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Arthropods in a Scab, *Venturia inaequalis* (Cke.) Wint., (Ascomycetes:Mycosphaerellacea), and European Red Mite, *Panonychus ulmi* (Koch), (Acari:Tetranychidae), Resistant Apple Orchard in Indiana

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Abstract

Three years of sampling an apple orchard with seven apple scab, *Venturia inaequalis* (Cke.) Wint., resistant selections, five of which were also resistant to European red mite, *Panonychus ulmi* (Koch), growing on three different rootstocks (EMVII, MM106, and MM111), showed a faunal composition consisting of nine orders from which 26 families were identified. Two specimens, a homopteran and a lepidopteran, were identified only to order. Seventy-four specimens were identified to genus only, and 59 to species. Three groups (aphids, leafhoppers, and ladybird beetles) and nine species of arthopods were found most frequently. Of these the ladybird beetles (grouped together), the green lacewing, *Chrysopa carnea* (Stephens), and the smooth yellow mite, *Zetzellia mali* (Ewing), were reported to be beneficial by other investigators. Significant differences ($P<0.05$) in the incidence of aphids and codling moth were found between rootstocks and between selections. Similar differences in incidence were found between rootstocks for ladybird beetles and between selections for Z. mali. These data suggest that the spectrum of arthropods found on selections developed through breeding efforts may require a less complicated pesticide protocol for management when compared with that required for cultivated apple cultivars. The protocol may depend on the trait/s for resistance that each selection carries.

Introduction

The cultivated apple is not a distinct species but is the product of interspecific hybridization; hence the legitimate nomenclature should be *Malus* x *domestica* Borkh. (14) Apple orchards support complexes of arthropod and disease species, the compositions of which vary among geographic regions (5, 15, 16, 17, 21) Reports by Cleveland and Hamilton (5) and Oatman *et al.* (17) deal with arthropods occurring on the aerial parts of the apple tree.

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The cultivated apple hosts a total of 193 diseases attributable to parasites or pathogens or specific physiological causes (11). Efforts to breed disease and arthropod pest resistance into apples have been aimed at enhancing the existing levels of the specific resistance to specific organisms or to incorporate multiple resistance to several organisms. Such breeding efforts may result in selections that alter the composition, diversity and dynamics of pest problems when compared to standard cultivars. For example, Reissig *et al.* (19) and Prokopy (18) found reduced damage in scab resistant apples when they used a considerably modified pesticide application schedule, even though no arthropod pest resistance has been reported in these selections. Goonewardene and Kwolek (10) also reported that rootstocks could significantly influence damage by three early season pests of apple. Therefore an understanding of the pests associated with and utilizing these genetically altered hosts may provide insights into more effective ways of managing such an apple agroecosystem.

Resistance to diseases, specifically to apple scab, was introduced into the cultivated apple by incorporating a gene or genes from small fruited cultivars of *M. floribunda* Sieb., *M. micromalus* Mak., *M. atrosanguinea* Schneid, *M. baccata jackii* Rehd., and *M. sargenti* Rehd. (14) Among these scab-resistant apple selections are some resistant to European red mite, *Panonychus ulmi* (Koch) (ERM) (9, 12), *Laspyresia pomonella* (L.), (Cm), *Conotrachelus nenuphar* (Herbst), (Pc), *Rhagoletis pomonella* (Walsh), (AM), and *Argyrotaenia velutinana* (Walker), (Av), (11). Apple selections from either the F3 or F4 or F5 or F6 generations, with resistance to specific pests, were available for our study.

Although commercial apple cultivars may differ in their susceptibility to both scab and arthropod pests, there have been no definitive reports on resistance, except against several aphids (18). Therefore, all commercially grown cultivars may be considered as being susceptible to damage by pests of economic importance. To reduce the level of damage growers use pesticides. Apples are reported to be one of the most heavily sprayed crops when pesticide treatment is taken on a per-acre basis (6). If the genotypes of these cultivars were changed through the incorporation of a specific gene or genes for resistance, they may, in their changed form, respond differently to pests and diseases. Complexes of pests and diseases present on the changed genotypes may also differ from those found on the original genotypes (cultivated apples). Some evidence that this may occur is provided by Prokopy (18). If such changes did occur, then pest control practices may require modifications for such genotypes when they are adopted for commercial production. Knowledge of the fauna present on these selections is an essential precursor to any form of management. Our objective, therefore, was to profile the fauna present on some advanced apple selections with scab and ERM resistance, and to analyze the impact of selections and rootstocks on the fauna.

Materials and Methods

Seven selections (HAR4T67(cv. 'Priscilla'), HAR10T166, HCR21T200 (cv. 'Redfree'), HCR23T125, S80ER-21T72, TSR16T223, and TSR37T73) form the F5 generation of the Purdue-Rutgers-Illinois (PRI) Cooperative Apple Breeding Program were used in the study at Lafayette Ind. Apple scab resistance had been introduced through the transfer of genes from; *M. floribunda* to HAR4T67, HAR10T166, HCR21T200, HCR12T125, and TSR-16T223; *M. micromalus* to TSR37T73; and *M. Zumi calocarpa* Rehd. to S80ER21T72. Other parents used in the development were 'Rome Beauty,' 'Jonathan,' 'Golden Delicious,' 'McIntosh,' 'Melba,' 'Raritan,' 'Starking,' 'Starr,' 'Wealthy,' 'Wolf River,' 'Early

McIntosh,' 'Jersey Black,' 'Macoun,' and 'Petrel.' Not all of the above cultivated apples (except 'Raritan' which is the product of a planned cross) were present as an ancestor in every selection, but one or more were used as parents in the breeding scheme.

