TAXONOMIC, DISTRIBUTIONAL, AND HYBRIDIZATION COMPARISONS BETWEEN TYPHLODROMUS LONGIPILUS NESBITT AND TYPHLODROMUS OCCIDENTALIS NESBITT (ACARINA: PHYTOSEIDAE)

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ABSTRACT

TAXONOMIC, DISTRIBUTIONAL, AND HYBRIDIZATION COMPARISONS
BETWEEN TYPHLODROMUS LONGIPILUS NESBITT
AND TYPHLODROMUS OCCIDENTALIS NESBITT
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By

Stephen Anthony Hoying

Investigations were made into the taxonomic, hybridizational, and geographic relationships between two similar phytoseiid mites, Typhlodromus longipilus Nesbitt and Typhlodromus occidentalis Nesbitt.

It was demonstrated using Multiple Range and Principal Component Analysis techniques, that there was a distinct anatomical separation interspecifically and a lesser separation intraspecifically.

Geographically, T. longipilus was found most frequently in the temperate northeastern portions of the United States and Canada. T. occidentalis was commonly encountered in the more arid agricultural regions of the western United States and Canada, and in glasshouses in the Netherlands.

Hybridization tests indicated significant reproductive isolation between T. longipilus and T. occidentalis. These tests showed that reported populations of T. longipilus from the Netherlands were conspecific with populations of T. occidentalis from California, Utah, and Washington.

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By

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To my family--

for understanding, support and love.

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INTRODUCTION

The taxonomy of the Phytoseiidae has been in a constant state of flux for the past two decades. This has largely been caused by the rapid increase in numbers of known species in the family, from 20 (Nesbitt, 1951) to over 450 (Chant, 1965). Major revisions and reviews of the family have been undertaken in an attempt to clarify the relationships between the species (Nesbitt, 1951; Baker and Wharton, 1952; Chant, 1959; Muma, 1961; Wainstein, 1962; Pritchard and Baker, 1962; Hirshmann, 1962; Schuster and Pritchard, 1963; Westerboer and Bernhard, 1963). Systematic disagreement within the family is particularly apparent at the generic level; where Chant (1959) designated only eight genera, Schuster and Pritchard (1963) sixteen, and Muma (1961) forty-three.

At the species level, the status of the mite predators, Typhlodromus longipilus Nesbitt and Typhlodromus occidentalis Nesbitt is indicative of the taxonomic problems that have arisen. Their morphological similarity have caused some authors to consider them conspecific (Schuster and Pritchard, 1963), while others considered them to be separate species (Nesbitt, 1951; Chant, 1959; Muma, 1961).

The original descriptions of T. longipilus and T. occidentalis were based on a limited number of specimens (Nesbitt, 1951) and a variety of characters, many of which have since proven to exhibit wide

variation (Croft and McMurtry, 1972; Davis, 1970). Quantitative analysis of taxonomic characters was extremely rare in the literature and in these instances, only limited numerical treatment of important diagnostic features (Nesbitt, 1951; Chant, 1959; Muma, 1961) was made. Some cases of erroneous intraspecific identifications in the literature (Fleschner and Ricker, 1954; Hantsbarger and O'Neill, 1954; Fleschner, 1958; Oatman, 1963; Burrill and McCormick, 1964) have persisted up to the present time and have caused confusion as to the geographic distributions of these two species. Hybridization studies to elucidate interspecific differences have been done by a few workers including Croft and McMurtry (1972) and Kennett (unpublished data); however there has been no published work on intraspecific relationships.

In the current literature, T. longipilus and T. occidentalis are commonly referred to by three different generic names including Typhlodromus (Chant, 1959; 1965), Galendromus (Muma, 1961), and Metaseiulus (Schuster and Pritchard, 1963). In this thesis, the generic system designed by Chant will be used for simplicity sake. The research herein was conducted to:

(1) Determine if T. longipilus and T. occidentalis were indeed distinct species using recognized taxonomic principles including hybridization studies.

(2) To identify and quantify taxonomic characters which could be used to distinguish between the two species, and to establish their geographic distribution as far as possible.

(3) If they were found to be conspecific, to combine, by hybridization, certain valuable features found in particular

populations in the western United States (high insecticide-resistance), with the essential features of populations in the eastern United States (the ability to survive under more humid environmental conditions), in an attempt to improve biocontrol in the eastern United States with another effective predator.

LITERATURE REVIEW

Taxonomy

Of the papers cited previously, only a few contain descriptions of T. longipilus and T. occidentalis. They include works by Nesbitt (1951), Cunliffe and Baker (1953), Chant (1959), Muma (1963), and Schuster and Pritchard (1963). A brief review of each is given since these publications contain the most detailed descriptions of these two species. All setal nomenclature used by these authors has been converted to that designed by Garman (1948) for the Phytoseiidae.

In Nesbitt's (1951) revision of the family Phytoseiidae, he included T. longipilus and T. occidentalis as new species. His descriptions included all the characteristics that were thought to be fundamental in phytoseiid taxonomy (Merwe and Ryke, 1963), including overall length and width of the mite; length, arrangement on the scutum, and numbers of dorsal and lateral setae; numbers and descriptions of the teeth on the fixed cheliceral digit; numbers of setal pairs on the sternal scutum; shape of the ventrianal shield and the number of pairs of setae thereon; a description of the peritremal plate; and the significant leg setation. He separated T. longipilus and T. occidentalis on the basis of anatomical differences which included overall length and width; the subjective character, the length of the dorsal setae based on the ratio of the setal lengths to

the distances between the bases of each succeeding seta; the more heavily sclerotized and noticeably imbricate dorsum of T. occidentalis; and four pairs of pre-anal setae on the ventrianal shield of T. longipilus versus only three corresponding pairs on T. occidentalis.

In 1953, Cunliffe and Baker published a practical field guide to the female phytoseiids commonly encountered in the United States. They included the characteristics as given by Nesbitt (1951) in his original description and also recognized the varying lengths of the peritreme as a discriminant diagnostic feature of T. longipilus and T. occidentalis. Peritreme length was measured in their description by comparing its anterior extension with its position on the adjacent coxal cavity. In T. occidentalis, the peritreme is very short, reaching the middle of coxa III; in T. longipilus, it is longer, reaching the posterior margin of coxa II. Cunliffe and Baker failed to use the peritreme length in their diagnostic key. Instead, these two species were again separated by the numbers of pre-anal setal pairs on the ventrianal shield.

Chant (1959) published the first world-wide review of the family Phytoseiidae. In it, he broke up each genus into smaller taxonomic units termed "family groups," each with a representative member after which the group was named. T. occidentalis, T. longipilus, T. gratus (Chant), and T. helveolus (Muma) were included in the T. OCCIDENTALIS group. This was the first time that these mites were lumped together by a classification system below the generic level.

Chant's descriptions of T. longipilus and T. occidentalis differed slightly with those of Nesbitt (1951). He included another

anatomical feature not previously used; the metapodal plates, of which both species were said to have only one pair. Another incongruity arose out of the taxonomic significance attributed to the numbers of pre-anal setae on the ventrianal plates. Chant stated that Nesbitt had obtained an aberrant specimen of T. occidentalis and that four rather than three pairs of pre-anal setae were the usual number, making it an unreliable characteristic.

Chant's description of T. longipilus placed most of its emphasis on the subjective length of the dorsal setae. He also used the lengths of the dorsal setae in relation to the distances between their bases as a diagnostic character. He recognized the differences in peritreme length between the two species and included it in his diagnostic key as a secondary feature.

Schuster and Pritchard (1963) published a review of the Phytoseiidae of California. In it they included only T. occidentalis, yet commented on the question of conspecificity of the two species. Their description of T. occidentalis was the first attempt at quantifying all characters used in distinguishing this species. They recognized the differences in peritreme length and stated that California specimens of T. occidentalis had peritremes ranging from 25-42 μ in length and that the peritreme length of T. longipilus varied from 64-80 μ in the limited number that they had measured from outside California. Unlike Cunliffe and Baker (1953), who used coxal position to mark the length of the peritreme, they used the position of lateral setae III as a marker. They found that the absolute length of the dorsal and lateral setae were comparable, and lengthened progressively from 25-60 μ.

From the above data, Schuster and Pritchard (1963) concluded that T. longipilus and T. occidentalis were probably not distinct species. They described T. occidentalis on the basis of dorsal shield length (315 μ) and width (216 μ) and pattern; length of the dorsal setae (25-60 μ) and the remaining setae (48-65 μ); length and width of the ventrianal plate (60 x 100 μ) and the number of pairs of setae thereon; length and width of the metapodal platelets; and measurements and descriptions of the spermatheca. They were the first to describe and diagram significant features of the male including the ventrianal shield and the spermodactyl.

Muma (1963) published an important paper on the genus Galendromus that included descriptions of T. longipilus and T. occidentalis. He used only two measurements in his descriptions of these two species, dorsal shield length and dorsal shield width. The mites that he compared showed distinct overlap in the length of the dorsal shield, with T. longipilus the narrowest. The dorsal setae of both species were said to be elongate, plumose, and subequal in length. Muma again used the difference in dorsal setae length as a key character; T. longipilus was said to have strong overlapping of the dorsal setae whereas T. occidentalis had only slight if any overlapping of the dorsal setae. The ventrianal scutum was described in both species, but for the first time pre-anal setation was not mentioned. He used the peritreme in his diagnostic key as the primary distinguishing feature, and the length of the dorsal setae as the secondary character. Muma stated that peritreme length in T. occidentalis was

short, extending to lateral setae V, while in T. longipilus it extended to lateral setae IV.

