Jul. 1977; on *P. virginiana* Mill. (Virginia pine), Blount Co., 8 Jul. 1976; on *Tsuga canadensis* (L.) (eastern hemlock), Blount Co., 13 Jul. 1977; Knox Co., 30 Oct. 1977; Sevier Co.,* 8 Aug. 1976.
- Chionaspis salicisnigrae* (Walsh), 1868 (black willow scale)*. Collection records: on *Liquidambar styraciflua* L. (sweetgum), Blount Co., 21 Sept. 1977; on *Salix nigra* Marsh. (black willow), Knox Co., 18 Mar. 1976.
- Chionaspis spinicola* (Dietz and Morrison), 1916 (spine scale)*. Collection records: on *Gleditsia triacanthos* L. (honeylocust), Knox Co., 16 Jul. 1975.
- Diaspidiotus ancylus* (Putnam), 1878 (Putnam scale). Collection records: on *Acer* sp., Giles Co.,* 25 Sept. 1975; on *Cornus florida* L. (flowering dogwood), Knox Co., 21 Jul. 1977; on *Platanus occidentalis* L. (sycamore), Knox Co., 17 Aug. 1977; on *Robinia pseudoacacia* L. (black locust) Cocke Co.,* 23 Aug. 1977.
- Diaspidiotus hunteri* (Newell), 1899*. Collection records: on *Liriodendron tulipifera* L. (yellow-poplar), Knox Co., 25 Jan. 1977.
- Diaspidiotus liquidambaris* (Kotinsky), 1903 (sweetgum scale). Collection records: on *Liquidambar styraciflua* L. (sweetgum), Blount Co.,* 29 Jun. 1976; Cocke Co.,* 1 Sept. 1977; Knox Co., 22 Jul. 1976; Sevier Co.,* 2 Aug. 1977.
- Diaspidiotus osborni* (Newell and Cockerell), 1898 (Osborn scale). Collection records: on *Betula pendula* Roth. (European white birch), Knox Co.,* 27 Dec. 1977; on *Cornus florida* L. (flowering dogwood), Blount Co.,* 26 Aug. 1976; on *Platanus occidentalis* L. (sycamore), Knox Co., 14 Jul. 1977; on *Quercus palustris* Muenchh. (pin oak), Knox Co., 5 Aug. 1977.
- Diaspidiotus uvae* (Comstock), 1881 (grape scale). Collection records: on *Vitis* sp. (grape), Blount Co.,* 17 Aug. 1976; Washington Co.,* 9 Jun. 1976.
- Diaspis boisduvalii* Signoret, 1869 (Boisduval scale). Collection records: on *Cattleya* sp. (orchid), Hamilton Co., Nov. 1975.
- Diaspis echinocacti* (Bouche), 1833 (cactus scale). Collection records: on *Zygocactus* sp., Loudon Co.,* 24 Oct. 1977.
- Fiorinia theae* Green, 1900 (tea scale). Collection records: on *Camellia* sp., Shelby Co.,* 27 Apr. 1976; on *Ilex cornuta* Lindl. and Pax. (Chinese holly), Bradley Co.,* 1 Aug. 1975; on *I. c. burfordi* DeFran. (Burford holly), Knox Co.,* 23 Jul. 1975; on *I. opaca* Ait. (American holly), Bradley Co., 1 Aug. 1975; Shelby Co., 26 Jun. 1975.
- Genaparlatoria pseudaspidiotus* (Lindinger), 1905 (vanda orchid scale)*. Collection records: on *Cattleya* sp. (orchid), Hamilton Co., Feb. 1975.
- Hemiberlesia diffinis* (Newstead), 1893 (diffinis scale). Collection records: on *Liriodendron tulipifera* L. (yellow-poplar), Knox Co.,* 23 Jun. 1975; on *Nyssa sylvatica* Marsh. (blackgum), Knox Co., 9 Jul. 1977.