Using a standard procedure (12) HCR21T200, HCR23T125, S80ER21-T72, TSR16T223, and TSR37T73 were identified on the basis of preference, as selections with resistance to ERM and HAR4T767 and HAR10T166 as susceptible (unpublished).

The selections were planted in 1976 as grafts on M.7, MM.106 and MM.111, in an orchard block at W. Lafayette, IN. (Fig. 1). Distance between trees within a row was 3.6m and the rows were 6.1 apart. Each selection-rootstock combination was replicated 4 times. A herbicide mixture (0.45 kg Sinbar + 0.95 L Paraquat per 380 l of water) was applied annually beginning in mid-spring of 1978. Fertilizer (34N-OP-OK) was applied (0.10 Kg per tree) in early spring of each year beginning in 1977. Summer pruning was targeted to the removal of water sprouts and for the training of each tree. An oil (70 sec superior oil) spray was applied at 'green tip' stage of bud development from 1977 to 1981 to reduce the negative impact on tree growth and development from overwintering arthropods other than ERM. An annual oil spray is recommended for control of certain pests including ERM eggs, from the 'dormant' to the 'green tip' stage of apple tree development (13) and we followed this protocol up to 1981 because we found no information in the literature which suggested that season long control of apple pests results from a single application of dormant oil. No foliar applications of any pesticides were made after 1981.

The study was commenced in 1982 on 25, 24 and 28 trees growing on the M.7, MM.106 and MM.111 rootstocks, respectively, because three trees growing on M.7 and four on MM.106 rootstocks had died prematurely. The trees ranged from 1.1-4.1, 1.1-5.1, and 2.0-4.5m in height and 2.5-7.0, 2.5-11.0 and 4.0-1.0 cm. in girth for M.7, MM.106, and MM.111, respectively.

The scientific names and the abbreviation used for most of the arthropods referred to in this paper are given in Table 1. Only those not mentioned in Table 1 and reported elsewhere in the text are identified by their scientific name. Pheromone traps (Pherocon[R]) were used for monitoring Cm, Av, oblique-banded leafroller (Cr) and Am. All trees were sampled weekly from 'green tip' to 'leaf fall' for the three years of the study. Thirty fruit per tree, including drops, were also examined for damage by Tp, Cr and Av and 60 per tree for Pc, Cm and Am damage. Fifteen leaves per tree, chosen at random, were examined for the following mites: ERM, two-spotted spider mite, *Tetranychus urticae* (Koch) (TSM), Fm, *Aculus schlectendali* (Nalepa) (RM), Sm and rough yellow *Agistemus fleschneri* (Summers). Ten leaves from the first-year growth were observed for all aphids (except the woolly apple aphid) and any predators. The presence of white apple leafhopper was observed on 30 leaves per tree, leafminers on 30 fruit cluster leaves per tree and woolly aphids on 15 terminals. All other arthropods present during weekly examinations were noted. The data were prepared for analysis on the basis of the presence or absence of the arthropods on each tree at each count during the 3-year study since we did not expect to develop 'threshold' values. Damage thresholds (3) have been established for most economic pests of apple and these would be no different if these same pests damaged the apple selections in our study. We, therefore, saw no need for development of new thresholds. Also in the grading of apples in Indiana the tolerance for arthropod damage on fruit is zero (7), therefore, the use of the criteria of the