Diagrams of the spermatheca were another descriptive feature in Muma's work. Males were described in terms of length and width of the dorsal scutum and structure of the ventrianal shield. He also mentioned the male peritreme length, and diagrammed the structure of the spermatophore bearer (spermodactyl of Schuster and Pritchard, 1963).

Muma and Denmark (1962, 1969) stated that T. occidentalis and T. longipilus were actually sibling species since they were identical in dorsal and ventral setation, leg chaetotaxy, and spermathecal and spermadactyl form. They concluded that such sibling species could only be distinguished by a systematic, numerical comparison of setal form and lengths, scutal size and form, and length to width ratios of spermatheca, spermatodactyls, peritremes, etc. T. longipilus and T. occidentalis were diagnosed together below the generic level as having median setae I as long as or longer than dorsal setae II, the peritreme not extending forward beyond lateral setae IV, the ventrianal scutum elongate with the ventrianal pores punctate, and the spermathecal cervix slender and saccular.

Geographic Distribution

There have been widely scattered reports of T. longipilus and T. occidentalis occurring throughout much of the temperate regions of the United States and Canada. Nesbitt (1951) originally reported specimens of T. longipilus from Ontario, Quebec, New Brunswick, Prince

Edward Island, Geneva, New York and Harwood, Washington. T. occidentalis was reported from British Columbia and Manitoba, Canada.

There are also many reports regarding the recovery of T. longipilus in the field. It has been reported from Washington, the Yakima (Burrill and McCormick, 1964) and Wenatchee areas (Hantsbarger and O'Neill, 1954); southern California (Fleschner and Ricker, 1954; Fleschner, 1958); Missouri (Poe and Enns, 1969; Zack, 1969); the delta region of Mississippi (Smith and Furr, 1975); Indiana (Hamilton, 1955); Ohio (Muma, 1961); Michigan (Croft, unpublished data); Wisconsin (Cunliffe and Baker, 1953; Oatman, 1963); Pennsylvania (Horsburg and Asquith, 1967); Ontario (Putnam, 1959); Manitoba (Robinson, 1951); Nova Scotia (Herbert, 1953); Quebec (Parent, 1958; 1973); New Jersey (Specht, 1968; Knisley and Swift, 1972); Bulgaria (Balewski, 1960); Honduras (Chant and Baker, 1965); Costa Rica (Chant and Baker, 1965); the Netherlands (Bravenboer, 1959; Kuchlein, 1965; 1966); and Switzerland (Van de Vrie, personal communication).

T. occidentalis has been reported from various locations throughout California (Schuster and Pritchard, 1963; McMurtry et al., 1970; Kinn and Dout, 1972); in Oregon along the Hood River and the Rogue River valleys (Westigard, 1970; Zwick, 1972); in Washington near Yakima and Wenatchee (Hoyt, 1969a), and in southern Washington (Pruszynski and Cone, 1973); Utah, northern region (Lee and Davis, 1968), and the central region (Leetham and Jorgensen, 1969); central British Columbia (Anderson et al., 1958; Downing and Moillet, 1971); Wisconsin (Oatman, 1963); and in Europe (Chant, 1959; Fransz, 1974).

The value of T. occidentalis as an insecticide-resistant natural enemy of many important phytophagus spider mites has facilitated its distribution to several other parts of the world. These include introductions into Idaho (Larson, 1970), and Colorado, U.S.A. (Quist, 1974), Australia (Springett, 1975) and the Netherlands (Kirby, 1973; Fransz, 1974) for actual field release, and in Israel (Swirski and Dorzia, 1969), and in the U.S.S.R. and Chile (unpublished data) for study and possible field release.

Ecology and Biology

T. longipilus and T. occidentalis have been found on a variety of plants and associated with a variety of prey. Extensive lists of host plants have been tabulated by Nesbitt (1951), Chant (1959), Schuster and Pritchard (1963), Specht (1968), Poe and Enns (1969), and McMurtry et al. (1971). Specht (1968) found T. longipilus on apple, oak, and burdock near apple, and in the greenhouse on large peaches, bean, cotton, chrysanthemum, hollyhock, maple, and rose. J. W. Smith (1975) reported T. longipilus on cotton; Poe and Enns (1969) on willow; Parent (1973), Knisley and Swift (1972), Oatman (1963), and Specht (1968) on apple; and Putnam (1959), Cunliffe and Baker (1953) on peaches.

Hoyt (1969a), Lee and Davis (1969), Quist (1974), and many others have reported T. occidentalis on apple; Flaherty and Huffaker (1970) on grape; Huffaker and Flaherty (1966) on strawberry; Westigard (1970) on pear; Pruzynski and Cone (1973) on hops; and Caltagirone (1970) on peaches.

More important than the host plant is the prey on which these predators feed. Both species are frequently found associated with large populations of tetranychid mites. T. occidentalis seems to thrive on prey that are strongly aggregrating and produce heavily webbed colonies (Flaherty, 1967). It feeds on Eotetranychus willamettei McGregor, Tetranychus mcdanieli McGregor, Tetranychus pacificus McGregor, and Tetranychus urticae Koch (McMurtry et al., 1970). Non-tetranychids that T. occidentalis is known to feed on include Eriophyes vitis Nalepa, Stenotarsonemus pallidus (Banks) (Schuster and Pritchard, 1963), and Aculus schlechtendali (Nalepa) (Hoyt, 1969a). The reported prey of T. longipilus include Panonychus ulmi (Koch), Tetranychus schoenei (McGregor), T. canadensis (McGregor), T. urticae Koch, Eotetranychus populi (Koch), E. ulmi (Reck), E. coryli (Reck), and Brevipalpus glomeratus Pritchard and Baker (Zack, 1969; Hamilton, 1955).

Some of the important biological and physiological parameters of these two species have also been evaluated. T. occidentalis, because of its importance as a biological control agent on many fruit crops in the western United States, has been extensively studied by Waters (1955), Sharma (1966), Lee and Davis (1968), Liang (1969), and Croft and McMurtry (1972). Conversely, T. longipilus has been studied infrequently due to its scarcity and relative unimportance as an effective biocontrol agent. However, it was used in a comparative study with the effective predator, Amblyseius fallacis Garman by Lee (1972). Also a species thought to be T. longipilus was extensively studied in Europe by Kuchlein (1965; 1966) and Bravenboer (1959), but

hybridization studies have shown it to be T. occidentalis (Kennett, unpublished data, see the results section).

Biological similarity between T. longipilus and T. occidentalis is evident from the available literature. Both species have an identical number of developmental stages, one larval and two nymphal (Lee, 1972; Lee and Davis, 1968). Rates of development are also similar. Liang (1969) reported the generation time of T. occidentalis to be 8.5 days at 20°C and Lee and Davis (1968) reported 6.3 days at 24°C. Lee (1972) showed T. longipilus to have a developmental time of 10.6 days at 20°C and 6.5 days at 25°C. T. longipilus produced 27-58 eggs at 25°C (Lee, 1972) whereas T. occidentalis produced 35 eggs at 20°C (Liang, 1969).

MATERIALS AND METHODS

Taxonomy

Previously prepared specimens of T. longipilus and T. occidentalis were obtained from 28 different geographic locations throughout the United States, Canada, and the Netherlands. Material was borrowed from researchers who had studied either of these two species in the past. Most of the specimens that were evaluated had been collected within the past 20 years. Table 1 contains a list of collectors, collection dates, geographic locations, and the host plants from which the specimens were taken. In addition, live colonies of mites were obtained from Washington (12, 13),[1] New Jersey (1,2), Michigan[2] (9), and California[2] (22), and were reared to provide a broader base for taxonomic comparison and other related biological studies.

Mites from live colonies were prepared for microscopic examination by mounting them in Hoyer's solution. Slides were then placed in a slide oven for 24 hours at 250°F to clear and fix the specimens so that important external and internal features could be viewed.

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[1] See Table 1 for exact locations.

[2] These colonies were subsequently lost to contamination by other phytoseiids.

Table 1.--Collection data for measured populations of T. longipilus and T. occidentalis.

Contributor	Population Code	Collection Date	Collection Location	Host
F. C. Swift	1	1973	Rutgers Univ.	Greenhouse Plants
F. C. Swift	2	1974	Rutgers Univ.	Greenhouse Plants
D. C. Herne	3	Jun. 1972 Oct. 1971	Vineland Stn., Ontario	Apple Foilage
W. L. Putman	4	May 1955 Mar. 1956 Jan. 1957 Mar. 1957 Oct. 1957	Vineland Stn. Ontario	Peach Foilage, Bark
B. Parent	5	Sep. 1954	Rougement Que.	Apple Foilage
S. L. Poe	6	Jun. 1972 Jul. 1968 Jan. 1969 Feb. 1969 Jun. 1969	Columbia Mo.	Corkscrew Willow Apple Foilage Prickly Lettuce
W. R. Enns	7	Aug. 1965 Oct. 1965 Jan. 1966 Mar. 1966 Apr. 1966 May 1966 Jul. 1966 Aug. 1967	Boonesville, Mo.	Oak Apple Maple Willow
E. R. Oatman	8	Sep. 1961	Door Co. Wisconsin	Apple Foilage
B. A. Croft	9	Nov. 1971	Clinton Co. Mich.	Apple

Table 1.--Continued.

