Seasonal Occurrence of Phytoseiid Mites (Acari: Phytoseiidae) in North Carolina Fraser Fir (*Abies fraseri* [Pursh] Poiret) Christmas Tree Plantations[1]

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Abstract The overwintering sites and seasonal abundance of phytoseiid mites were determined in North Carolina Fraser fir Christmas tree plantations. Potential overwintering sites for the mites include Fraser fir branches, Fraser fir bark, surface litter composed of Fraser fir needles, a mixture of fescue grass (*Festuca* spp.) and nimblewill (*Mhlenbergia schreberi* J.F. Gmelin.), mixed herbaceous debris from the previous growing season, and a monocultural cover crop of white clover (*Trifolium repens* L.). Twelve species of mites (n = 414) in the family Phytoseiidae were collected. *Arrenoseius morgani* (Chant) (n = 160), *Typhlodromips sessor* (DeLeon) (n = 156), and *Typhlodromalus peregrinus* (Muma) (n = 34) were the most abundant. During the spring and summer Fraser fir plantations with a ground cover consisting of white clover were compared with plantations with bare ground to assess the abundance and species composition of phytoseiid mites. A total of 512 phytoseiids representing 8 species was collected. Phytoseiid mite abundance was not significantly different between clover ground cover and bare ground plantations. *Typhlodromips sessor* (DeLeon), *Typhlodromalus peregrinus* (Muma), and *Arrenoseius morgani* (Chant) were the most abundant species in both plantation types.

Key Words Phytoseiidae, *Abies fraseri*, ground cover, biological control

The spruce spider mite, *Oligonychus ununguis* Jacobi (Acari: Prostigmata), is one of the most detrimental mites attacking conifers (Johnson and Lyon 1994). This pest has a wide host range, is frequently encountered on nursery crops (Lehman 1982), and is especially troublesome in plantation and ornamental plantings (Rose and Lindquist 1977, Johnson and Lyon 1994). It is an important pest of Fraser fir, *Abies fraseri* (Pursh) Poiret, grown for Christmas trees in North Carolina (Sidebottom 2002).

Predatory mites in the family Phytoseiidae (Acari: Mesostigmata) are significant predators of phytophagous mites in the family Tetranychidae (McMurtry et al. 1970) and many have been extensively studied as biological control agents of mite pests (Moraes et al. 2004). Phytoseiid mites have been observed in North Carolina Fraser fir plantations infested with spruce spider mite (Boyne and Hain 1983), and Boyne (1980) observed an apparent decline in a spruce spider mite population on Fraser fir following an increase in the abundance of *Neoseiulus fallacis* (Garman). These observations and subsequent research have suggested that Fraser fir production areas

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may be well suited for a pest control program utilizing phytoseiid mites to control spruce spider mite (Kramer and Hain 1989, Mangini and Hain 2007, Williams et al. 2011).

The seasonal dynamics of natural enemy populations are a vital component of efficacious biological control programs (Khan and Fent 2005). Phytoseiid mites are known to overwinter in a variety of locations on trees and in debris located in close proximity to orchards where perennial crops are grown (Pratt and Croft 2000, Chant 1959, Putman 1959, Leetham and Jorgensen 1969, Knisley and Swift 1971). The predator *N. fallacis*, for example, overwintered in ground cover debris in Michigan apple orchards (McGroarty and Croft 1978), but this species was found in greater densities overwintering on apple twigs than in ground cover debris in New York apple orchards (Nyrop et al. 1994). Several authors have reported on the overwintering sites of the phytoseiid *Typhlodromus pyri* Scheuten (Chant 1959, Zacharda 1989) and noted that they spend the winter in bark crevices. Khan and Fent (2005), for example, noted that *T. pyri* overwintered in the cracks and crevices of older apple tree twigs. These and other studies suggest that ground covers may not influence the population dynamics of some species of phytoseiid mites in at least some perennial crops (Stanyard et al. 1997).