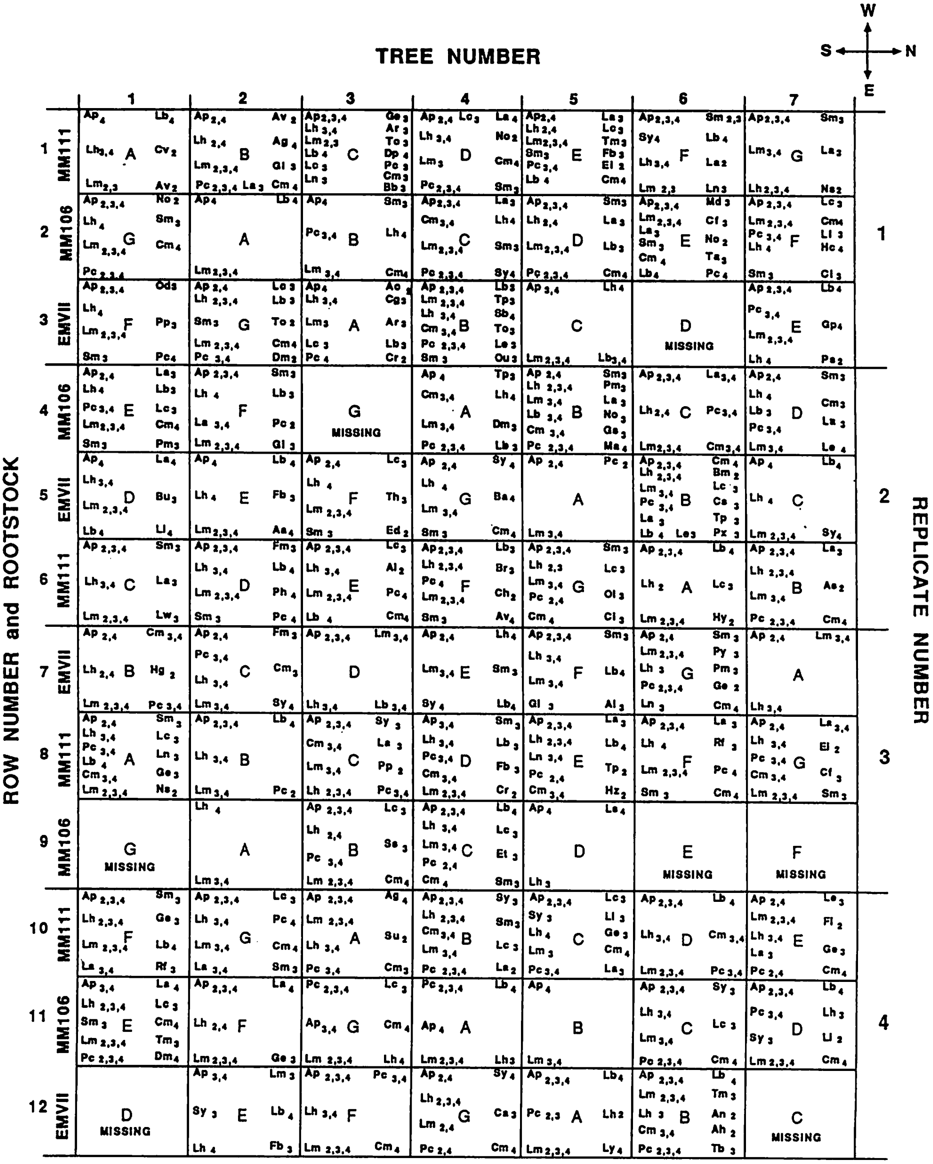

Fig. 1. Shows the layout of the orchard of seven apple scab resistant selections. Within the square around each selection the abbreviation of the names of the fauna found in a three year survey are as noted in Table 1, column 5, with the exception of the following:
Ap = *A. pomi; D. plantaginea; E. lanigerum*
Lh = *E. maligna; J. olitoria; P. americana; T. pomaria; M. pruninosa*
Lb = *A. bipunctata; C. maculata; H. convergens; O. V. nigrum.*
The year in which the arthropod was found is listed as a subscript to the abbreviation: 2 = 1982; 3 = 1983 and 4 = 1984. The five ERM resistant selections were A (HCR23T125); B (HCR21T200), C (TSR16T223), D (S80ER21T72), and E (TSR37T73); and the ERM susceptible selections were F (HAR10T166) and G (HAR4T67).

presence or absence of damage for evaluation is justified for fruit pests.

Arthropods not readily identified in the field were returned to the laboratory in individual vials containing 2.5 ml of 70% ETOH. All arthropods that could not be identified were shipped in alcohol to The Systematic Entomology Laboratory, Agric. Res. Serv., Beltsville, MD 20705.

The incidence of each arthropod found in each year on each tree was recorded, using the abbreviated names reported in Table 1, on the orchard plan. A composite of the incidence for the period of the study was thus developed as shown in Fig. 1. From the list of several arthropods found, we then developed those that were most frequently present and these data were analyzed. Graphs were prepared to show differences of arthropod incidence between arthropods and selections.

When the data were treated as described above probable differences in arthropod incidence between rootstocks and selections were evident. To understand the significance of these differences we analyzed the frequency distribution of the 12 most frequently occurring arthropods, namely the aphid group (Ap), leafhopper group (Lh), leafminer group (Lm), redbanded leafroller (Av), greenlooper(Gl), plum curcurlio (Pc), codling moth (Cm), dagger moth (Ag), *C. violacea* (Cv), ladybird beetle group (Lb), lacewing (La) and the smooth yellow mite (Sm), using the X^2 test. We used X^2 values to determine differences among rootstocks and among selections for each of these arthropods, using the criterion of absence (O) or presence (1) for all three years as well as for each of the years assigned the value (1), (2), and (3) to denote presence in 1, 2, and 3 years, respectively. Only the data for Ap and Lh were adequate for separating by years of incidence. Data for each of the other arthropods were not separated according to years of incidence, but combined to indicate presence or absence. This procedure allowed some tests to have 2 and others 6 degrees of freedom for rootstocks and 6 and 18 degrees of freedom for selections.

Results and Discussion

The complexity of the arthropod fauna present in an apple orchard becomes evident when the information provided by Cleveland and Hamilton (15), Oatman *et al.* (17), Brunner *et al.* (4) and from Table 1 is combined to develop a single list. From such a list we found 660 species, and 330 genera (not identified to species) 9 families (identified only to family) and 3 orders (not identified further), for a grand total of 1002 different arthropods. In this paper the terms genus or genera, family and order are used to refer to identify the point to which the respective arthropod/s have been identified in those cases where identification had not progressed to species. It is interesting to note that there were three, 33 and 14 species and one, six and zero genera of arthropods that were reported by Cleveland and Hamilton (5) in Indiana, Oatman *et al.* (17) in Wisconsin and Brunner *et al.* (4) in Michigan, respectively, that were also found by us (Table 1). Cleveland and Hamilton (5) reported 38 species and 49 genera that were also found by Oatman *et al.* (17). Twenty-one species were listed by both Oatman *et al.* (17) and Brunner *et al.* (4). Our list also contained 29 species listed by Brunner *et al.* (4). No species or genera that were reported by Cleveland and Hamilton (5) and Brunner *et al.* (4) were common. Not one species was common to all four lists. None of the annual pests Am, Cm, Pc, and Av were reported by Cleveland and Hamilton (5); whereas they were found to be present by Oatman *et al.* (17) and Brunner *et al.* (4). We found no Am or ERM in any of the years. In view of these reports these absence of ERM even on the two susceptible selections cannot be readily explained

Table 1. Arthropod fauna found in a three year (1982, 1983, and 1984) study of an unsprayed block of seven scab-resistant apple selections, five of which were also resistant to European red mite, growing on M.7, MM.106, and MM.111 rootstocks.