Contributor	Population Code	Collection Date	Collection Location	Host
D. W. Davis	11	Mar. 1967 May, 1967 to Jul. 1967 Aug. 1968	Utah Co. Utah	Apple Foilage Cherry Bark Cherry Duff
B. A. Croft	12	Nov. 1971 Oct. 1971	Wenatchee, Washington	Apple
L. K. Tanagoshi	13	Jan. 1973	Wenatchee, Washington	Apple
D. W. Davis	14	Apr. 1967 Aug. 1967 Mar. 1968 Apr. 1968 Apr. 1969 Jul. 1969	Lake Co., Utah	Peach Litter Apple Bark Apple Foilage Apple Spurs
D. W. Davis	15	Mar. 1967 Apr. 1967 Jul. 1967 Sep. 1967 Mar. 1968 Apr. 1968 Jul. 1968	Utah Co. Orem Utah	Apple Foilage Apple Bark
M. Van De Vrie	16	Jan. 1966	Naaldwijk, Netherlands	Greenhouse Plants
D. W. Davis	17	Aug. 1967 Sep. 1967 Mar. 1968 Apr. 1968 Aug. 1969	Box Elder Co. Utah	Apple

Table 1.--Continued.

Contributor	Population Code	Collection Date	Collection Location	Host
D. W. Davis	18	Apr. 1967 Aug. 1967 Mar. 1968 Apr. 1969 Jul. 1969	Utah Co. Payson Utah	Apple Leaves Apple Bark
D. W. Davis	19	Jun. 1967 Jul. 1967	Salt Lake Co. Utah	Apple Leaves
B. A. Croft	20	Jul. 1968 to Sep. 1968 Nov. 1968	Yuciapa, California	Apple
B. A. Croft	21	Jul. 1968 to Sep. 1968	Wenatchee, Washington	Apple
B. A. Croft	22	Sep. 1968	Riverside, California	Citrus
B. A. Croft	23	Sep. 1968	Provo, Utah	Apple
H. B. Specht	24	Sep. 1960 Sep. 1961	Nova Scotia, Canada	Apple Beech Maple
H. B. Specht	25	Aug. 1957 Sep. 1957 Jan. 1958 Apr. 1958	Warren Co. New Jersey	Apple Peach
C. D. Jorgensen	26	Aug. 1965	Emery Co. Utah	Apple

Table 1.--Continued.

Contributor	Population Code	Collection Date	Collection Location	Host
C. D. Jorgensen	27	Jul. 1965 Aug. 1965 Nov. 1965 Jan. 1966 Feb. 1966	Utah Co. Provo Utah	Cherry Bark Apple Foilage
J. W. Smith	28	Sep. 1971	Coaloma Co. Mississippi	Cotton
H. B. Specht	29	Jul. 1963	Prince Edward Is. Nova Scotia	Apple

Ten features were selected for comparative study between the two mite species: dorsal shield length (DSL), measured between the clunal setae, dorsal setae, and the vertical setae; dorsal shield width (DSW), measured between lateral setae IV and V; the lengths of various setae including: lateral setae I (lPS), dorsal setae II (DCSII), dorsal setae III (DCSIII), dorsal setae IV (DCSIV), dorsal setae V (DCSV)--setal lengths were measured from the middle of their bases to their distal tips; peritreme length (P), measured from the proximal end to the distal tip; distance between DCSII and DCSIII, and DCSIV and V--measured between the widest part of each circular base. Figure 1 illustrates these measurements. Subjective observations were also made on the ventrianal plate shape and on the numbers and arrangement of the pre-anal setae thereon.

Much of the variation between members of the same population was caused by the variety of positions that the mites took when they were placed in the mounting media. To reduce this variation, several procedures were followed when selecting characters for measurement:

(1) The characters to be measured on the specimens had to be undamaged.

(2) Characters had to be easily visible, that is, not obscured by other heavily sclerotized characters.

(3) Eight of the ten characters available for measurement were paired--only the one most easily and accurately measured was utilized.

All specimens were examined using a calibrated micrometer fitted into the ocular of an AO SERIES 20 Phasestar phasecontrast

Fig. 1.--Dorsal scutum of T. longipilus illustrating the characters measured.

DSL	- Dorsal shield length
DSW	- Dorsal shield width
IPS	Lateral setae I
DCSII	- Dorsal setae II
DCSIII	- Dorsal setae III
DCSIV	- Dorsal setae IV
DCSV	- Dorsal setae V
P	- Peritreme
DDCSII & III	- Setal base distances
DDCSIV & V	- Setal base distances

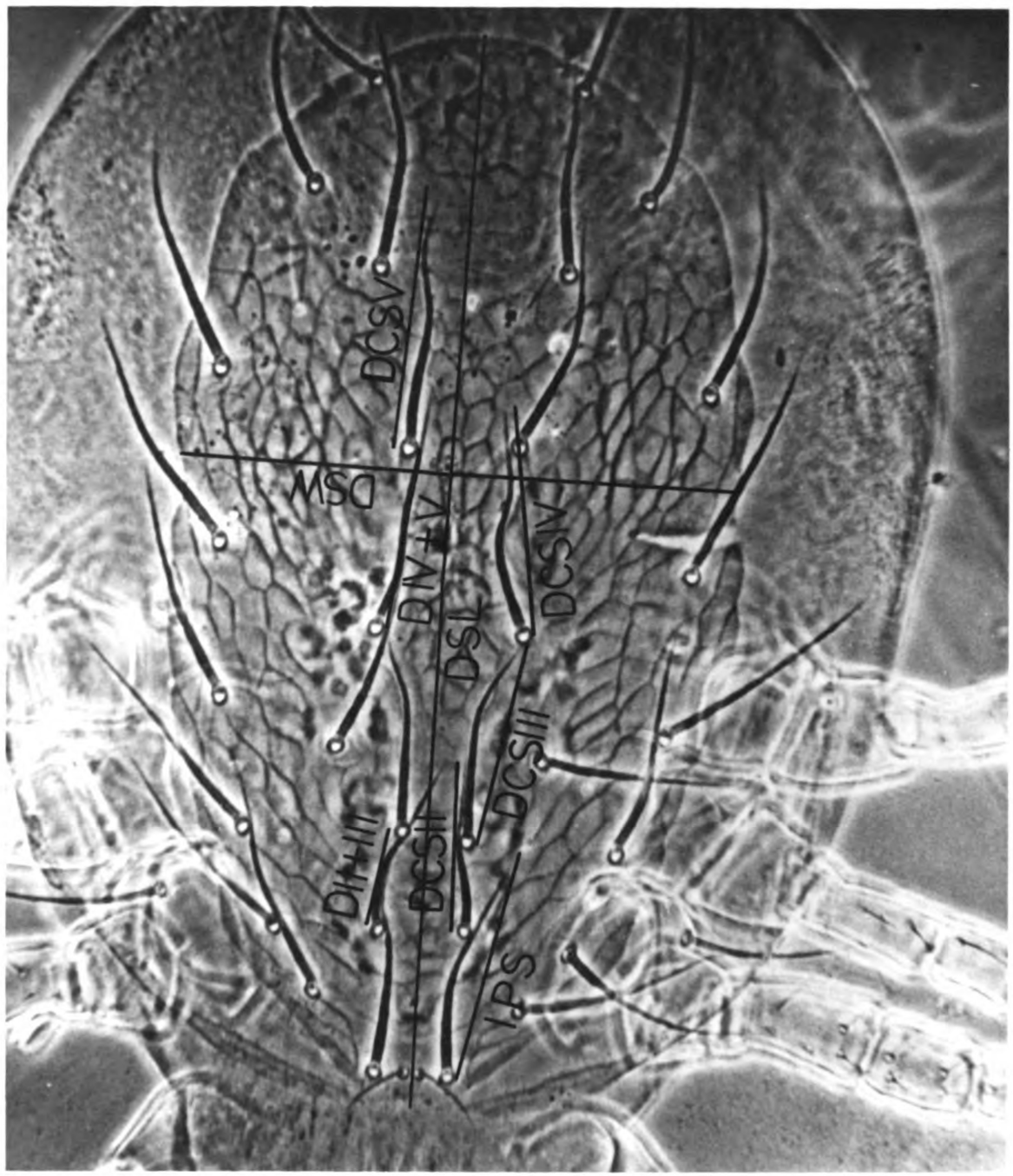

Fig. 1.--Dorsal scutum of T. longipilus illustrating the characters measured.

microscope. All measurements were taken at 450X and measured to the nearest unit (each increment consisted of 2.247 μ).

Student-Newman-Keuls multiple range tests were performed on selected populations of T. longipilus and T. occidentalis to determine which of the ten measured characters were most valuable in distinguishing between the two species. All samples gathered for comparison could not be used in the analysis due to the low number of replicates in some of the measured populations. Data were subsequently standardized by eliminating all samples with fewer than six individuals and by reducing all remaining samples to six replicates by random selection of six of each character from among the whole population.

A Principal Component Analysis (Cooley and Lohnes, 1971; Anderberg, 1973) of selected populations of T. longipilus and T. occidentalis was also performed using a computer program designed at Michigan State University. This was a multivariate technique that utilized all the specified characters to plot relationships between individuals. This was done by reducing all variables to the standard form of zero mean and unit variance for amalgamation into a single index of similarity. Variables were also weighted according to their significance as discriminant characters. Percentage significance values were calculated by this analysis to give the percentage contribution of each transformed variable to the new space and thus give the features a rank.