- Hemiberlesia lataniae* (Signoret), 1869 (latania scale). Collection records: on *Ilex cornuta burfordi* DeFran. (Burford holly), Knox Co.,* 25 Feb. 1977; on *I. crenata* Thunb. (Japanese holly), Shelby Co.,* 17 Aug. 1977; on *I. c. hetzi* (Hetzi holly), Knox Co., 8 Jul. 1977.
- Lepidosaphes beckii* (Newman), 1869 (purple scale). Collection records: on *Citrus limon* Burm. (ornamental lemon), Sequatchie Co.,* 29 Jul. 1977; on *C. sinensis* Osbeck. (sweet orange), Knox Co.,* Nov. 1974.
- Lepidosaphes ulmi* (L.), 1758 (oystershell scale). Collection records: on *Acer saccharinum* L. (silver maple), Knox Co., 7 Aug. 1975; on *Acer* sp., Jefferson Co.,* 22 Mar. 1976.
- Lepidosaphes yanagicola* Kuwana, 1925 (yanagicola scale). Collection records: on *Cladrastis lutea* (Michx.) (yellowwood), Knox Co., 3 Nov. 1977.
- Melanaspis obscura* (Comstock), 1881 (obscure scale). Collection records: on *Liriodendron tulipifera* L. (yellow-poplar), Knox Co.,* 19 Jun. 1975; on *Quercus alba* L. (white oak), Blount Co., 5 Aug. 1976; on *Q. nigra* L. (water oak), Knox Co., 17 Jun. 1975; on *Q. palustris* Muenchh. (pin oak), Knox Co., 28 May 1976; Williamson Co.,* 9 Jun. 1976; on *Q. phellos* L. (willow oak), Knox Co., Jun. 1976; on *Quercus* sp., Hamilton Co., 30 Sept. 1977; Madison Co.,* 26 Jun. 1975; Shelby Co., 26 Jun. 1975; Washington Co.,* 27 Oct. 1975.
- Melanaspis tenebricosa* (Comstock), 1881 (gloomy scale). Collection records: on *Acer saccharinum* L. (silver maple), Knox Co., 7 Sept. 1977; Lawrence Co.,* 16 Jul. 1976; Shelby Co., 26 Jun. 1975.
- Parlatoria proteus* (Curtis), 1843 (proteus scale)*. Collection records: on *Hoya* sp., Loudon Co., 24 Oct. 1977.
- Pinnaspis aspidistrae* (Signoret), 1869 (fern scale). Collection records: on *Liriope muscari* Bail. (lilyturf), Knox Co.,* 13 Feb. 1976; on *L. spicata* Lour. (creeping lilyturf), Knox Co., 27 Mar. 1975; on *Pteris cretica* L. (stove fern), Knox Co., 23 Oct. 1975.
- Protodiaspis varus* Hoke, 1928*. Collection records: on *Quercus palustris* Muenchh. (pin oak), Knox Co., 19 Aug. 1977.
- Pseudaulacaspis cockerelli* (Cooley), 1897 (false oleander scale). Collection records: on palm, Shelby Co., 6 Feb. 1976.
- Pseudaulacaspis pentagona* (Targioni-Tozzetti), 1885 (white peach scale). Collection records: on *Broussonetia papyrifera* (L.) (paper mulberry), Knox Co.,* 4 Jun. 1977; on *Morus rubra* L. (red mulberry), Knox Co., 2 Jul. 1976; on *Prunus persica* (L.) (peach), Grainger Co.,* 19 Apr. 1976; Knox Co., 30 Jul. 1975; Jefferson Co.,* 8 Mar. 1977; on *Prunus* sp., Knox Co., 16 Jun. 1976; Sullivan Co.,* 11 Apr. 1977.
- Quadraspidiotus forbesi* (Johnson), 1896 (Forbes scale). Collection records: on *Ilex* sp., (holly), Shelby Co.,* 2 Jul. 1977; on *Robinia pseudoacacia* L. (black locust), Cocke Co.,* 23 Aug. 1977.