Abbreviation[1]	Common Name	Scientific Name	Order:Family	Probable Status	Reported by other investigators[2]
Aa	Fruit tree leafroller	*Archips argyrospila* (Walker)	Lepidoptera:Tortricidae	Pest	
Ac	American dagger moth	*Acronicta americana* (Harris)	Lepidoptera:Noctuidae	Pest	
Ag	Dagger moth	*Acronicta interrupta* (Guenee)	Lepidoptera:Noctuidae	Pest	B
Ah		*Archips* sp.	Lepidoptera:Tortricidae	Pest	B
Ai	Leaf crumpler	*Acrobasis indigenella* (Zeller)	Lepidoptera:Pyralidae	Pest	B
Al	Fall canker-worm	*Alsophila pometaria* (Harris)	Lepidoptera:Geometridae	Pest	B
An		*Acanalonia* sp.	Homoptera:Acanaloniidae	Pest	
Ap	Apple aphid	*Aphis pomi* (DeGeer)	Homoptera:Aphididae	Pest	B;D
Ap	Rosy apple aphid	*Dysaphis plantaginea* (Passerini)	Homoptera:Aphididae	Pest	D
Ap	Woolly apple aphid	*Eriosoma lanigerum* (Hausmann)	Homoptera:Aphididae	Pest	B;D
Ar		*Archips rosana* (L.)	Lepidoptera:Tortricidae	Pest	
As		*Acronicta* sp.	Lepidoptera:Noctuidae	Pest	B
Av	Red banded leafroller	*Argyrotaenia velutinana* (Walker)	Lepidoptera:Tortricidae	Pest	B;D
Ba	Braconid	(Genus unrecognized)	Hymenoptera:Braconidae	Beneficial	
Bb	Pepper and salt moth	*Biston betularia cognataria* (Guenee)	Lepidoptera:Geometridae	Pest	
Bm		*Balsa malana* (Fitch)	Lepidoptera:Noctuidae	Pest	B
Br	Seed beetles	(Genus unrecognized)	Coleoptera:Bruchidae		
Bu		*Brachiacantha ursina* (F.)	Coleoptera:Coccinelidae	Beneficial	
Cf	Crane fly	*Tipula* sp.	Diptera:Tipulidae		
Cg		*Cryptocephalus guttulatus* (Oliv.)	Coleoptera:Chrysomelidae	Pest	B
Ch		*Choristoneura fractivittana* (Clemens)	Lepidoptera:Tortricidae	Pest	
Ci	17-year cicada	*Magicicada* sp.	Homoptera:Cicadidae	Pest	
Cm	Codling moth	*Cydia pomonella* (L.)	Lepidoptera:Olethreutidae	Pest	B;D
Cr	Oblique banded leafroller	*Choristoneura rosaceana* (Harris)	Lepidoptera:Tortricidae	Pest	B;D
Cs		*Chauliognathus* sp.	Coleoptera:Cantharidae	Beneficial	
Cv		*Crepidodera violacea* (Melsheimer)	Coleoptera:Chrysomelidae	Pest	
Dm	Yellow necked caterpillar	*Datana ministra* (Drury)	Lepidoptera:Notodontidae	Pest	B
Dp		*Delphinia picta* (F.)	Diptera:Otitidae		
Ed		*Eutromula dariana* (Clerck)	Lepidoptera: Glyphipterygidae	Pest	
Ei	Imbricated snout beetle	*Epicaerus imbricatus* (Say)	Coleoptera:Curculionidae	Pest	
Et	Linden looper	*Erannis tiliaria* (Harris)	Lepidoptera:Geometridae	Pest	B

Table 1. Continued.