One hundred and sixty individuals were randomly selected for treatment using the above analysis. These individuals were selected to give an equal balance in numbers between the designated species,

T. longipilus (A) and T. occidentalis (B), and to represent a wide geographic area with little duplication from each area. These populations included: T. longipilus (A) from New Jersey (2),[1] Ontario (4), Missouri (7), Michigan (9), Nova Scotia (24), New Jersey (25), and T. occidentalis (B) from Utah (11), the Netherlands (16), Utah (17), California (20), Washington (21), and California (22).

Hybridization Studies

Two populations of T. longipilus and one population of T. occidentalis were used. The colonies of T. longipilus were obtained from (1) Dr. F. C. Swift who collected the mites from the Rutgers University greenhouses, and (2) from greenhouses in Naaldwijk, The Netherlands, collected by Dr. M. Van de Vrie. Both T. longipilus stocks were originally cultured from less than 30 adult female mites. The T. occidentalis population was cultured from a field population maintained by Dr. L. K. Tanagoshi at Wenatchee, Washington. This colony was started from a 250 mite sample received in late 1973.

Cultures were reared and maintained on units similar to those described by Croft (1970) and McMurtry and Scriven (1964). The rearing units consisted of 20 cm^2 stainless steel pans; water soaked polyurethane foam rubber pads; construction paper arenas waterproofed with a non-toxic sealer; and water saturated cellucotton®[1] stripping placed around the edge of the cardboard arenas to serve as a

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[1]See Table 1 for more detailed information as to geographic location.

[2]Cellucotton distributed by Bauer and Black, Chicago, Ill.

confinement barrier. Three glass coverslips placed over cotton fibres on the arenas served as protected oviposition sites. Rearing units were kept in water filled trays to prevent contamination of populations and species.

Two types of test units were used for the hybridization experiments. Originally, all crosses were made on units consisting of small water-filled jars in which excised bean or apple leaves (2.5 cm in diameter) were floated on water saturated foam rubber disks. This method was replaced with a more efficient method later in the tests. The new units consisted of four whole bush lima bean leaves, including the petiole, placed ventral side up on a water saturated, 18 cm^2 foam rubber pad, in a 20 cm^2 stainless steel pan. The edges of the bean leaves were lined with a Tanglefoot[1]-xylene mixture to prevent escape by the predator or contamination of the tests by unwanted populations.

Female deutonymphs of the desired population were selected from the rearing units and placed singly on these units for 48 hours before the appropriate male to be used in the test was added. This enforced delay was to insure that the female mite had not previously mated with a member of its own population. Due to the males propensity to wander off the excised bean leaf unit, and to become entangled in the protective barrier of the tanglefoot-ringed bean leaf unit, additional males were added throughout the test when one was observed missing. This insured that mating was not limited by lack of males. Death or loss of the female resulted in the termination of the test. Tests were also terminated after eight days if no eggs were produced,

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[1]Mapco Products by Michel and Pelton Co., Emeryville, Calif.

and continued indefinitely if eggs were produced to build up a judicious supply of F_1 progeny for future testing. Upon termination of each test, the original male and female was prepared for microscopic examination, and peritreme lengths checked to insure that the proper mites were used in the test.

All tests were performed in the laboratory at 22.5° ± 5°C and approximately 95% RH due to the transpiration of the leaves on which the tests were conducted. Photoperiod was controlled, allowing 16 hours of light per day. An abundance of mixed stages of Tetranychus urticae Koch were provided throughout the tests to serve as prey.

Crosses were designed so that every possible combination of the two species would be tested. Periodically, intraspecific control crosses were performed to insure that there was no loss in fecundity throughout the test period.

RESULTS

Taxonomy

Table 2 shows the mean length of characters among all populations of T. longipilus and T. occidentalis measured. Preliminary assignment to species was made on the basis of peritreme length. Table 2 also gives the sample size and the standard error of the mean. Table 3 shows the results of the Student-Newman-Keuls Multiple Range test performed independently on each of ten characters compared from 20 populations designated as T. longipilus and T. occidentalis. Only two characters, the peritreme and dorsal setae II, consistently separated the two species. The eight other characters were of varying degrees of usefulness.

Dorsal shield length, dorsal setae III, and the distance between the bases of dorsal setae IV and V, showed no overlap between character length means. However, the mean differences between certain populations of both species were not significantly different making absolute determination to species impossible. Dorsal setae IV and dorsal shield width were slightly less reliable characters. For each population, there was overlap of character means between one or more populations. There was no correlation between the species designation and the character mean lengths of dorsal setae V, lateral setae I, and the distance between the bases of dorsal setae II and III.

Table 2.--The mean lengths of measured characters of all populations of T. longipilus and T. occidentalis.

Characters \ Populations and Code[1]	Ontario (4)	Ontario (3)	Quebec (5)	Wisconsin (8)	Mississippi (28)	New Jersey (1)	New Jersey (2)	New Jersey (25)	Nova Scotia (24)	Michigan (9)	Missouri (6)	Missouri (7)	Prince Edward Island (29)
#Individuals	19	2	1	6	4	6	17	11	9	31	9	13	5
Dorsal Shield Length ± SE[2]	334.80±1.37	335.93	321.32	327.69±2.63	298.85±1.59	316.38±3.19	317.36±1.20	330.31±4.16	333.05±2.53	310.88±1.87	312.58±1.89	322.22±2.04	314.13±3.58
Dorsal Shield Width ± SE	168.88±1.13	161.78	164.03	169.27±2.07	145.49±1.41	158.79±1.51	161.39±1.30	176.39±2.07	170.27±1.04	161.57±.85	160.79±1.51	162.23±2.00	152.80±1.88
Prolateral Setae I Length ± SE	65.16±1.20	69.66	60.67	63.29±3.19	40.45±1.59	55.80±2.88	64.10±.97	69.04±1.05	67.16±1.57	55.81±.97	62.42±1.34	62.92±1.71	41.80±1.15
Dorsal Setae II Length ± SE	52.51±.91	58.42	53.93	54.83±1.35	29.21±.95	50.55±1.26	54.06±1.01	57.20±.88	53.43±1.35	51.10±.56	51.93±1.15	54.57±1.01	31.01±.45
Dorsal Setae III Length ± SE	58.54±1.06	67.41	56.18	61.79±1.12	38.76±1.41	59.16±1.26	57.89±1.15	64.35±1.44	59.41±1.26	59.00±.43	59.67±1.35	61.53±1.19	40.90±.84
Dorsal Setae IV Length ± SE	71.08±.83	74.15	69.66	70.78±.49	50.56±1.45	71.53±.90	70.98±.95	74.15±1.10	72.65±1.51	68.57±.52	68.41±1.89	71.01±1.51	54.83±.55
Dorsal Setae V Length ± SE	72.14±1.21	76.40	69.66	74.53±.70	50.00±1.08	71.16±.94	70.32±1.14	78.85±1.33	73.16±1.30	71.69±.63	71.40±1.39	71.72±1.15	58.42±.71
Peritreme Length	74.28±2.72	97.75	67.41	76.02±2.75	96.62±2.75	76.40±2.47	79.31±1.66	80.48±1.60	83.64±2.14	69.51±.79	72.15±1.73	78.94±2.40	88.08±2.96
Distance Between Dorsal Setae II and Dorsal Setae III	29.45±.56	28.09	31.46	29.59±.38	25.84±.65	- -	27.36±.40	29.21±0.43	30.20±.54	28.92±.27	28.96±.79	30.11±.43	27.86±.90
Dorsal Setae IV Dorsal Setae V	60.31±.54	61.79	65.16	59.17±.94	51.12±1.41	- -	56.44±.38	59.44±.97	60.17±.47	60.31±.54	57.92±1.10	58.87±.74	57.52±.90

Table 2.--Continued.

Characters \ Populations and Code	California (20)	California (22)	Washington (21)	Utah (11)	Utah (14)	Utah (26)	Utah (23)	Netherlands (16)	Lab (13)	Lab ( )	Utah (17)	Utah (15)	Utah (19)	Utah (18)	Utah (27)
# Individuals	19	9	12	14	11	4	13	18	15	10	13	22	14	11	9
Dorsal Shield Length ± SE	335.05±2.17	347.54±2.75	361.58±2.42	355.03±2.40	355.23±2.67	371.88±4.35	362.80±2.05	359.64±2.31	343.79±1.98	343.57±3.30	372.83±2.17	352.98±1.88	363.37±2.41	355.93±3.56	340.80±1.91
Dorsal Shield Width ± SE	174.64±2.59	188.75±1.45	193.43±1.12	189.69±2.09	187.52±1.75	196.05±5.76	194.97±2.13	190.37±1.62	176.46±1.93	175.72±2.90	198.95±1.72	190.18±1.08	199.02±1.26	188.75±1.60	169.77±2.22
Prolateral Setae I Length	51.81±1.04	58.17±.70	63.67±.89	59.55±1.08	59.65±1.10	57.86±3.23	64.30±.94	57.92±.64	48.24±1.57	45.84±1.62	65.16±1.14	59.95±.79	62.92±.85	60.87±1.01	53.65±.96
Dorsal Setae II Length	32.64±.72	37.95±1.09	38.57±1.26	37.88±.79	35.52±.58	43.82±2.97	40.79±.91	39.82±.52	34.75±1.03	35.28±1.26	38.37±.82	39.02±.65	39.16±.56	36.77±.50	34.70±1.00
Dorsal Setae III Length	39.26±.90	46.19±1.25	50.37±1.08	48.95±.88	46.17±.88	63.48±2.32	52.55±.79	51.93±.76	48.24±1.12	45.84±1.39	58.07±1.08	49.54±.92	51.36±.78	47.60±.94	45.19±1.15
Dorsal Setae IV Length	54.87±1.12	66.16±1.30	67.60±1.40	66.61±1.17	63.14±1.30	80.33±1.41	69.31±.98	65.79±.85	64.71±.94	60.67±1.69	73.29±.97	66.80±.85	68.37±.90	65.98±1.39	63.92±1.07
Dorsal Setae V Length	58.07±1.35	69.41±1.69	71.72±1.25	69.98±1.06	68.39±1.12	82.58±3.23	73.11±.87	66.54±.61	67.26±1.03	62.92±1.51	74.32±.93	70.17±.88	72.23±.46	68.02±1.13	66.91±.33
Peritreme Length	34.89±.63	36.45±.50	36.70±.80	41.09±.93	33.86±.27	46.06±.65	40.62±1.00	36.61±.63	33.93±.91	33.95±.1.01	40.79±.88	39.32±.58	39.97±.63	38.81±1.05	38.70±.50
Distance Between Dorsal Setae II and Dorsal Setae III	28.15±.78	26.71±.45	28.28±.80	27.12±.56	27.99±.47	30.90±1.08	28.69±.39	28.21±.40	27.86±.54	- -	28.87±.62	27.58±.47	27.45±.35	26.96±.43	26.47±.33
Dorsal Setae IV Dorsal Setae V	62.21±.99	63.17±.70	64.98±.58	66.93±.67	65.78±.86	74.15±.205	67.06±.62	68.78±.61	64.56±.67	- -	71.90±.62	68.13±.65	67.25±.73	66.59±.92	65.16±.75

