NEW YORK
FRUIT QUARTERLY

Editorial

The NYBGA is glad to be on board!

With this issue of the *New York Fruit Quarterly* we launch the first of a new and improved publication, one which will feature in each issue at least one article specifically about berry production. This is in addition to the usual offering of high-caliber articles on tree fruit and general-interest pomology topics. The new and improved *Quarterly* will now be mailed, not only to the tree fruit growers of New York State, but also to the roughly 150 members of the New York State Berry Growers Association.

How did this come about? For some time now, the editors of the *Quarterly* have been holding discussions with the NYSBGA and the Hort Society trying to reach a mutually beneficial arrangement…..and we've done it! The editors will solicit berry-related articles for each issue, the financial arrangement was worked out with the Hort Society , and the Berry Growers' membership was signed up to start receiving the mailings.

Why is this a win-win situation for all concerned? First and foremost, because more growers will now be receiving the *Quarterly*. More growers will be seeing the excellent and timely articles on general- interest topics like nutrition, irrigation and post-harvest management. These articles, which are of interest to all fruit growers, were previously read only by the apple growers of New York State. The authors ofthese articles will now have an additional a readership of 150 fruit growers, and the small fruit faculty at Cornell have another vehicle to reach not only berry growers, but virtually all the tree fruit growers in the state as well. Since many tree fruit growers currently produce, or are thinking about producing berry crops, this makes the new and improved *Quarterly* beneficial to many of them as well.

As current Chair of the Board of the New York State Berry Growers Association, I especially want to thank the Hort Society for ratifying this venture and welcoming us on board. In fact, the Hort Society deserves another big thanks for their general spirit of cooperation. This spirit has resulted in the rebirth of a Hort Show in New York State in the form of the Empire State Fruit and Vegetable Expo, a collaboration of the New York State Vegetable Growers Association, the Empire State Potato Growers Club, the New York State Berry Growers Association and Cornell Cooperative Extension. The 2005 show will be held in Syracuse on Feb 15-17, 2005 and is a must-see for all fruit growers!

We hope you enjoy the new and improved *Fruit Quarterly*. Speaking for the berry growers "We're glad to be on board!"

Regina Rieckenberg
Chair, NYS Berry Growers Association

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Where Do the Geneva® Apple Rootstocks Fit in New York State?

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The Geneva® apple rootstock project has released five rootstocks for commercial propagation and sales. Additionally two more rootstocks will be released in December of 2004 and licensed nurseries will begin commercial sales. None of the new rootstocks areperfect; each has strengths and weaknesses. However, all have good fire blight resistance and are very productive. Commercial nurserymen and apple growers must understand their strengths and deficiencies before their adoption.

High-density apple orchards on dwarfing rootstocks have become common in many apple growing regions of the world. This has allowed apple growers to achieve earlier production, higher production and better fruit quality than previously. However, for many apple growers in North America, New Zealand and many locations in Europe, the bacterial disease fire blight is a serious threat to dwarf apple orchards. M.9 and M.26, the most common dwarfing apple rootstocks, are very susceptible to this disease and in some locations this disease limits the planting of dwarfing rootstocks. Outbreaks of the disease in the Eastern US have decimated many dwarf apple orchards. There is a great need to develop new, highly productive apple rootstocks that are resistant to the biotic and climatic stresses common in North America.

Fire blight usually infects the blossoms during bloom and results in diseased branches that die and give the appearance of burned leaves, thus the name fire blight. Research by Dr. Aldwinckle has shown that once inside the tree, the bacteria can travel symptomless down the trunk to the graft union and the rootstock below. With highly susceptible rootstocks like M.9 and M.26 the rootstock cambium, xylem and phloem at the graft union are killed causing the death of the tree (Figure 1). Although fire blight has been a serious problem for many years in North America, losses of whole orchards were not common until dwarfing rootstocks came into use. With seedling rootstocks that were not as susceptible to fire blight as M.9 and M.26, the scion could become infected but the tree usually survived if the infected parts of the scion were pruned away. The use of resistant dwarfing rootstocks will not prevent the scion from becoming infected, however, since the rootstock will survive an infection the tree will usually survive. This allows growers to prune out the infected parts of the scion and regrow the lost canopy quickly, and thus restore full production much more rapidly than replanting an entire infected dwarf orchard.