Quadraspidiotus juglansregiae (Comstock), 1881 (walnut scale). Collection records: on *Acer* sp. (maple), Knox Co.,* 30 Dec. 1977; on *Cladrastis lutea* (Michx.) (yellowwood), Knox Co., 2 Sept. 1977; on *Cornus florida* L. (flowering dogwood), Blount Co.,* 17 Aug. 1976; Knox Co., 4 Apr. 1975; on *Fraxinus americana* L. (white ash), Knox Co., 16 Aug. 1975; on *Ilex crenata* Thunb. (Japanese holly), Shelby Co., 17 Aug. 1977; on *Liriodendron tulipifera* L. (yellow-poplar), Knox Co., 25 Jun. 1976; on *Quercus palustris* Muenchh. (pin oak), Knox Co., 6 Aug. 1976.

Quadraspidiotus perniciosus (Comstock), 1881 (San Jose scale). Collection records: on *Betula pendula* Roth. (European white birch), Knox Co., 27 Dec. 1977; on *Liriodendron tulipifera* L. (yellow-poplar), Knox Co., 26 Jun. 1975; on *Malus hybrida* Desf. (flowering crab apple), Knox Co., 7 Aug. 1975; on *Malus pumila* Mill. (apple), Cocke Co.,* 23 Aug. 1977; Davidson Co., 29 Aug. 1976; Polk Co., 6 Oct. 1976; Sullivan Co., 11 Apr. 1977; on *Prunus persica* (L.) (peach), Sullivan Co., 11 Apr. 1977; on *Pyrus* sp., Morgan Co.,* 12 Jul. 1976.

Unaspis euonymi (Comstock), 1881 (euonymus scale). Collection records: on *Euonymus alata* (Thunb.) (winged euonymus), Blount Co.,* 18 May 1977; Campbell Co.,* 31 Aug. 1976; Knox Co.,* 22 Aug. 1976.

Velataspis dentata (Hoke), 1921, (dentata scale). Collection records: on *Cornus florida* L. (flowering dogwood), Blount Co.,* 7 Aug. 1977.

CONCLUSIONS

In this study, 74 species on 206 hosts were collected from November 1974 through December 1977.

Twenty-six species were recorded for the first time in Tennessee, and 142 new county records were obtained.

Several species are host specific at least to the plant family level. Oligophagous species obtained were: *Asterolecanium minus*, *Kermes galliformis*, *K. pubescens*, *Lecanium quercifex* and *Protodiaspis varus* on Fagaceae; *Diaspis echinocacti* and *Eriococcus coccineus* on Cactaceae; *Diaspidiotus liquidambaris* on Hamamelidaceae; *Chionaspis pinifoliae*, *Matsucoccus gallicolus*, *Toumeyella parvicornus* and *T. pini* on Pinaceae; and *Neolecanium cornuparvum* on Magnoliaceae. All other species collected were polyphagous (eg. *Lepidosaphes ulmi* and *Planococcus citri*) and have been recorded on hundreds of hosts.

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A MATHEMATICAL ANALYSIS OF WORLD CHESS CHAMPIONSHIP SYSTEMS

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ABSTRACT

In 1975 Robert Fischer resigned his title as Chess Champion of the World in a dispute with FIDE, the world chess organization, over the match rules for his upcoming title defense. Proceeding from the premise that it is the object of every chess match to determine which of two players is the better, several match systems are analyzed. The systems are compared in terms of the match winning probabilities of two hypothetical players, Alpha and Beta, under each set of match rules. Formulas for these probabilities are derived in terms of the symbols, A, B, and D which represent the per game probabilities of a win by Alpha, a win by Beta, and a drawn game, respectively. The systems are then compared to determine which one most favors the better player. The match systems treated include the 1972 match rules, in effect when Fischer won his title; the Fischer system, proposed in 1975; and the 1978 system, used in the recent world championship match between Anatoly Karpov and Victor Korchnoi.

INTRODUCTION

In 1975 Robert Fischer resigned his title as World Chess Champion in a dispute with FIDE, the world chess organization, over the match rules for his title

defense. When Fischer won the title the match rules were as follows:

- (1) The match consisted of a maximum of twenty-four games with 1 point being awarded to the winner of a game and $\frac{1}{2}$ point to each player for a drawn game.
- (2) The first player to score more than 12 points wins the match and the title, but in the event of a drawn match (12-12) the champion retains the title.

Fischer proposed that this system be changed as follows:

- (1) The first player to score 10 wins, wins the match and title.
- (2) Draws do not count and, therefore, there is no fixed limit on the number of games played.
- (3) Should the score ever reach 9-9, the match is declared a draw and the champion retains his title.

FIDE agreed to all of Fischer's proposals except the last. Opponents argued that this clause gave the Champion an unfair advantage, since a challenger would have to win by at least a two game margin (10-8), whereas a one game margin would be sufficient under the old