[1]See Table 1 for specific location of population.

[2]Standard error of the mean.

Table 3.--Taxonomic comparisons of selected populations of T. longipilus and T. occidentalis.

Location[1]	Species Desig.	Taxonomic Characters: Dorsal Shield Length 2 (DSL)	Dorsal Shield Width (DSW)	Prolateral Setae I (IPS)	Dorsal Setae II (DCSII)	Dorsal Setae III (DCSIII)	Dorsal Setae IV (DCSIV)	Dorsal Setae V (DCSV)	Peritreme (P)	Distance Dorsal Setae II & III (DDCSII&III)	Distance Doral Setae IV & V (DDCSIV&V)
Michigan (9)	T.l.	138.833 a	71.667 a	23.667 de	23.000 a	26.833 a	31.667 abc	33.000 a	30.667 b	12.500 a	25.667 a
Missouri (6)	T.l.	138.833 a	71.000 a	27.833 abc	23.167 a	26.667 a	30.833 abcd	31.667 ab	32.000 ab	12.500 a	25.333 a
Missouri (7)	T.l.	143.167 ab	72.667 a	27.167 abcd	24.167 a	27.667 a	31.000 abcd	31.833 ab	35.500 a	13.500 a	26.667 ab
New Jersey (2)	T.l.	144.000 ab	70.000 a	29.167 abc	25.167 a	26.167 a	31.833 abc	32.167 ab	35.667 a	12.000 a	25.500 a
Wisconsin (8)	T.l.	145.833 ab	75.333 a	27.833 abc	24.333 a	27.500 a	31.500 abc	33.167 a	33.833 ab	13.167 a	26.333 ab
Nova Scotia (24)	T.l.	146.667 ab	75.167 a	29.667 ab	23.833 a	26.000 a	32.167 abc	33.000 a	36.000 a	13.333 a	26.667 ab
New Jersey (25)	T.l.	147.167 ab	79.000 b	30.500 a	25.000 a	27.833 a	33.167 a	33.167 a	35.333 a	12.833 a	26.667 ab
Ontario (4)	T.l.	148.167 b	75.000 a	30.000 ab	23.667 a	26.333 a	32.000 abc	33.167 a	34.333 ab	13.167 a	26.500 ab
California (20)	T.O.	149.000 b	78.333 b	22.833 e	14.167 c	17.500 c	24.667 e	25.000 c	15.500 c	13.000 a	28.333 bc
Washington (13)	T.O.	151.500 b	80.167 bc	22.833 e	15.500 bc	21.667 b	28.167 cd	28.667 b	15.167 c	12.333 a	28.333 bc
Utah (18)	T.O.	154.667 c	83.167 bcd	27.500 abcd	16.500 bc	21.000 b	28.667 cd	29.500 ab	16.667 c	12.000 a	29.000 cd
Utah (11)	T.O.	155.833 c	82.833 bc	25.333 cde	16.500 bc	20.833 b	28.833 bcd	30.167 ab	17.500 c	11.833 a	29.167 cd
California (22)	T.O.	156.500 c	84.667 cd	26.000 bcde	17.000 bc	20.833 b	29.667 abcd	31.000 ab	16.333 c	12.333 a	28.500 bc
Utah (14)	T.O.	158.333 c	83.500 bcd	27.167 abcd	16.000 bc	21.000 b	27.333 de	29.000 ab	17.000 c	12.333 a	29.500 cde
Utah (15)	T.O.	158.500 c	85.000 cd	26.667 abcde	17.167 bc	21.500 b	29.333 abcd	30.667 ab	17.500 c	12.333 a	30.833 def
Washington (21)	T.O.	161.167 cd	85.833 cd	28.667 abc	17.667 b	22.500 b	30.500 abcd	32.167 ab	16.000 c	12.833 a	28.500 bc
Utah (19)	T.O.	161.333 cd	89.000 d	27.000 abcd	17.500 b	23.500 b	29.833 abcd	32.333 ab	18.167 c	13.333 a	29.667 cdef
Netherlands (16)	T.O.	162.500 cd	85.167 cd	26.500 abcde	18.500 b	24.000 b	30.333 abcd	30.333 ab	16.333 c	12.833 a	31.333 ef
Utah (23)	T.O.	162.500 cd	89.000 d	29.333 abc	18.167 b	23.500 b	31.333 abcd	32.833 a	18.667 c	12.833 a	29.833 cdef
Utah (17)	T.O.	167.833 d	89.000 d	30.167 ab	17.000 bc	25.333 a	32.833 ab	32.833 a	18.000 c	12.500 a	31.667 f
F-values of ANOVA		26.214**	32.273**	9.017**	36.719**	23.850**	7.937**	7.979**	94.484**	1.517 NS	19.603**

[1]See Table 1 for specific location of populations.

[2]Subset mean lengths and statistical significance, individual column values followed by the same letter are not significantly different, P = .01**, Student-Newman-Keuls multiple range test.

Consequently, these features proved to be totally unreliable for diagnostic purposes.

Other taxonomic characters, such as the numbers of cheliceral digits, plumosity of the setae, size and shape of the spermatheca, although mentioned in many publications, were determined to be too difficult to accurately measure in this study due to the variety of preparation techniques used by the original collectors. Observations made on the ventrianal shield confirmed the contention of Davis (1970) that this feature was too variable to be used as a discriminant character.

Figure 2 shows the results of the Principal Component Analysis. Two distinct groups were formed which corresponded exactly to the designated populations of T. longipilus and T. occidentalis. It was significant that 90.9% of the variance was conserved when the ten dimensional data was compressed and projected onto a two dimensional graph for visual representation. This meant that any grouping or cluster seen in the graph could be considered an accurate representation of the data expressed in ten dimensions.

The percentage significance values calculated indicated that the dorsal shield length and the peritreme length were the most valuable features in discriminating between T. longipilus and T. occidentalis. Using the Principal Component Analysis, these characters contributed 20.87% and 19.78% respectively toward the new space. The remaining measured characters were ranked in order of their contribution toward the new space and included: dorsal shield width 13.61%, dorsal setae II 9.64%, dorsal setae III 9.11%, dorsal setae IV 7.54%,