Abbreviation[1]	Common Name	Scientific Name	Order:Family	Probable Status	Reported by other investigators[2]
Fb	Flea beetle	(Genus unrecognized)	Coleoptera:Chrysomelidae	Pest	
Fl	Flatid plant hopper	(Genus unrecognized)	Homoptera:Flatidae	Pest	
Fm	Fallacis mite	*Amblyseius fallacis* (Garman)	Acari:Phytoseiidae	Beneficial	
Ge	Geometrid moth	(Genus unrecognized)	Lepidoptera:Geometridae	Pest	
Gl	Greenlooper	*Synchlore aerata* (F.)	Lepidoptera:Geometridae	Pest	
Gp	Lesser apple worm	*Grapholitha prunivora* (Walsh)	Lepidoptera:Olethreutidae	Pest	B;D
Gs		*Goniozus* sp.	Hymenoptera:Bethylidae	Beneficial	
Hc	Fall webworm	*Hyphantria cunea* (Drury)	Lepidoptera:Arctiidae	Pest	B;D
Hg	Saddled prominent	*Heterocampa guttivitta* (Walker)	Lepidoptera:Notodontidae	Pest	B
Hy		cocoon (Genus unrecognized)	Hymenoptera:Braconidae		
Hz	Corn earworm	*Heliothis zea* (Boddie)	Lepidoptera:Noctuidae	Pest	
La	Common green lacewing	*Chrysopa carnea* (Stephens)	Neuroptera:Chrysopidae	Beneficial	B
Lb	Two spotted lady beetle	*Adalia bipunctata* (L.)	Coleoptera:Coccinellidae	Beneficial	B;C
Lb	Spotted Lady-bird beetle	*Coleomegilla maculata lengi* (Timberlake)	Coleoptera:Coccinellidae	Beneficial	B
Lb	Convergent ladybird beetle	*Hippodamia convergens* (Gue'rin-Me'neville)	Coleoptera:Coccinellidae	Beneficial	B;C
Lb	Ash-gray ladybird beetle	*Olla v. nigrum* (Mulsant)	Coleoptera:Coccinellidae	Beneficial	
Lc	Case maker	*Coleophora* sp.	Lepidoptera:Coleophoridae	Pest	B;C
Le		(Genus unrecognized)	Lepidoptera:(Family unrecognized)	Pest	
Lh	Apple leaf hopper	*Empoasca maligna* (Walsh)	Homoptera:Cicadellidae	Pest	B
Lh		*Jikradia olitoria* (Say)	Homoptera:Cicadellidae	Pest	
Lh		*Penthimia americana* (Fitch)	Homoptera:Cicadellidae	Pest	B
Lh	White apple leafhopper	*Typhlocyba pomaria* (McAtee)	Homoptera:Cicadellidae	Pest	B;D
Lh	Flatid plant hopper	*Metcalfa pruinosa* (Say)	Homoptera:Flatidae	Pest	B;C
Lh		Nymphs (Genus unrecognized)	Homoptera:(Family unrecognized)	Pest	
Li	Viceroy butterfly	*Basilarchia archippus* (Cramer)	Lepidoptera:Nymphalidae	Pest	
Ll		*Litargus tetrspilotus* (Le Conte)	Coleoptera: Mycetophagidae	Fungus feeder	B
Lm	Spotted tenti-form leafminer	*Phyllonorycter blancardella* (F.)	Lepidoptera:Gracillariidae	Pest	D
Ln	Firefly	*Photuris pennsylvanica* (DeGeer)	Coleoptera:Lampyridae		
Ls		*Lithophane* sp.	Lepidoptera:Noctuidae	Pest	B
Lw	Leafwebber	(Genus unrecognized)	Lepidoptera:Pyralidae	Pest	
Ly		(Genus unrecognized)	Hemiptera:Lygaeidae	Pest	

Table 1. Continued.

Abbreviation[1]	Common Name	Scientific Name	Order:Family	Probable Status	Reported by other investigators[2]
Ma	Eastern tent caterpillar	*Malacosoma americanum* (F.)	Lepidoptera: Lasiocampidae	Pest	B;D
Md		*Melanophthalma distinguenda* (Comolli)	Coleoptera:Lathridiidae	Fungus feeder	B
No		(Genus unrecognized)	Lepidoptera:Noctuidae	Pest	
Ns		*Nephopteryx* sp.	Lepidoptera:Pyralidae	Pest	
Od	Locust leafminer	*Odontota dorsalis* (Thunberg)	Coleoptera:Chrysomelidae	Pest	
Ol	Whitemarked tussock moth	*Orgyia leucostigma* (J. E. Smith)	Lepidoptera:Lymantriidae	Pest	D
Ou		*Oreana unicolorella* (Hulst)	Lepidoptera:Pyralidae	Pest	B
Pc	Plum curculio	*Conotrachelus nenuphar* (Herbst)	Coleoptera:Curculionidae	Pest	B;D
Ph	Apple leaf skeletonizer	*psorosina hammondi* (Riley)	Lepidoptera:Pyralidae	Pest	B
Pm	Smut beetle	*Phalacrus politus* (Melsheimer)	Coleoptera:Phalacridae	Pest	
Pp	Meadow spittlebug	*Philaenus spumarius* (L.)	Homoptera:Cercopidae	Pest	B
Ps		*Phyllonorycter* sp.	Lepidoptera:Gracillariidae	Pest	
Px		*Paria sexnotata* (Say)	Coleoptera:Chrysomelidae	Pest	
Py		*Pyropyga* sp.	Coleoptera:Lampyridae	Beneficial	
Rf	Robber fly	*Efferia aestuans* (L.)	Diptera:Asilidae	Beneficial	
Sb	Buffalo treehopper	*Stictocephala bisonia* (Kopp & Yonke)	Homoptera:Membracidae	Pest	B
Sm	Smooth yellow mite	*Zetzellia mali* (Ewing)	Acari:Phytoseiidae	Beneficial	
Ss		*Schizura* sp.	Lepidoptera:Notodontidae	Pest	B
Su	Unicorn caterpillar	*Schizura unicornis* (J. E. Smith)	Lepidoptera:Notodontidae	Pest	B
Sy	Syrphid fly	(Genus unrecognized)	Diptera:Syrphidae	Beneficial	
Ta	Tachinid fly	*Winthemia* sp.	Diptera:Tachinidae	Beneficial	
Tb	Issid planthopper	*Thionia bullata* (Say)	Homoptera:Issidae	Pest	
Th	Thrips	*Thrips* sp.	Thysanoptera:Thripidae	Pest	B
Tm	Tussock moth	*Halysidota tessellaris* (J. E. Smith)	Lepidoptera:Arctiidae	Pest	B
To	Leafroller moth	(Genus unrecognized)	Lepidoptera:Tortricidae	Pest	
Tp	Tarnished plant bug	*Lygus lineolaris* (Palisot de Beauvois)	Hemiptera:Miridae	Pest	B;D

[1]All aphids found were noted by the abbreviation *Ap*; all leafhoppers except the unrecognized flatid planthopper and the buffalo treehopper were given the abbreviation *Lh*; and all coccinellids with a common name carry the abbreviation *Lb*.
[2]For complete citation see references cited: B = Oatman et al. (17); C = Cleveland and Hamilton (5); D = Brunner et al. (4).

except by assuming that it is probably somehow related to ERM resistance. Strickler *et al.* (1987) reported finding a biomass of<0.32 mm^3 of ERM in three and five of the nine abandoned orchards of cultivated apples in 1981 and 1982, respectively. In only three of these orchards was ERM not found in both years. It has also been reported by Strickler and Whalon (22) that numbers of mites can be high in both commercial and abandoned orchards.