Nonetheless, ground cover is an important component of the Fraser fir IPM program in North Carolina, as it may decrease runoff and sedimentation and influence fertilizer uptake in these agricultural areas (Sidebottom 1997). The effect of naturally-occurring ground cover on phytoseiid mite diversity in Fraser fir production areas has been studied by Mangini and Hain (2007), and Williams et al. (2011) evaluated the abundance and species composition of phytoseiid mites in 4 ground cover crops used in Christmas tree production. Little additional information on phytoseiid mite diversity in Fraser fir trees or their overwintering habitats exists for North Carolina Fraser fir production areas.

The goals of this project were to evaluate potential overwintering refuges of phytoseiid mites in commercial Fraser fir plantations and to compare phytoseiid mite diversity during the spring and summer in Fraser fir with a white clover cover crop to trees grown on bare ground. The results of this study may be potentially useful in a biological control program for spruce spider mites in Fraser fir plantations.

Materials and Methods

Overwintering study. Overwintering studies were conducted from December 2006 to March 2007 in Ashe, Alleghany and Watauga counties in North Carolina. Samples were collected from a total of 37 privately-owned Fraser fir plantations. Twenty of the sampled sites had a mixed herbaceous and grass ground cover during the previous fall and were each sampled once. Seventeen plantations had a ground cover consisting of white clover (*Trifolium repens* L.) and were all were sampled on a single day, 28 February 2007. Plantation sizes averaged approx. 2 ha in size. Fraser fir tree sizes ranged from 0.3 m to 2.4 m in height and were planted in rows 1.5 m apart.

The following potential overwintering sites were sampled from mixed herbaceous and grass ground cover sites: Fraser fir bark ($n = 9$), Fraser fir needle surface litter ($n = 13$), a mixture of fescue grass (*Festuca* spp.) and nimblewill (*Mhlenbergia schreberi* J.F. Gmelin.) ($n = 21$), a mixture of herbaceous debris from the previous growing season ($n = 10$), and white clover ($n = 17$).

The mixed species ground cover and mixed grasses were each collected separately from 3 randomly selected fixed surface areas (20 × 20 cm) located between the rows of Fraser fir. The mixed ground cover consisted of multiple species of naturally-occurring ground cover vegetation debris and was carefully gathered by hand. Mixed species of grasses (Poacae) were clipped at the soil line from fixed surface areas (20 × 20 cm).

Samples from each treatment were combined and placed in a plastic bag to make a single composite sample of each ground cover type from each plantation. No attempts were made to identify the ground cover debris from the previous years' growing season. No living vegetation debris was collected. The debris was primarily composed of woody stems and leaves.

Fraser fir needles were carefully gathered by hand from 3 randomly selected fixed surface areas (20 × 20 cm) located directly beneath trees, and placed into plastic bags. Fraser fir branches were collected ($n = 15$) from fields that had a mixed herbaceous and grass ground cover during the previous fall. Fraser fir branches ($n = 17$) were collected from plantations with a white clover cover crop. Samples were taken from 10 trees at each plantation by cutting 1 randomly-selected Fraser fir 14-cm branch every 6.0 m along a single transect. Samples were placed in plastic bags and transported to the laboratory in coolers. Bark samples were collected by cutting 20 - 30 strips 30 cm long × 2.4 cm wide from 5 trees that appeared to have crevices suitable as habitat for phytoseiid mites.

Samples collected from plantations planted in clover consisted of Fraser fir branches collected as previously described and 3 samples of white clover from a fixed area (20 × 20 cm) from each plantation. Clover ground cover samples were collected from under the trees.

The clover was removed by cutting into the soil 1 - 2 cm deep and gently removing the plug by hand. Two Fraser fir cones were picked by hand from 5 trees and combined into 1 composite sample.

Arthropods were extracted from the branches and from cover crop samples using Tullgren funnels outfitted with a 40 w incandescent bulb for drying. A cup with 70% ethanol and a few drops of glycerin was placed under each funnel to collect mites. Samples were left in the funnels for 5 days. Funnels were washed and wiped clean between uses to avoid cross contamination.