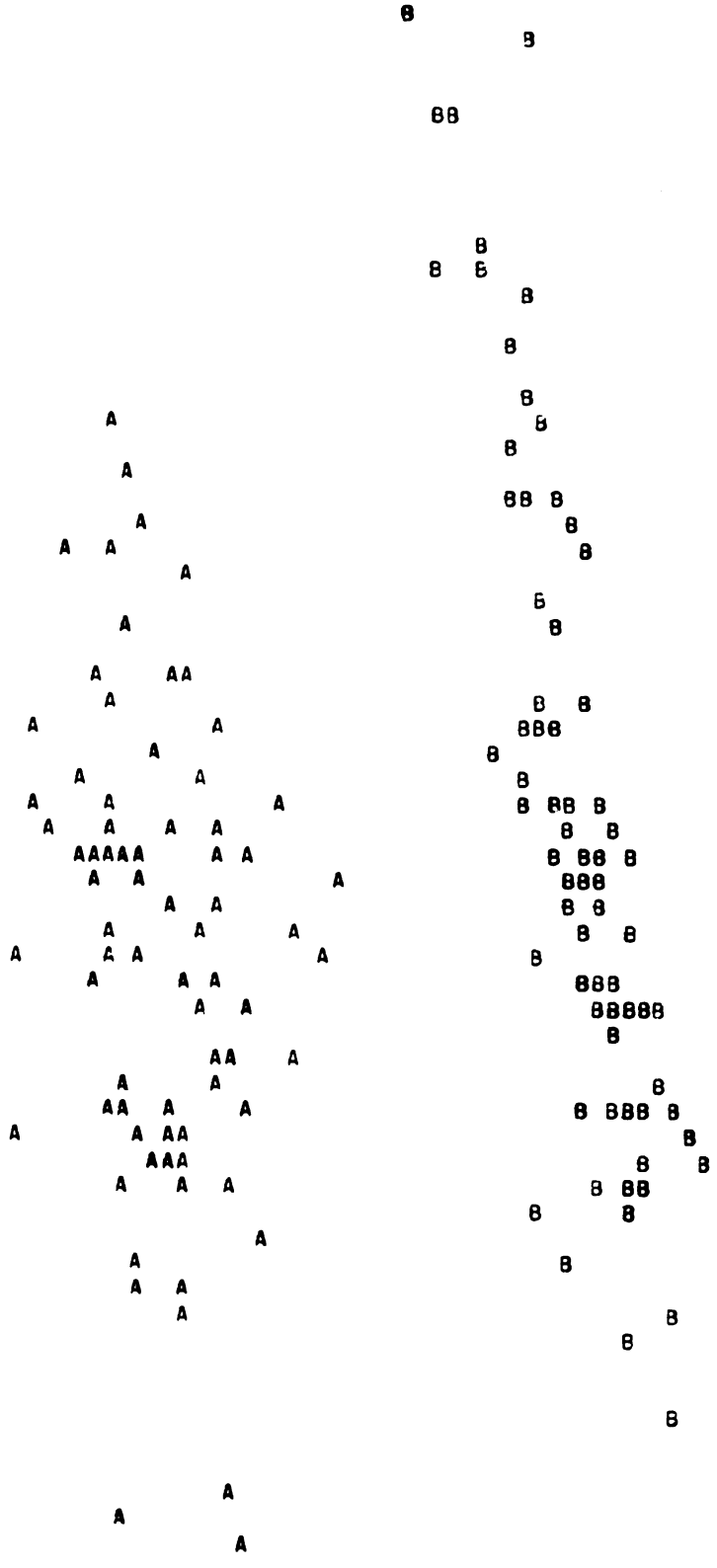

Fig. 2.--Principal Component Analysis of selected populations of T. longipilus (A) and T. occidentalis (B).

lateral setae I 7.30%, dorsal setae V 7.19%, distance between the bases of dorsal setae IV and V 3.94%, and between II and III 1.02%.

An attempt to discriminate between geographic populations of T. occidentalis was also made using Principal Component techniques. Figure 3 displays the results of this analysis on 14 populations from widely separated areas of the United States. As one would expect, it was much more difficult to differentiate between populations of the same species than between different species. Although no absolute separation was achieved by any of the selected populations, certain ones tended to form somewhat distinguishable groups. This can be seen quite clearly in Figure 4 of samples from Yuciapa, California (i) versus Box Elder County, Utah (f).

Hybridization Studies

Reproductive isolation is an important factor in determining species specificity (Mayr, 1971). Table 4 indicates that the European T. longipilus and the Washington T. occidentalis are conspecific, with very little if any reproductive isolation existing between them. This would seem to indicate that these two forms may have recently been members of a sympatric population. Results from the geographic distribution portion of this study tend to support this conclusion. On the other hand, T. longipilus from New Jersey showed no reproductive compatibility with either the population presumed to be T. longipilus from Europe, or with T. occidentalis from Washington. This confirms data seen in the taxonomic portion of this study that T. longipilus from Europe is dissimilar to T. longipilus from New Jersey, and in fact, the European mite is indistinguishable from T. occidentalis.

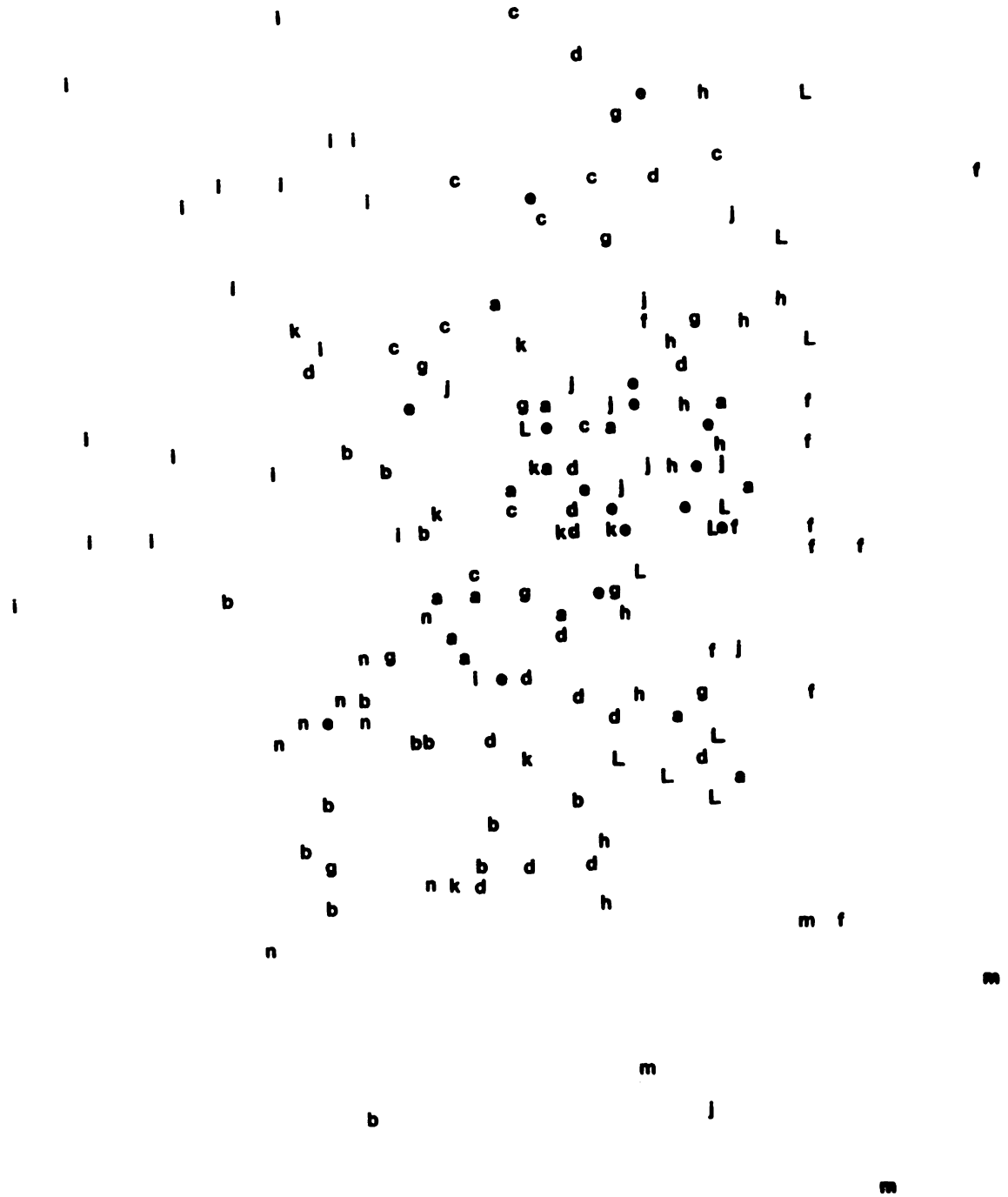

Fig. 3.--Principal Component Analysis of 14 populations of T. occidentalis from widely separated geographic regions.