Cornell University has had an apple rootstock breeding project located at Geneva NY since 1968. The project was led by Drs. James Cummins and Herb Aldwinckle until Dr. Cummins' retirement in 1993. In 1998 the USDA's Agricultural Research Service joined the

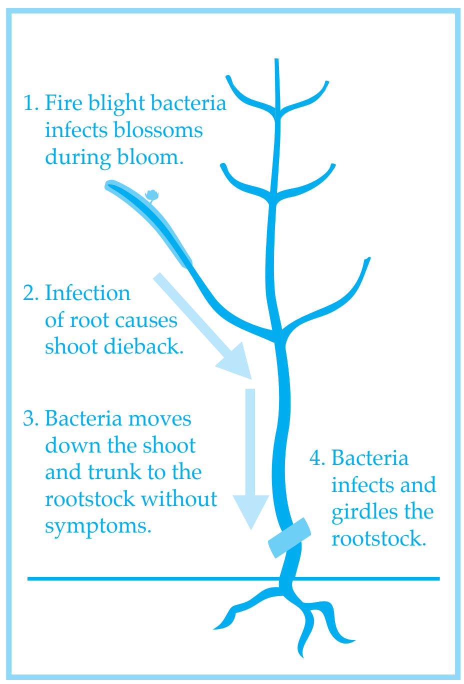

Figure 1. Four steps of fire blight infection of the scion which leads to infection of a susceptible rootstock and tree death.

project along with a new lead scientist (Dr. Gennaro Fazio). The project continues to be joint program between the USDA and Cornell University with Drs. Robinson and Aldwinckle continuing to contribute significant efforts to the program. The objectives of the project are to develop rootstocks with improved nursery and orchard characteristics that are better adapted to the problems of fire blight (*Erwinia amylovora*), crown rot (*Phytophthora spp.*) and replant disease which are common in the USA (Cummins and Aldwinckle, 1983). Additionally, some selections from this project show resistance to woolly apple aphid which is a problem in the warmer apple growing areas of the world. By the early 1990's, Dr. Cummins had selected several promising fire blight-resistant apple rootstocks with a wide range of dwarfing. These were then tested in second level orchard trials that included on-farm trials within New York State (Robinson and Hoying, 2003) and national trials in the USA, and Canada (Robinson et. al., 2003), France (Masseron and Simard, 2002) and New Zealand (personal communication from Stuart Tustin). In this paper, we discuss the combined results from these trials and where these stocks fit in the New York apple industry.

TABLE 1

Ten year performance of G.65 in two trials in NY state.

Trial	**Rootstock**	**TCA (% of M.9)**	**Yield Efficiency (% of M.9)**	**Fruit Size (% of M.9)**
1991 Empire	G.65	58*	111 NS	----
1992 Liberty	G.65	58*	97 NS	91*

*Significantly different than M.9 or NS=Not significantly different than M.9 ($p<0.05$).

TABLE 2

Performance of G.16 in three trials in NY state.

Trial	Rootstock	TCA (% of M.9)	Yield Efficiency (% of M.9)	Fruit Size (% of M.9)
1998 Jonagold	G.16	91 NS	111 NS	91*
1998 Gala	G.16	113*	111 NS	92*
1999 McIntosh	G.16	113 NS	131 NS	92 NS

*Significantly different than M.9 or NS=Not significantly different than M.9 ($p<0.05$).

TABLE 3

Performance of G.41 in four trials in NY state.

Trial	**Rootstock**	**TCA (% of M.9)**	**Yield Efficiency (% of M.9)**	**Fruit Size (% of M.9)**
1991 Empire	G.41	99 NS	123 NS	----
1993 Liberty	G.41	90*	125*	----
1998 Jonagold	G.41	96 NS	155*	93*
1999 McIntosh	G.41	126 NS	124 NS	105 NS

*Significantly different than M.9 or NS=Not significantly different than M.9 ($p<0.05$).

