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)[1]

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Abstract A study was conducted to determine the utility of ground cover vegetation in managing the natural enemies of spruce spider mite (*Oligonychus ununguis* Jacobi) in Fraser fir production areas in 2 locations in North Carolina (Laurel Springs, Waynesville). Predatory phytoseiid mites were sampled by collecting vegetation from 4 ground cover species in experimental Fraser fir plots: white Dutch clover (*Trifolium repens* L.), mammoth red clover (*Trifolium pretense* L.), birdfoot trefoil (*Lotus corniculatus* L.), and fescue (*Festuca* spp.). The most abundant phytoseiid mite species were *Typhlodromips sessor* (DeLeon), *Arrenoseius morgani* (Chant), *Proprioseiopsis solens* (DeLeon), and *Typhlodromalus peregrinus* (Muma). There were no statistical differences in the effects of ground cover vegetation on phytoseiid mite abundance or diversity.

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

The spruce spider mite (*Oligonychus ununguis* Jacobi) (Acari: Prostigmata) is regarded as one of the most serious mites attacking conifers (Johnson and Lyon 1994). In North Carolina, the quality of plantation-grown Fraser fir (*Abies fraseri* [Pursh] Poiret) Christmas trees is often reduced when the feeding of spruce spider mites causes discoloration of needles (Boyne and Hain 1983, Mangini and Hain 2007).

Predatory mites in the family Phytoseiidae (Acari: Mesostigmata) are common predators of phytophagous mites (Moraes et al. 2004). Currently, there is little information available on the phytoseiid mites associated with Fraser fir Christmas tree production in North Carolina. Several studies have investigated the feasibility of using phytoseiid mites as components of biological control programs for the management of spruce spider mite in Fraser fir production (Boyne and Hain 1983, Kramer and Hain 1989, Mangini and Hain 1991). Fifteen species of phytoseiid mites were found during a survey of ground covers used in North Carolina Fraser fir production (Mangini and Hain 2007). However, this survey did not compare the ground cover predatory mite fauna to the communities actually found on Fraser fir trees.

Ground cover management is an important component of the Fraser fir integrated pest management program in North Carolina (Sidebottom 1997). As well as potentially providing habitat for phytoseiids, ground covers may decrease runoff and sedimentation and influence fertilizer uptake in these agricultural areas (Sidebottom 1997).

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The goal of this study was to gather information relating to the appropriate ground cover vegetation to use in managing the natural enemies of spruce spider mite in Fraser fir production areas in North Carolina. Four ground covers were evaluated to determine: (1) their impact on species abundance or diversity of phytoseiid mites, either on the trees or in the ground cover; (2) their influence on the abundance of phytoseiid mites known to be natural enemies of spruce spider mite, and; 3) their effect on the species composition of the phytoseiid mites found in the ground cover compared with those found on the adjacent Fraser firs.

Materials and Methods

The study areas were located in western North Carolina at the Upper Mountain Research Station located near Laurel Springs, Ashe Co., and the Mountain Research Station located near Waynesville, Haywood Co. The study consisted of 3 ground cover treatments and 1 control: white Dutch clover (*Trifolium repens* L.), mammoth red clover (*Trifolium pretense* L.), birdfoot trefoil (*Lotus corniculatus* L.), and fescue (*Festuca* spp.) as the control. Our goal was to simulate actual growing conditions a tree farmer may encounter when minimal herbicide applications are used. Therefore, there was encroachment of several species of herbaceous vegetation into the plots throughout the growing season. The fescue treatments tended to have less encroachment of herbaceous vegetation because it out-competed other species. The treatments were chosen because these species are currently being used as ground covers in North Carolina Fraser fir plantations. Ground covers and Fraser fir trees were established in eight, 9.1 × 13.7 m blocks in a complete randomized block design replicated twice in each study location. Fraser trees were between 30.5 cm and 48.3 cm tall at the time they were planted. Trees were planted in 24 rows with 19 trees per row for a total of 456 trees per location. Trees were planted 1.5 m apart. The number of trees per block varied from 50 - 57. Both the ground covers and the Fraser fir transplants were planted in March 2005 at each location. Each site was mowed once per yr, usually during midsummer. Periodic herbicidal treatments using glyphosate were applied to the ground covers in a 0.60 m band along the rows of trees to eliminate competition with the trees. Thus, the ground covers were in a 0.90 m band between the tree rows.