Differences between the arthropod faunal complexes of cultivated apple, as reported by Cleveland and Hamilton (5), Oatman *et al.* (17), and Brunner *et al.* (4), and that found on apples with resistance introduced from planned crosses, are apparent from our data. Although the effects of cultivars, rootstocks, orchard locations, cultural and production practices cannot be readily compared between these studies, it is likely that any one of the above factors could have an impact on the fauna present. To formulate an effective pest management program using supplemental control measures, one would have to consider differences that exist in the faunal profile, especially if chemicals are to be used. Specificity of action, the frequency of use, and the impact on the fauna would then have to be considered.

We have reported 61 species, 14 genera, 9 families and 3 orders of arthropods (Table 1). Among these were 9 species, 5 genera and 2 families of beneficial arthropods. During the three years, the most common pests were aphids (Ap) [*Aphis pomi* De Geer, *Dysaphis plantaginea* (Passerini), and *Eriosoma lanigerum* (Hausmann)], leaf hoppers (Lh)[*Empoasca maligna* Welsh, *Jikradia olitoria* (Say), *Penthimia americana* Fitch, *Typhlocyba pomaria* McAtee, *Metcalfa pruinosa*, (Say)], Lm, Av, greenlooper (Gl), Pc, Cm, Ag, and Cv. The most common beneficial insects were: Ladybird beetles (Lb)[*Adalia bipunctata* (L.), *Coleomegilla maculata lengi* Timberlake, *Hippodamia convergens* Guerin-Meneville, and *Olla v. nigrum* Mulsant], La and Sm.

Frequencies of occurrence of the above 12 arthropods during the study are shown in Figure 2 for each rootstock. The value "n" denotes the number of trees of each rootstock surveyed. Differences in arthropod incidence seen between rootstocks were: more aphids on MM.111 than on M.7 and the fewest on MM.106; Av and La more common on MM.111 rootstock while La was present less frequently on M.7; and fewest Cm present on M.7. The data show that significant ($P<0.05$) effects of rootstocks on the arthropod fauna present on these apple selections. Differences in ERM infestations between seedling and MM.106 rootstock was also reported by Sacco *et al.* (20).

In Table 2 we have reported a summary of the X^2 values. Incidence of Ap and Cm was significantly influenced both by rootstock and selection; whereas Lh and La were by rootstocks only and Lb by selection only.

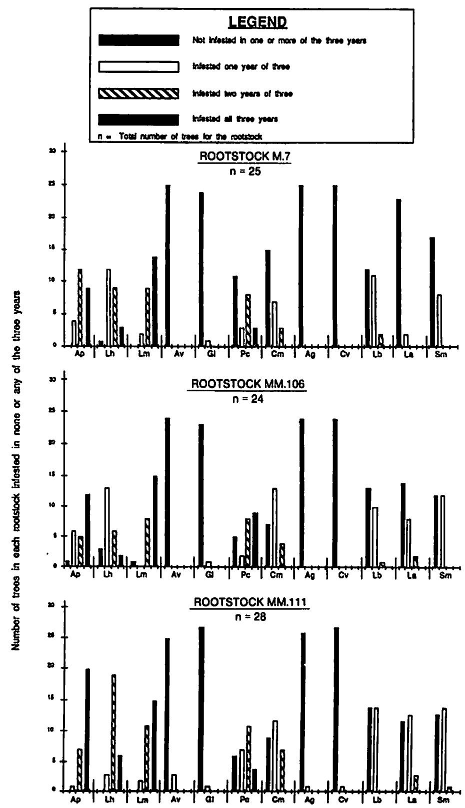

Fig. 2. The distribution by apple rootstock or the arthropods most frequently occurring on seven scab resistant apple selections, five of which were also resistant to European red mite, during 3 year study. We grouped 3 species of aphids in the category *Ap;* 5 species + nymphs of leafhoppers as *Lh* and 3 species of ladybird beetles as *Lb* (see Table 1, Column 5 for explanation of abbreviations) for this graphical representation.

Table 2. Summary of Chi-square values for 12 frequently occurring arthropods in a 3-year survey of pest resistant apples growing on three rootstocks.