CG Rootstocks

To date five rootstocks from this project have been patented and released for commercial propagation and sale by licensed nurseries. Additionally two more rootstocks are being released in December of 2004, and licensed nurseries will be authorized to begin commercial sales.

• **Geneva®65** The most dwarfing CG rootstocks is G.65. It is significantly more dwarfing than M.9 (about 60% the size of M.9) and is similar in vigor as M.27 (Table 1). It is a cross of 'M.27' X 'Beauty Crab'. It has proven to be highly resistant to fire blight and *Phytophthora*, but is not resistant to woolly apple aphid. It has very high yield efficiency but fruit size from trees on G.65 has been only about 90 percent that of trees on M.9 (Table 1). G.65 is somewhat difficult to propagate in stoolbeds which has limited its commercial production but it is available from several nurseries in the USA in limited amounts. G.65 may be too dwarfing for most situations but we believe it has a place in very high planting densities (Super Spindle) with large- fruited varieties such as Jonagold and Mutsu. With these two varieties and other similar large-fruited varieties, fruit size is often too large for optimum commercial packouts. G.65 used as a rootstock would help hold down fruit size. Under these conditions, G.65 has a significant advantage over M.27 due to its fire blight resistance. Orchards with this rootstock should be planted at very high densities of 4,000-6,000 trees/ha.

• **Geneva® 16** G.16 is a fully dwarfing rootstock with tree growth and vigor similar to the vigorous clones of M.9 (i.e. Nic29 or Pajam2). It is a cross of 'Ottawa 3' X *Malus floribunda,* is essentially immune to fire blight and highly tolerant to *Phytophthora*, but it is not resistant to woolly apple aphid. G.16 has excellent performance in the stoolbed and produces a large tree in the nursery. Tree growth in the first two years in the orchard is vigorous, but with the onset of cropping, tree vigor is moderated resulting in a final tree similar in size to M.9. Precocity and cumulative yield efficiency have been similar or slightly better than M.9 (Table 2). G.16 appears to have wide soil adaptability and some tolerance to replant disease. It has very good midwinter hardiness and survived a recent winter freeze event in Northern NY that killed many M.9, M.26, M7 and MM.111 trees. However, it does appear to have some susceptibility to very early winter freeze events. This is likely due to its vigorous growth characteristics in the nursery and in the orchard during the first few years. Its greatest known deficiency it that it is sensitive to one or more latent viruses in scion wood. Infected scion wood results in death of the trees in the nursery or the first year in the orchard. If virus-free wood is used it appears that G.16 is currently one of the best alternatives to M.9 in high fire blight areas. Most commercial nurseries in the US produce trees on G.16 but some scion varieties are not available on this stock because virus-free scion wood is not available. Orchards with this rootstock should be planted at high densities of 2,000-4,000 trees/ha.

• **Geneva® 41** A second fully dwarfing stock with vigor similar to M.9 is G.41 (formerly CG.3041). It is a cross of 'Malling 27' X 'Robusta 5'. It is scheduled for commercial release and propagation in December 2004 and will be named Geneva® 41. It is highly resistant to fire blight and *Phytophthora* but it is not resistant to woolly apple aphids. G.41 is a shy rooter and will require higher planting densities in the stoolbed or tissue culture to improve its rooting. It also produces some side shoots in the stoolbed. In the orchard its precocity and productivity have been exceptional, surpassing

TABLE 4

Ten year performance of G.11 in two trials in NY state.

Trial	Rootstock	TCA (% of M.9)	Yield Efficiency (% of M.9)	Fruit Size (% of M.9)
1992 Liberty	G.11	84 NS	114 NS	103 NS
1993 Liberty	G.11	140*	95 NS	—

*Significantly different than M.9 or NS=Not significantly different than M.9 ($p<0.05$).

TABLE 5

Performance of G.202 in two trials in NY state.

Trial	Rootstock	TCA (% of M.9)	Yield Efficiency (% of M.9)	Fruit Size (% of M.9)
1991 Empire	G.202	153 *	101 NS	—
1998 Gala	G.202	93 NS	86 NS	90*

*Significantly different than M.9 or NS=Not significantly different than M.9 ($p<0.05$).

TABLE 6

Performance of G.935 in two trials in NY state.