Arthropods were sorted using a 10 - 50x stereo-microscope. Predatory mites were removed and mounted with Hoyer's medium on glass microscope slides and covered with a 12-mm diam cover slip. Slides were dried for 48 h in a drying oven at 50°C (Krantz 1978). Generic and specific identifications were made at 40 - 100x with a phase contrast microscope. The senior author performed all identifications. Only adult females were identified during the study. A representative number of slides were verified by Gilberto de Moraes (Universidade de Sao Paulo, Piracicaba, Brazil). Specimens are maintained in the Forest Entomology Laboratory at North Carolina State University in Raleigh. Shannon's diversity and evenness values were calculated to evaluate phytoseiid overwintering sites in Fraser fir plantations (Vandermeer 1981).

Clover ground cover and bare ground comparison. Fifteen sites located in Ashe and Alleghany counties, NC, were each sampled on the same days (4 April, 1 June, 2 July, 2 August, and 4 September 2007). Ten of these plantations had a ground cover crop consisting of white clover, but in 5 bare ground plantations the ground cover had been eliminated by herbicides. Fraser fir trees were sampled at each plantation following the same methodology as described in the overwintering study.

A white clover sample also was collected at each of the 10 plantations that used it as a cover crop. The clover was collected from 3 randomly selected locations at each site and placed into a 7.5-L bag to form a single composite sample from each site. Samples were collected from between rows of Fraser fir by cutting the clover at the soil line.

An analysis of variance (ANOVA) test was used to compare abundance of phytoseiid mites in the Fraser fir trees growing in fields with a clover ground cover to trees growing on bare ground (Proc GLM, SAS Institute 2007); the factors used in the analysis were site, day, and ground cover. Shannon's diversity values were calculated to evaluate predatory mite diversity and evenness on Fraser fir trees growing with and without a clover ground cover (Vandermeer 1981).

Results and Discussion

Overwintering study. Twelve species of phytoseiid mites were collected during this study (Table 1). The most abundant were *Arrenoseius morgani* (Chant) ($n = 160$), *Typhlodromips sessor* (DeLeon) ($n = 156$) and *Typhlodromalus peregrinus* (Muma) ($n = 34$). The mixed- grass ground samples and Fraser fir needle samples yielded the greatest numbers of phytoseiid mites, with 174 and 158 specimens, respectively. The mixed-grass samples had the greatest diversity of phytoseiids. The Fraser fir branches collected from plantations with a white clover ground cover yielded more phytoseiid mites than the Fraser fir branches collected from plantations with a mixed species herbaceous ground cover (Table 1). Shannon's diversity was greatest (0.451) in mixed-grass overwintering sites and in Fraser fir trees (0.379) growing in plantations with a white clover cover crop (Table 2).

These data support previous research which found that certain species of phytoseiid mites overwinter in trees as well as in ground cover crops (Nyrop et al. 1994). Pratt and Croft (2000) found that *N. fallacis* overwintered in greater densities on ornamental conifers than on evergreen shrubs, herbaceous perennials, deciduous shrubs or shade trees; however, we collected only 1 specimen of *N. fallacis* from Fraser fir branches during our winter sampling. Our study found that during the winter this species was found in mixed-grass ground covers, as well as in mixed ground cover debris, and on the foliage of Fraser fir. *Typhlodromalus peregrinus* was collected in the greatest density from the Fraser fir branches; it is considered a generalist predator that feeds on pollen and small arthropods, including spider mites (McMurtry and Croft 1997). There is evidence to suggest that generalist predators more readily occupy microhabitats on trees throughout the season than specialist predators, which must seek new prey populations when food availability is scarce (McMurtry 1992). For example, when prey mite populations were low on apple trees, *Typhlodromus pyri* Scheuten, a generalist predator, did not migrate as readily as the specialist predator *T. occidentalis* (Dunley and Croft 1990).

Clover ground cover and bare ground comparison. A total of 512 Phytoseiidae representing 8 different species was collected during the spring and summer sampling (Table 3). *Typhlodromips sessor*, *T. peregrinus*, and *A. morgani* were the most abundant species collected from Fraser fir with either a clover ground cover or with the trees on bare ground. *Neoseiulus fallacis* was found in greatest abundance on Fraser fir branches with a clover cover crop, and 3 species of phytoseiid mites were found in the clover samples. The most abundant species in the clover, *Neoseiulus vagus* (Denmark), was never collected from Fraser fir foliage. However, *A. morgani* and *T. sessor*

Table 1. Phytoseiidae collected from overwintering sites in Fraser fir plantations, in Ashe, Watauga, and Avery Counties, NC.