	Rootstock[4]		Selection[5]	
Arthropod	df	x^2	df	x^2
Aphids[1]	6	13.06	18	29.12
Leafhoppers[2]	6	19.70**	6	5.96
P. blancardella	2	0.44	6	6.10
A. velutinana	2	5.46	6	3.76
C. nenuphar	2	4.32	6	5.34
C. pomonella	2	6.05*	6	18.26**
A. interrupta	2	3.59	6	4.53
C. violacea	2	1.77	6	5.49
Ladybird Beetles[3]	2	0.19	6	13.84**
C. carnea	2	14.21	6	9.59
Z. mali	2	2.77	6	19.61**
S. aerata	2	0.01	6	8.82

[1]Refers to: *A. pomi; D. plantaginea; E. lanigerum.*
[2]Refers to: *E. maligna; J. olitoria; P. americana; T. pomaria; M. pruniosa.*
[3]Refers to: *A. bipunctata; C. maculata; H. convergens; O. v. nigrum.*
[4]Refers to: EMVII; MM106, MM111.
[5]Refers to: HCR23T125; HCR21T200; TSR16T223; S80ER21T71; TSR37T73; HAR10T166; HAR4T67.
*Significant at $P < 0.05$.
**Significant at $P < 0.01$.

The frequencies of incidence of the 12 arthropods on each of the seven apple selections are shown in Figure 3. This value "n" denotes the number of trees of each selection surveyed. Fewest Ap, Cm, La, and Sm were found on HCR23T125. Cm was found in smaller numbers on HAR10T166.

It was evident from our data that both selections and rootstocks influenced the arthropod fauna that were found. Since no scab was observed, it must be concluded that the genetically incorporated resistance to this disease was effective. No other diseases of economic significance were found. It was also evident from our data that if management procedures for resistant (specifically scab and ERM resistant) selections are to be developed, efforts should be channelled to reducing the damage from only those pest arthropods in the complex of the 12 most frequently observed. In this complex there were eight reported pests (Tables 2 and 3), one (*C. violacea*) of unknown status and three beneficial insects (Tables 2 and 3).

The formulation of a protocol for pest control in the apple agroecosystem consisting of ERM and scab resistant selections, requires information on the seasonal sequence and yearly frequency of the arthropods found. In Table 3, we have reported this information for each of the most frequently found arthropods and on which rootstock. It can be seen that the pests, (Av, Pc, Ap, Lh, Cm, Ag, Cv, and Gl) were present from May to September of most years. Lm occurred later in this time frame, and so did the beneficial (predator) arthropods (La, and Sm). Some Lb were not present in May but their numbers were greater in July and August. This data suggests that pest management procedures should probably commence on or about petal fall (late April-early May). To compensate for the general lag in occurrence of the beneficial species, supplemental measures may be needed. It is likely that pest management protocols using pesticides on the apple selections used in this study will in all probability alter the faunal composition. Removal of natural enemies from ERM susceptible selections, through pesticide use, may result in a build-up of ERM.

Table 3. Seasonal sequence and yearly occurrence of arthropods on seven scab resistant apple selections, five of which were also resistant to European red mite in a 3-year study.

	Month of Year[a] of Occurrence						
Arthropod	**Apr**	**May**	**June**	**Jul**	**Aug**	**Sept**	**Oct**
Aphids[b,c] (Ap)			Q all rs	0 all rs,[d] Ø all rs, Q all rs	0 all rs, Ø all rs, Q all rs		Ø M111,
Leafhoppers[e] (Lh)			Q all rs	0 all rs, Ø all rs Q all rs,	0 all rs, Ø all rs Q all rs	Q all rs	Ø M111, Q all rs
P. blancardella (Cm)				0 all rs Ø all rs Q all rs	0 all rs Ø all rs Q all rs	0 all rs Ø all rs Q all rs	0 all rs Ø all rs Q all rs
A. velutinana[f] (Av)		0 M111		Ø M111 Q M111			
C. nenuphar[g] (Pc)		Ø M106	Q all rs	0 all rs, Ø all rs Q all rs	0 all rs, Ø all rs Q all rs	0 all rs, Q M111	
C. pomonella[g,h]			Q all rs	Ø all rs Q all rs	Ø all rs Q all rs	Ø all rs	Ø M106
A. interupta[f] (Ag)				0 M111			
C. violacea[f] (Cv)			0 M111				
Ladybird beetles[f] (Lb)		Ø all rs		Q all rs	Ø all rs, Q all rs		
C. carnea[f] (La)				0 M111 Ø all rs, Q all rs	Ø all rs		
Z. mali (Sm)				0 M111		0 all rs	
S. aerata (Gl)		0 all rs					

[a]year of occurrence; 0 = 1982, Ø = 1983, Q = 1984.
[b]aphids: *A. pomi; D. plantaginea;* and *E. lanigerum.*
[c]Though present on all rootstocks, aphids were found more frequently on MM111 and EMVII than on MM106.
[d]All rs = the arthropod was found on all three rootstocks (EMVII, MM106, and MM111).
[e]Leafhopper = *E. maligna; J. olitoria; P. americana;* and *M. pruniosa.*
[f]Only found on MM111.
[g]Damage assessed from surveys of fruit.
[h]Least frequently found on EMVII, although present on all rootstock.
[i]Ladybird beetles = A. bipunctata; C. maculata; H. convergens; and *O. v. nigrum.*
[j]Most frequently found on MM111 and least frequently found on EMVII, though found on all rootstock.