Samples were collected monthly from both sites between April and September 2007: 19 May, 16 June, 4 July, 2 August, and 4 September at Laurel Springs; 19 May, 11 June, 25 June, 11 August and 1 September at Waynesville. Foliar samples were collected from each block by cutting 1 randomly-selected 14-cm branch from each of 10 Fraser fir trees. Samples were placed in 7.5-L plastic bags and transported to the laboratory in coolers. Three randomly chosen fixed surface area (20 × 20 cm) samples were collected from the ground cover vegetation in each plot by cutting the ground cover at the soil line between rows of Fraser fir and placing the sample into a 7.5-L plastic bag for transport to the laboratory.

Arthropods were extracted from the branches using Tullgren funnels outfitted with a 40-w incandescent bulb for drying. A cup with 70% ethanol and a few drops of glycerin were placed under each funnel to collect mites. Samples were left in the funnels for 5 d. Funnels were washed and wiped clean between uses to avoid cross contamination. Arthropods were sorted using a 10 - 50x stereo-microscope. Phytoseiid mites were removed and mounted with Hoyer's medium on glass microscope slides and covered with 12-mm diam cover slips. Slides were dried for 48 h in a drying oven set at 50°C (Krantz 1978). Generic and specific identifications were made using a phase- contrast

microscope at 40 - 100x. The senior author performed all identifications. A few slides of each species 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. We pooled the data from the 2 locations to address site-specific differences in encroaching vegetation which could potentially influence phytoseiid abundances. An analysis of variance (ANOVA) test was used to determine if there was a difference among ground covers with respect to their influence on the abundance of phytoseiid mites both in the Fraser fir and/or in the ground cover vegetation (Proc GLM, SAS 2007). The analysis was conducted by site, day and ground cover. Shannon's diversity and evenness values were calculated to compare phytoseiid diversity/evenness among the different ground cover vegetation plots (Vandermeer 1981).

Results and Discussion

Ten species were identified from the phytoseiid mites collected during the study. The most abundant species found were *Typhlodromips sessor* (DeLeon) (n = 257), *Arrenoseius morgani* (Chant) (n = 127), *Proprioseiopsis solens* (DeLeon) (n = 92), and *Typhlodromalus peregrinus* (Muma) (n = 52).

A total of 678 phytoseiid mites was collected from the Fraser fir trees (Table 1), and 58 were collected from the ground covers (Table 2). The Fraser fir trees yielded the greatest diversity of phytoseiid mites with 9 species collected, whereas 5 species were collected from the ground covers. *Chelaseius floridanus* (Muma) and *Neoseiulus vagus* (Denmark) were collected exclusively from ground cover. Mite species diversity on the Fraser fir trees was similar in all ground cover treatments. The exceptions were *Phytoseius* sp., collected just once, and a small number (n = 13) of *Typhlodromina conspicua* (Garman). Neither phytoseiid mite abundance nor diversity were statistically different among ground cover treatments in newly-established Fraser fir plantations when analyzed by site, day and ground cover (Table 3). Our results have significance for cultural practices currently used in Fraser fir IPM programs and suggest that the ground covers evaluated in this study may not significantly influence the species of phytoseiid mites found on the Fraser fir trees. The role of ground cover crops on *N. fallacis* populations in apple orchards also has been questioned by some researchers (Nyrop et al. 1994).