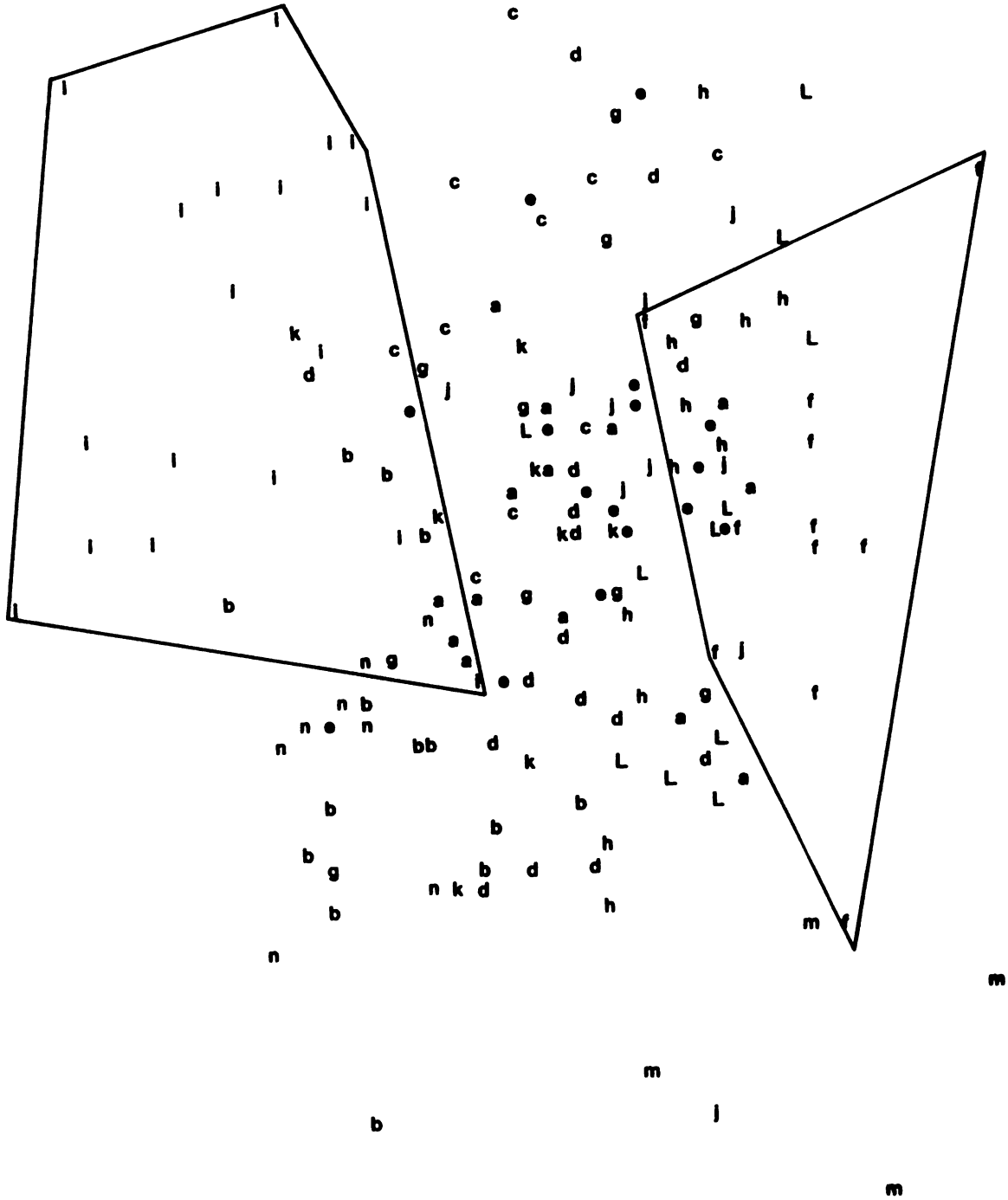

Fig. 4.--The separation of populations of T. occidentalis from Yuciapa, California (i) and Box Elder County, Utah (f) using the Principal Component Analysis.

Table 4.--Hybridization parameters of crosses between two populations of T. longipilus and one population of T. occidentalis.

Crosses X	# Females	# Mite Day Observations	# Eggs	# Eggs/Day	% Females Ovipositing
T.1.E.[a] X T.1.E.	15	70	133	1.90	100.00
T.1.E.X T.o.W.[b]	15	82	165	2.01	100.00
T.1.E.X T.1.N.[c]	26	120	0	0.00	0
T.o.W.X T.o.W.	7	35	67	1.91	85.71
T.o.W.X T.1.E.	10	46	90	1.96	90.00
T.o.W.X T.1.N.	28	137	0	0.00	0
T.1.N.X T.1.N.	19	84	187	2.23	100.00
T.1.N.X T.o.E.	30	153	0	0.00	0
T.1.N.X T.o.W.	11	57	0	0.00	0

[a]Population from the Netherlands.

[b]Population from Washington.

[c]Population from New Jersey.

Although there was not a single confirmed case of hybridization between the New Jersey population and either the European or Washington populations, the possibility that hybridization may occur still exists. Croft (unpublished data) has obtained male offspring from similar crosses. In preliminary crosses conducted by the author, some degree of hybridization was seen. However, insufficient care in technique was taken to insure the reliability of these early crosses.

Normal precopulatory and copulatory behavior was observed to occur in both homogametic and heterogametic crosses.[1] Higher participant mortality in heterogametic crosses suggested that there was significant incompatibility between populations. This mortality was usually due to entrapment in the tanglefoot-xylene border suggesting that increased excitement between heterogametic pairs caused increased mobility and more opportunity for contact with the border. Males, generally the more mobile of the two sexes, appeared to become ensnared more frequently than the females.

Females that were not producing eggs after eight days of confinement with males of other populations were mated with males from their own population to determine if, in fact, they were capable of producing offspring. These crosses almost always resulted in the production of offspring within two days. Infrequently, females from interspecific crosses were seen to contain a developed egg. These eggs had been maintained within the female but had not been deposited.

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[1]Mating among members of the same strain, race or species are homogametic, and those between different strains, races, or species are heterogametic (Dobzhansky and Mayr, 1944).

Geographic Distribution

Figure 5 shows the distributions of T. longipilus and T. occidentalis in the United States and Canada as determined by the author from the literature and materials used in this study. Basically, the map accurately reflects the distribution of the two species. However, there have been some errors due to original misidentification.

The reports made by Fleschner and Ricker (1954), and Fleschner (1958) of T. longipilus in California, as an important biological control agent of plant feeding mites, were certainly in error. There have been no other reports of this species on avocado or citrus since that time. Also, in Fleschner (1958), no mention was made of morphologically similar T. occidentalis, which is known to be abundant in the same area and on the same crops (McMurtry et al., 1971). Specimens of T. occidentalis obtained for study from this general area of California (Riverside (22) and Yuciapa (20)) proved to be considerably smaller in overall length and width than the majority of mites measured, probably causing the misidentifications. The Yuciapa population of T. occidentalis particularly mimicked many of the characters of the T. longipilus samples that were compared. Using the Student-Newman-Keuls procedure, the Yuciapa population of T. occidentalis was indistinguishable from six separate T. longipilus populations when their dorsal shield lengths were compared; from one population when dorsal shield widths were compared; and from one population when lateral setae I were compared. Similarly, the Riverside population of T. occidentalis was indistinguishable from eight separate T.

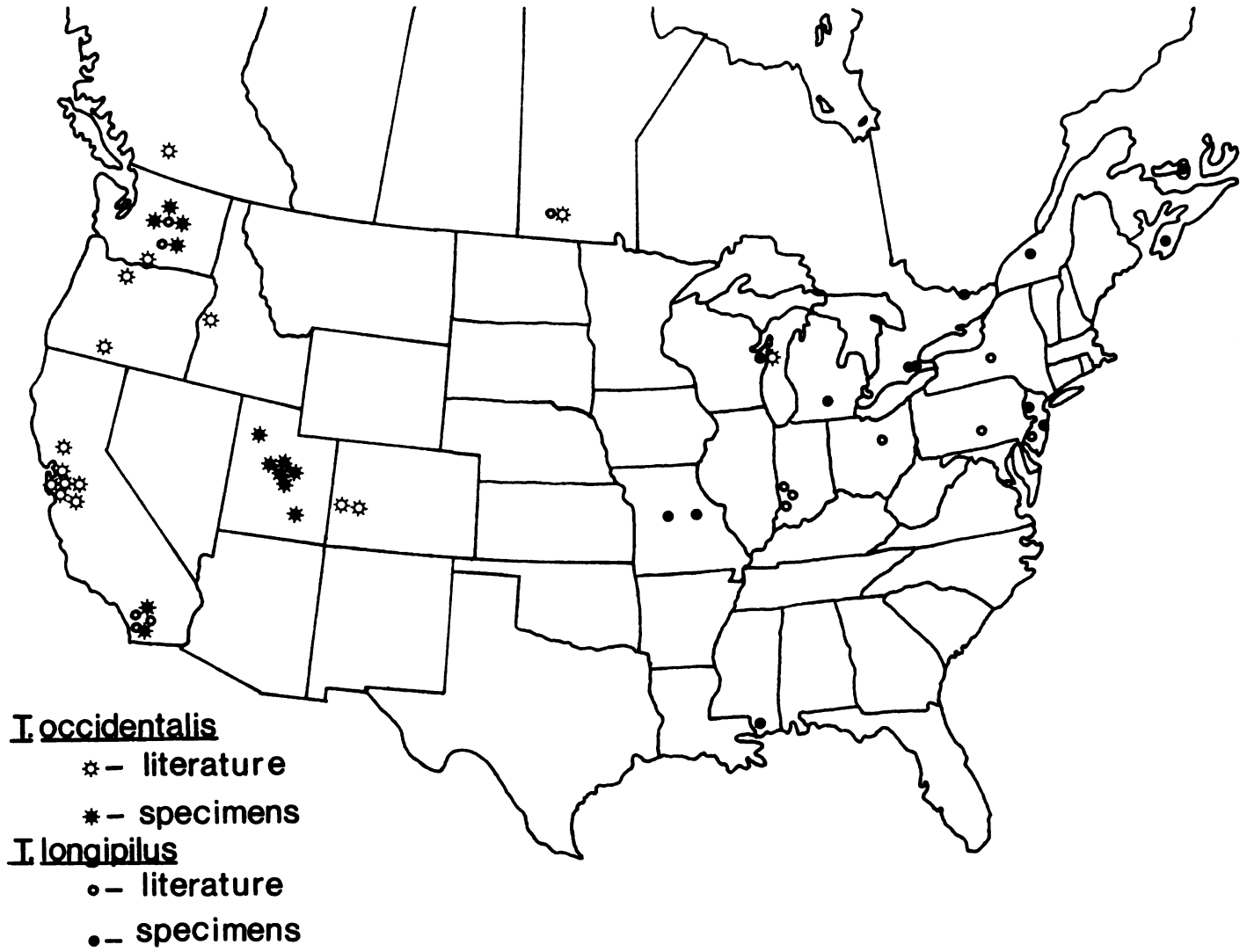

Fig. 5.--Geographic distribution of T. longipilus and T. occidentalis in the United States and Canada.

longipilus populations when various characters were compared.[1] Other reports of T. longipilus in the Pacific northwest have also been erroneous. Nesbitt (1951), Hantsbarger and O'Neill (1954), and Burrill and McCormick (1964), reported that this species was present in Washington apple orchards. However, Hoyt (1969b) discounted these reports suggesting that the species was T. occidentalis since T. longipilus could no longer be found and that subsequent determinations of specimens labeled T. longipilus were actually T. occidentalis. Examination of material gathered for this study from the Wenatchee area also failed to turn up any specimens that met all the criteria necessary to call the species T. longipilus. Here again, this confusion may have been caused by the inability to distinguish between these two species using earlier taxonomic publications. In this study, Washington samples of T. occidentalis were insignificantly different from various T. longipilus populations if any eight of the ten characters used in identification were compared.