Phytoseiidae Species	Clover	Bark	Mixed grasses	Mixed ground cover	F.fir Branches*	F.Fir branches**	F.fir needles**	F. fir Cones**	Total Phyto.
Amblyseiella setosa Muma	0	0	0	0	0	0	0	2	2
Arrenoseius morgani (Chant)	0	0	5	1	0	0	154	0	160
Chelaseius vicinus (Muma)	0	0	2	0	0	0	0	0	2
Neoseiulus fallacis (Garman)	0	0	6	1	1	0	0	0	8
Neoseiulus vagus (Denmark)	1	0	24	4	0	0	0	0	29
Proprioseiopsis clause (Muma)	0	0	3	0	0	0	0	0	3
Proprioseiopsis solens (DeLeon)	0	0	0	0	6	0	0	0	6
Proprioseiopsis okanagensis (Chant)	0	0	3	0	0	0	2	0	5
Tenorioseius gracilisetae (Muma)	0	0	3	0	0	0	0	0	3
Typhlodromalus peregrinus (Muma)	0	0	2	1	29	2	0	0	34

Table 1. Continued.

Phytoseiidae Species	Clover	Bark	Mixed grasses	Mixed ground cover	F.fir Branches*	F.Fir branches**	F.fir needles**	F. fir Cones**	Total Phyto.
Typhlodromus(Anthoseius) claudiglans (Schuster)	0	6	0	0	0	0	0	0	6
Typhlodromips sessor (DeLeon)	2		126	20	5	1	2	0	156
Total Phytoseiids	3	6	174	27	41	3	158	2	414
No. samples collected	15	9	21	10	17	15	13	1	
Mean Phytoseiids/sample	0.2	0.6	8.3	2.7	2.4	0.2	12.1	0.5	

* Collected from Fraser fir with a white clover cover crop.

* Collected from Fraser fir with a mixed herbaceous and grass ground cover.

Table 2. Shannon's diversity (H) and evenness (E) values for phytoseiid mite overwintering sites in Fraser fir plantations, in Ashe, Watauga, and Avery Counties, NC 2006 - 2007.

Overwintering sites	Shannon's diversity (H)	Shannon's evenness (E)
Clover	0.276	0.918
Bark	0.000	
Mixed grasses	0.451	0.472
Mixed ground covers	0.378	0.541
Fraser fir branches*	0.379	0.630
Fraser Fir branches**	0.276	0.918
Fraser fir cones	0.000	
Fraser fir needles	0.059	0.123

* Collected from Fraser fir with a white clover cover crop.
** Collected from Fraser fir growing on bare ground.

were both collected in the clover samples and were common on Fraser fir branches. Shannon's diversity (H) and evenness (E) values were greatest (H = 0.625, E = 0.894) on Fraser fir trees growing in fields with a clover ground cover (Table 3). Phytoseiid mite abundance was not significantly different in clover ground cover versus bare ground, by ground cover type ($F = 0.07$; $df = 1$; $P = .788$), day ($F = 1.99$; $df = 4$; $P = 0.116$) or site ($F = 1.52$; $df = 17$; $P = 0.140$) (Table 4). There is sufficient biological information on 4 of the species collected during these seasonal studies (*N. fallacis*, *T. sessor, T. peregrinus*, and *Typhlodromus (Anthoseius) claudiglans* (Schuster)) to suggest that they could be useful in a biological control program on Fraser fir trees (McMurtry and Croft 1997). Both *N. fallacis* and *T. sessor* were found in the Fraser fir foliage. *Typhlodromus (Anthoseius) claudiglans* (Schuster) was found only in bark crevices during the winter, and not on foliage. *Typhlodromalus peregrinus* was the most abundant phytoseiid mite collected on Fraser fir foliage during the winter whereas *T. sessor* was found in greater abundance during the spring and summer. *Arrenoseius morgani* was previously reported to be commonly associated with spruce spider mite (Lehman 1982), but unfortunately research investigating its potential as a biological control agent of spruce spider mite in North Carolina Fraser fir plantations has not been conducted. The results of this study have several implications for pest management in Fraser fir Christmas tree production. First, the great diversity of predatory phytoseiids identified suggests that some may have potential use as predators of spruce spider mites. Because this information is critical in a scouting program, additional research should quantify the impact of these predators on spider mites. Second, whereas the clover cover crop was not found to influence predator diversity or abundance, this does not diminish the importance of cover crops for reducing erosion and sedimentation and for improving fertilizer uptake. At times, cover crops may also provide pollen as an alternative food source for predaceous mites. Further research is needed in this area and should include a survey of vegetation surrounding Christmas tree plantations as a refuge for natural enemies, influence of plantation size on natural enemy populations, and a larger range of ground cover species that might provide habitat for natural enemies.