Certain species of phytoseiid mites may favor the structure of Fraser fir plantations independent of the ground cover type. *Typhlodromips sessor,* for example, is a common species widely distributed along the Atlantic coastal states of the USA (Sciarappa et al. 1977). It is considered a generalist and consumes both plant and animal matter (Sciarappa et al. 1977, McMurtry and Croft 1997). This species is commonly found on herbaceous plants with pubescent leaves and/or thorns (Sciarappa et al. 1977), which may account for its lack of abundance in the species of ground covers we evaluated in this study. However, it is well adapted to early successional plant communities and can be common in 1-to 5-year-old fields (Sciarappa et al. 1977). Because Fraser fir Christmas trees are grown on a short rotational schedule, these plantations are similar to early successional plant communities. It is, therefore, not surprising that we found *T. sessor* to be the most abundant species on the Fraser fir trees during this investigation, independent of the ground cover type. *Typhlodromalus peregrinus* is a generalist predator known to feed on spider mites and pollen (Muma 1971). The food preference for members of the *P. dorsatus* group, of which *P. solens* is an affiliate, is

Table 1. Total number and Shannon's diversity and evenness values of Phytoseiidae collected from Fraser fir trees from plots with four ground covers at Upper Mountain Research Station (Laurel Springs, NC) and Mountain Research Station (Waynesville, NC).

Phytoseiid Species	Fescue	White clover	Red clover	Birdfoot Trefoil	Total phytoseiids
Arrenoseius morgani (Chant)	38	20	31	38	127
Neoseiulus fallacis (Garman)	23	5	8	1	37
Neoseiulus vagus (Denmark)					0
Proprioseiopsis solens (*DeLeon)*	13	44	13	22	92
Proprioseiopsis okanagensis *(Chant)*	1	1	1		3
Phytoseius sp.				1	1
Typhlodromina conspicua (Garman)	4		5	4	13
Typhlodromalus peregrinus *(Muma)*	6	23	22	1	52
Typhlodromips sessor (DeLeon)	108	11	97	41	257
Unidentified males	20	5	9	13	47
Unidentified immatures	14	6	8	9	37
Unidentified phytoseiids	3	4	1	4	12
Total Phytoseiids/ground cover	230	119	195	134	678
Shannon's Diversity	0.563	0.627	0.589	0.570	
Shannon's Evenness	0.666	0.805	0.697	0.674	

Table 2. Total number and Shannon's diversity and evenness values of Phytoseiidae collected from four ground covers at Upper Mountain Research Station (Laurel Springs, NC) and Mountain Research Station (Waynesville, NC).

Phytoseiid Species	Fescue	White clover	Red clover	Birdfoot Trefoil	Total phytoseiids
Arrenoseius morgani (Chant)	1		1		2
Chelaseius floridanus (Muma)		1			1
Neoseiulus fallacis (Garman)				1	1
Neoseiulus vagus (Denmark)	4	8	23	2	37
Proprioseiopsis solens (*DeLeon)*					0
Proprioseiopsi okanagensis *(Chant)*		10	1		11
Phytoseius sp.					0
Typhlodromina conspicua (Garman)					0
Typhlodromalus peregrinus *(Muma)*					0
Typhlodromips sessor (DeLeon)	2	3			5
Unidentified males					0
Unidentified immatures	1				1
Unidentified phytoseiids					
Total Phytoseiids/ground cover	8	22	25	3	58
Shannon's Diversity	0.217	0.0372	0.0145	0.276	
Shannon's Evenness	0.722	0.780	0.304	0.918	

Table 3. ANOVA test results for four ground covers on phytoseiid mite abundance at Upper Mountain Research Station (Laurel Springs, NC) and Mountain Research Station (Waynesville, NC).

Source	DF	SS	MS	F	P> F
Model	12	131	10.9	0.83	0.621
Site	1	0.00	0.00	0.00	1.00
Day	8	71.4	8.92	0.68	0.70
Ground cover	3	34.4	11.4	0.87	0.46
Error	27	356	13.2		

*Type III SS

likely to be phytophagous mites (Muma 1971). *Arrenoseius morgani* was previously reported to be commonly associated with spruce spider mite (Lehman 1982).

The results of this study have several implications for pest management in Frasier fir Christmas tree production. One, a great diversity of predatory phytoseiids were identified, and most were collected in the trees. This information is critical in a scouting program; yet, additional research should quantify the impact of these predators on spider mites. Second, while specific cover crops were not found to influence predator diversity or abundance, this does not diminish the importance of cover crops for reducing erosion and sedimentation and improving fertilizer uptake. Also, the cover crops may provide an alternative food source, i.e., pollen at times. Further research is needed in this area and should include a range of ground cover species as well as a bare soil comparison.

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