Several other authors have erred in their assessment of the distribution of these two species by accepting previous literature citations as valid. Of these, Chant (1959) stated that T. longipilus was the more common of the two in the west.

Muma (1963) began to distinguish between the two by implying that T. longipilus was the more common eastern species and that T. occidentalis was the more common western species. He, however, stated that both species were found throughout the temperate regions of the United States and Canada.

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[1]See Table 2 for characters and populations in question.

Oatman (1963) was the only one to report T. occidentalis east of Colorado. Specimens he found in Wisconsin proved to be T. longipilus upon further examination in this study.

It is apparent from Figure 5 that sympatric interaction of T. longipilus and T. occidentalis may occur in the western great plains region of the United States and Canada. For this reason, the early report of T. longipilus by Robinson (1951) in Manitoba is interesting. Almost simultaneously Nesbitt (1951) reported mites from the same area to be T. occidentalis, but due to his identification of Washington specimens to be T. longipilus, we cannot be sure which species is present in Manitoba.

In a further attempt to determine the distribution of T. longipilus and T. occidentalis in the central region of North America, a survey of state and university collections of mites was made by contacting personnel in the states of North Dakota, S. Dakota, Nebraska, Iowa, New Mexico, Kansas, and Colorado. Every state, with the exception of Colorado, failed to locate a single specimen of either species. Colorado personnel reported that introductions of insecticide-resistant strains of T. occidentalis has been made but no knowledge of the endemic fauna was available (Quist, 1974). In these states, it is impossible to say if either species, or both are present, but rather it is concluded that the phytoseiid fauna has not been sufficiently studied.

Another interesting case is that of the confusion of the species identity in Europe. This has proven to be simply a case of

misidentification based on the belief that the two species were conspecific by European workers.

T. longipilus had been reported in greenhouses in Naaldwijk, the Netherlands, since 1954, when Bravenboer first used it in elementary biocontrol studies. It was originally identified by Nesbitt and Van Eyndhoven (Bravenboer, personal communication). Through further communications with Fransz and Bravenboer, it was ascertained that the predatory mite that each had published on (using different specific names) was identical even to the point of collection. The author has determined this species to be T. occidentalis using the keys of Muma (1963) and Chant (1959). Hybridization studies reported in this thesis and by Kennett (unpublished data) have shown that the Netherlands population freely hybridizes with populations of T. occidentalis from Washington, California, and Utah, thus can be considered to be conspecific with these populations.

It is believed that this species was not originally endemic to Europe, but rather was imported from the western United States on young fruit trees. Fransz (1974) stated that the predator was imported from the northeastern United States on peach trees; this would seem unlikely since peach orchards are relatively scarce in the northeast and since our studies failed to recover a single specimen of T. occidentalis from this area.

SUMMARY AND CONCLUSIONS

This thesis was directed toward the question of the conspecificity of the two similar phytoseiid mites, Typhlodromus longipilus and Typhlodromus occidentalis. The three areas of study that were undertaken to elucidate the actual relationship between these two species included: hybridization, taxonomic, and geographic distribution comparisons.

Through hybridization studies, European populations of T. longipilus were shown to be T. occidentalis and exhibited complete reproductive compatibility with populations of T. occidentalis from Utah, California, and Washington. Populations designated T. longipilus from New Jersey were reproductively incompatible with populations of T. occidentalis from Washington and Europe.

Quantitative taxonomic comparisons were made on ten characters that were believed would exhibit a significant difference between T. longipilus and T. occidentalis if one did exist. A comparison of each of the measured characters from 20 randomly selected populations showed that only two, peritreme and dorsal setae II, could effectively separate these two species. The eight other measured characters, dorsal shield length, dorsal shield width, various dorsal setae and intersetal distances, proved to be unreliable individually as discriminant characters. When all ten characters were used collectively

in a multivariate analysis, a distinct separation between the two species was shown. This technique, when employed interspecifically, partially differentiated geographically separated populations.

The geographic distribution determination done in this study has incorporated reliable literature citations with direct observations to accurately reflect the distribution of T. longipilus and T. occidentalis. It is believed that there is no overlap in the distribution of these two species in North America, with the possible exception of Manitoba where both species have been reported. Specimens of T. longipilus were obtained from the more humid regions of the eastern United States and Canada--particularly in the northern temperate climatic zone, whereas specimens of T. occidentalis were commonly obtained from the more arid agricultural regions of the western United States.

Based on the results obtained in this study, it was determined that T. longipilus and T. occidentalis are indeed distinct species.

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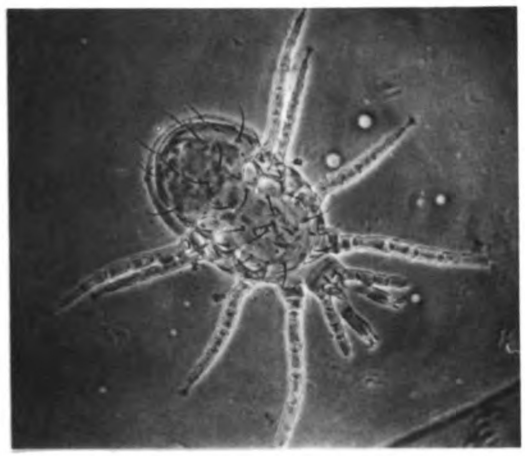
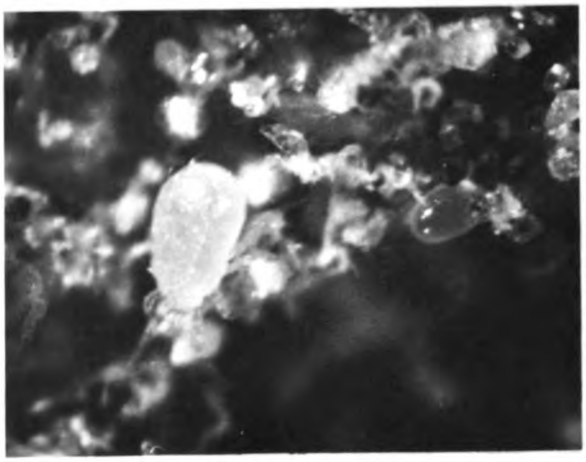
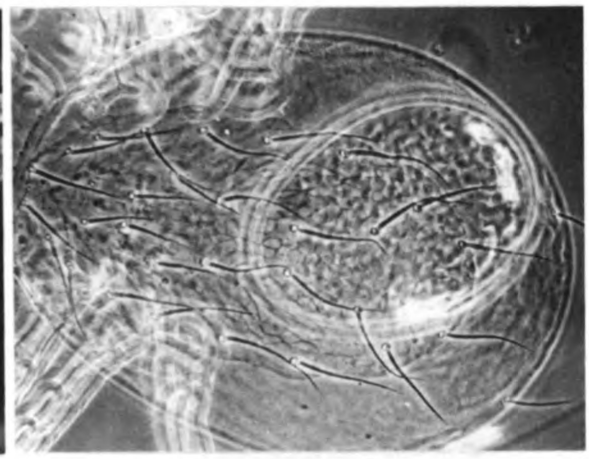
APPENDIX

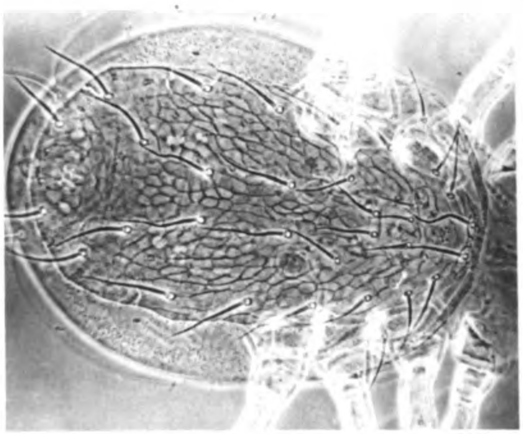
Fig. A-1.--Selected physical features of the taxonomy of T. longipilus and T. occidentalis.

Upper Left - adult female T. longipilus (100 x)
Upper Right - adult male T. longipilus (100 x)
Middle Left - live T. occidentalis and egg (30 x)
Middle Right - T. longipilus with internal egg (450 x)
Lower Left - dorsal shield of T. occidentalis (450 x)
Lower Right - dorsal shield of T. longipilus (450 x)









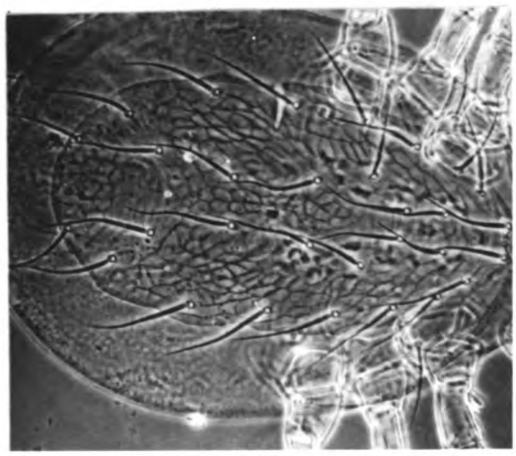


Fig. A-2.--Peritremes, spermatheca, and chelicera.

Upper Left - peritreme of female T. occidentalis (1000 x)
Upper Right - peritreme of male T. occidentalis (1000 x)
Middle Left - peritreme of T. longipilus (450 x)
Middle Right - peritreme of T. occidentalis (450 x)
Lower Left - spermatheca (1000 x)
Lower Right - chelicera of female (1000 x)