Table 3. Phytoseiidae collected from Fraser fir in plantations with either a white clover cover crop or bare ground, Ashe County N.C.

Phytoseiidae Species	Fraser fir branches*	Fraser Fir branches**	White Clover	Total Phytoseiidae
Amblyseiella setosa Muma	0	6	0	6
Arrenoseius morgani (Chant)	66	14	7	87
Neoseiulus fallacis (Garman)	7	2	0	9
Neoseiulus vagus (Denmark)	0	0	26	26
Proprioseiopsis solens (DeLeon)	45	4	0	49
Typhlodromalus peregrinus (Muma)	68	24	0	92
Typhlodromina conspicua	0	1	0	1
Typhlodromips sessor (DeLeon)	93	63	15	171
Unidentified males	23	11	3	37
Unidentified immatures	10	24	0	34
Total Phytoseiids	312	149	51	512
No. samples collected	50	20	50	
Mean Phytoseiids/sample	6.2	7.4	1.0	
Shannon's Diversity	0.625	0.564	0.424	
Shannon's Evenness	0.894	0.667	0.889	

* Collected from Fraser fir with a white clover cover crop.
** Collected from Fraser fir growing on bare ground.

Table 4. ANOVA test results for the influence of clover ground cover and bare ground on phytoseiid mite abundance on Fraser fir trees.

Source	DF	SS	MS	F	P
Model	22	4980	226	1.44	0.159
Site	17	4061*	238	1.52	0.140
Day	4	1248*	312	1.99	0.116
Ground cover	1	11.4*	11.4	0.07	0.788
Error	37	5813	157		

* Type III SS.

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References Cited

Boyne, J. V. 1980. Studies on the population dynamics of the spruce spider mite *Oligonychus ununguis* (Jacobi) (Acarina: Tetranychidae) and the predator of *Neoseiulus fallacis* (Garman) (Acarina: Phytoseiidae). M.S. Thesis. N.C. State University. Raleigh. 111 pp.

Boyne, J. V. and F. P. Hain. 1983. Responses of *Neoseiulus fallacis* (Acarina: Phytoseiidae) to different prey densities of *Oligonychus ununguis* (Acarina: Tetranychidae) and to different relative humidity regimes. Can. Entomol. 115: 1607-1614.

Chant, D. A. 1959. Phytoseiid mites (Acari: Phytoseiidae). Part I. Bionomics of seven species in southeastern England. Part II. A taxonomic review of the family Phytoseiidae with descriptions of 38 new species. Can. Entomol.: 1-119.

Dunley, J. E. and B. A. Croft. 1990. Dispersal between and colonization of apple by *Metaseiulus occidentalis* and *Typhlodromus pyri* (Acarina: Phytoseiidae). Exp. Appl. Acarol. 10: 137-149.

Johnson, W. T. and H. H. Lyon. 1994. Insects that feed on trees and shrubs, Second edition, revised. Cornell Univ. Press, Ithaca, NY.

Khan, A. I. and M. Fent. 2005. Seasonal population dynamics of *Typhlodromus pyi* (Acari, Phytoseiidae) in apple orchards in the region Meckenheim. J. Pest Sci. 78: 1-6.

Knisley, C. B. and F. C. Swift. 1971. Biological studies of *Amblyseius umbraticus* (Acarina: Phytoseiidae). Ann. Entomol. Soc. Am. 64: 813-822.