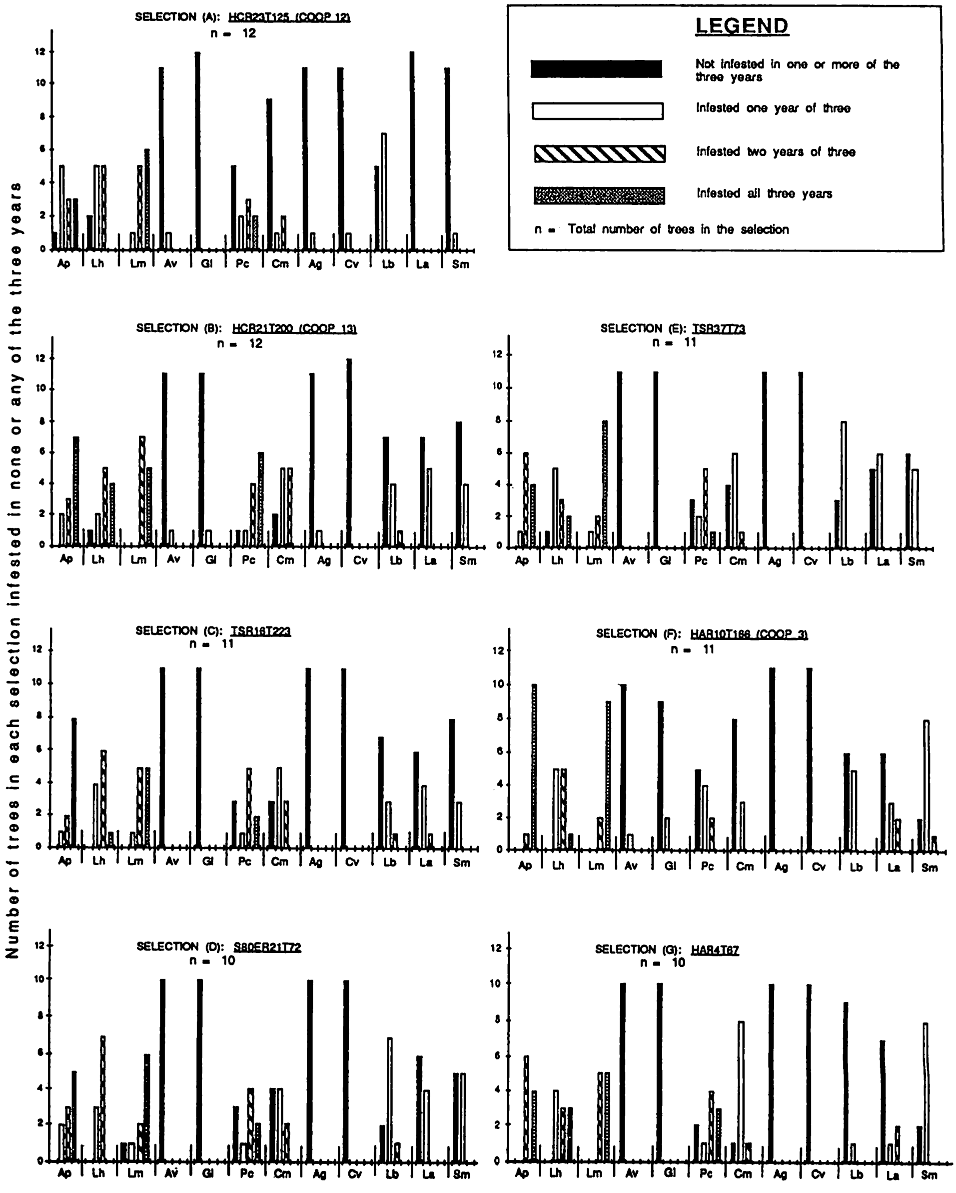

Fig. 3. The distribution by apple selection of the arthropods most frequently occurring on seven scab resistant apple selections, five of which were also resistant to European red mite, in a 3 year study. We grouped 3 species of aphids in the category *Ap;* 5 species + nymphs of leafhoppers as *Lh* and 3 species of ladybird beetles as *Lb* (see Table 1, Column 5 for explanation of abbreviations) for constructing this graphical representation.

A choice of either the 13 most popular cultivars of cultivated apple, of which only 'Cortland' is the product of a planned cross (2) or apples from planned breeding, having various traits for resistance (24), will be available to the grower through past or future releases. It is likely that these selections with resistant traits, because they are genotypically different from the 13 most commercially popular cultivars which have little if any pest resistance, may require the establishment of supplementary pest control protocols. These protocols may be different to those recommended by Battenfield (3) or Hayden *et al.* (13) in that they may require a fewer number of critically timed sprays.

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Effect of Training System on Precocity and Yield in 'Anjou' Pear[1]

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Abstract

Four training systems were evaluated for their ability to promote precocity in 'Anjou' pears. Both the angle-trained and spindle-trained trees produced significantly higher yields than central-leader trees with or without spreaders in the first 5 years of production after which production was similar in all 4 systems. Labour input during the tenure of the study was lower for angle- than for spindle-trained trees.

Predominant pear training systems are palmettes in Italy, flattened forms in France and spindle forms in Germany (4). The central leader system, which is common in British Columbia, is not noted for precocity and also requires several years to reach full production. A lack of capital return during this period and fluctuating fresh market prices have discouraged growers from establishing new pear orchards in British Columbia. This study evaluates the merits of 4 pear training systems to promote precocity in 'Anjou' pear. Labor input into each system was also considered.

Materials and Methods

One-year-old 'Anjou' pears on 'Bartlett' seedling rootstock were planted at 2.4 x 4.5 m in 1974. Each training system consisted of a single row of 30 trees separated by a buffer row of 'Bartlett' trees. All rows were orientated in a N-S direction. Vegetation in the tree rows was controlled with paraquat, and sod in the alleyways was mowed bi-weekly. Fertilizer (34-0-0) was applied at 225 kg ha^{-1} and urea sprays were used when leaf color dictated its need. Irrigation was provided by an overhead system. The 4 training systems were:

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