Trial	Rootstock	TCA (% of M.9)	Yield Efficiency (% of M.9)	Fruit Size (% of M.9)
1991 Empire	G.935	138*	122 NS	—
1998 Gala	G.935	207*	112*	101 NS

*Significantly different than M.9 or NS=Not significantly different than M.9 ($p<0.05$).

TABLE 7

Performance of G.30 in two trials in NY state.

Trial	Rootstock	TCA (% of M.9)	Yield Efficiency (% of M.9)	Fruit Size (% of M.9)
1991 Empire	G.30	191*	101 NS	—
1992 Liberty	G.30	177*	116 NS	106 NS

*Significantly different than M.9 or NS=Not significantly different than M.9 ($p<0.05$).

M.9 (Table 3). It also has excellent fruit size and induces wide branch angles, and has very good winter hardiness. Although it is similar in tree size and yield efficiency to G.16 and M.9, it does not have the virus sensitivity of G.16. It has similar graft union strength to M.9 and will require trellising or individual tree stakes. G.41 has also been tested in France where it was shown to be smaller in tree size than M.9Pajam2 but more productive while producing similar fruit size as M.9 (Masseron and Simard, 2002). Several commercial nurseries in the USA have limited amounts of G.41 for sale this year. Orchards planted with this rootstock should be planted at densities of 2,000-4,000 trees/ha. It appears that G.41 will become one of the best alternatives to M.9 in high fire blight areas.

• **Geneva®11** G.11 is a dwarf rootstock that produces a tree that is similar in size to M.26. It is a cross of 'Malling 26' X 'Robusta 5'. It has good propagation characteristics in the stoolbed and in the nursery. In the orchard it has higher yield efficiency than M.26 (similar to M.9) and produces fruit size similar to M.26 (Table 4). It has moderately high resistance to fire blight (similar to M.7) and good resistance to'*Phytophthora* root rot, but is not resistant to woolly apple aphid. It has also been tested in France where trees on G.11 were 15 percent smaller than M.9Pajam2 but 14 percent greater productivity and similar fruit size as M.9Pajam2 (Masseron and Simard, 2002). Orchards planted with this rootstock should be planted at densities of 1,500-2,500 trees/ha. Presently G.11 is available only in North America and is just beginning commercial sales. Its fire blight tolerance should make it an excellent replacement for M.26 in fire blight prone areas.

• **Geneva®202** G.202 is a semi dwarfing rootstock that produces a tree slightly larger than M.26. It is a cross of 'Malling 27' X 'Robusta 5'. It is resistant to fire blight and *Phytophthora*, but also has good resistance to woolly apple aphid which is important in many warmer climates where woolly apple aphid is an important rootstock pest. G.202 performs moderately well in the stoolbed and produces good quality nursery trees. G.202 has been tested mostly in New York state and New Zealand. In New York it produces a tree 50 percent larger than M.9 and with slightly lower yield efficiency (Table 5). In New Zealand, it has been found to be much more productive than M.26 and is one of the best stocks available. It appears that G.202 will be a useful alternative to M.26 in climates that have problems with woolly apple aphid. Orchards planted with this rootstock should be planted at densities of 1,500-2,500 trees/ha. It was released for commercial propagation in New Zealand by Cornell University in May 2002 and in the US in 2004. Presently it is only available in New Zealand, but rootstock nurseries in the US are beginning production of this stock.

• **Geneva® 5935** A second semi dwarfing stock that produces a tree slightly larger than M.26 is G.5935. It is a cross of 'Ottawa 3' X 'Robusta 5'. It has good propagability in the stoolbed and produces a large tree in the nursery. G.5935 is the most precocious and productive semi dwarf CG rootstock available. It has similar efficiency to M.9 along with excellent fruit size and wide crotch angles. In addition, it is very winter hardy. It is highly resistant to fire blight but it is not resistant to woolly apple aphid. In US trials, it produces a tree about 40-100 percent larger than M.9 but with similar or higher yield efficiency and fruit size as M.9 (Table 6). Orchards planted with this rootstock should be planted at densities of 1,500-2,500 trees/ha. It is scheduled for commercial release and propagation in December 2004 and will be named Geneva® 935. It appears that G.935 will be an excellent replacement for M.26.