Kramer, D. A. and F. P. Hain. 1989. The effect of constant-humidity and variable-humidity and temperature regimes on the survival and developmental periods of *Oligonychus ununguis* (Acarina: Tetranychidae) and *Neoseiulus fallacis* (Acarina: Phytoseiidae). Environ. Entomol. 18: 741-746.

Krantz, G. W. 1978. A manual of acarology, 2nd Edition, Oregon State Univ. Bookstores, Corvallis, 509 p.

Leetham, J. W. and C. D. Jorgensen. 1969. Overwintering phytoseiid mites in central Utah apple orchards. Great Basin Nat. 29: 96-104.

Lehman, R. D. 1982. Mites (Acari) of Pennsylvania conifers. Trans. Am. Entomol. Soc. 108: 181-286.

Mangini, A. C. and F. P. Hain. 2007. Phytoseiidae (Acari: Mesostigmata) from cover crops in western North Carolina. J. Entomol. Sci. 42: 415-420.

McGroarty, D. L. and B. A. Croft. 1978. Sampling the density and distribution of *Amblyseius fallacis* Garman (Acarina: Phytoseiidae) in the ground cover of Michigan apple orchards. Can. Entomol. 110: 785-794.

McMurtry, J. A. 1992. Dynamics and potential impacts of 'generalist' phytoseiids in agroecosystems and possibilities for establishment of exotic species. Exp. Appl. Acarol. 14: 371-382.

McMurtry, J. A. and B. A. Croft. 1997. Life-styles of phytoseiid mites and their roles in biological control. Annu. Rev. Entomol. 42: 291-321.

McMurtry, J. A., C. B. Huffake and M. van de Vrie. 1970. Ecology of tetranychid mites and their natural enemies: a review. 1. Tetranychid enemies: their biological characters and the impact of spray practices. Hilgardia 40: 331-390.

Moraes, G.J. de, J. A. McMurtry, H. A. Denmark and C. B. Campos. 2004. A revised catalog of the mite family Phytoseiidae. Zootaxa (434). Magnolia Press, Auckland, New Zealand. pp. 1-494.

Nyrop, J., J. C. Minns and C. P. Herring. 1994. Influence of ground cover on dynamics of *Amblyseius fallacis* Garman (Acarina: Phytoseiidae) in New York apple orchards. Agric. Ecosyst. Environ. 50: 61-72.

Pratt, D. P. and B. A. Croft. 2000. Overwintering and comparative sampling of *Neoseiulus fallacis* (Acari: Phytoseiidae) on ornamental nursery plants. Environ. Entomol. 29: 1034-1040.

Putman, W. L. 1959. Hibernation sites of phytoseiids (Acarina: Phytoseiidae) in Ontario peach orchards. Can. Entomol. 91: 735-741.

Rose, A. H. and O. H. Lindquist. 1977. Insects of eastern spruces, fir and hemlock. Can. For. Serv., For. Tech. Rep. 23.

SAS Institute. 2007. The SAS System, Version 9.1. SAS Institute, Cary NC.

Sidebottom, J. R. 1997. IPM checklist in established Fraser Fir Christmas tree plantations. Christmas Tree Notes CTN-032. North Carolina Coop. Ext. Ser., Raleigh.

Sidebottom, J. R. 2002. The spruce spider mite on Fraser Fir. Christmas Tree Notes CTN- 029. North Carolina Coop. Ext. Ser., Raleigh.

Stanyard, M. J., R. E. Foster and T. J. Gibb. 1997. Effects of orchard ground cover and mite management options on the population dynamics of European red mite (Acari: Tetranychidae) and *Amblyseius fallacis* (Acari: Phytoseiidae) in apple. J. Econ. Entomol. 90: 595-603.

Vandermeer, J. 1981. Elementary mathematical ecology. John Wiley and Sons, USA.

Williams, L., F. P. Hain and D. Orr. 2011. Influence of four ground cover vegetation types used in North Carolina Fraser fir Christmas tree plantations on abundance and species composition of Phytoseiid mites (Acari: Phytoseiidae). J. Entomol. Sci. 46: 216-222.

Zacharda, M. 1989. Seasonal history of *Typhlodromus pyri* (Acari: Mesostigmata, Phytoseiidae) in a commercial apple orchard in Czechoslovakia. Exp. Appl. Acarol. 6: 307-325.