• **Geneva®30** G.30 is a very productive semi-dwarf rootstock with large fruit size that has proven to be widely adaptable. It is not only highly resistant to fire blight and *Phytophthora*, but is also resistant to apple replant disease and is very winter hardy. It is a cross of 'Robusta 5' X 'Malling 9'. Although it is highly productive in the orchard it is difficult to manage in the nursery. It produces numerous side shoots (spines) on each shoot in the propagation bed. This requires manual trimming of these shoots either before or after harvest from the stoolbed. The removal of the lateral shoots on the liner also removes essentially all of the lateral buds so that new growth the next year in the nursery row must depend on the development of adventitious buds. This is a slow process which allows 10-30 percent of the plants to dry out and die before they begin to grow. A solution to this problem is to remove only the side shoots on the lower 25 cm of the liner leaving 5-10 cm at the top of the liner untrimmed with live buds for next year.

During the early years in the orchard, tree growth of G.30 is vigorous and very similar to M.7. However, branch angles have been wider than M.7 and the heavy crops on G.30 starting in year three limit tree growth and vigor in later years so that by year 10 it is usually significantly smaller than M.7 and often closer to the size of M.26. G.30 has a relatively weak graft union when it is young. With Gala, R.I. Greening, Honeycrisp, Jonagold, and JoBurn there have been significant tree losses from breakage at the graft union following strong winds. Work by Johnson and Robinson (unpublished) has shown that the graft union of Gala and G.30 is more brittle than M.26 and the union of Empire and G.30 is more brittle than M.7. This means that although G.30 is a semi dwarf tree, it requires a multi-wire trellis to support the tree. Despite its problems G.30 has found a niche in the apple industry due to its high productivity and wide soil and climate adaptability. Cumulative yield efficiency has been three-five times better than M.7 and is very similar to M.9 (Table 7). In France it has produced a tree slightly larger than M.9Pajam2 but with similar productivity as M.9 (Masseron and Simard, 2004). Orchards planted with this rootstock should be planted at moderate densities of 1,000-1,500 trees/ha, but it will require tree support in all situations.

Summary

Fire blight is an important limiting factor to dwarf apple trees in Eastern North America due to the extreme susceptibility of M.9 and M.26 to this disease. Fire blight-resistant rootstocks have been developed through the rootstock breeding project of Cornell University and the federal USDA-Agricultural Research Service at the Geneva Experiment Station. To date five rootstocks from this project have been patented and released to several licensed nurseries for commercial propagation and sale. Additionally two more rootstocks will be released in December of 2004 and licensed nurseries will be authorized to begin commercial sales. None of the new rootstocks is perfect; each has strengths and weaknesses. All have good fire blight resistance and are quite productive. However, each has deficiencies that must be understood by commercial nurserymen and apple growers before their adoption. Currently we suggest G.30 as an excellent semi-dwarfing stock for spur type varieties, replant sites and for northern climates with short cool growing seasons, however, trees on G.30 must be trellised to prevent graft union breakage. In the near future G.935 may replace G.30 for orchards planted with densities of 1,000-1,500 trees/ha. G.11 and G.202 are possible replacements for M.26 and should be used for dwarf orchards planted at densities from 1,500 to 2,000 trees/ha. G.16 and G.41 are possible replacements for M.9 and should be used for orchards planted at densities from 2,000-4,000 trees/ha. For excessively large fruited varieties planted at very high densities of 4,000-6,000 trees/ha, G.65 is better than M.27.

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Phenolics and Antioxidant Capacity in Selected New York State Plums

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We dedicate this paper to Professor Robert Andersen who retired recently after a long and dedicated career in stone fruits breeding at Cornell University-Geneva.

Plums may be good sources of natural antioxidants due to their high levels of phenolic phytochemicals. The predominant phenolics in plums are hydroxycinnamic acids and anthocyanidin derivatives. When compared to other common fruits, plums have higher phenolic content and higher antioxidant capacity indicating that an increased consumption of plums through our diet is highly desirable for the associated health benefits.

Antioxidants are compounds that retard or inhibit the oxidation of molecules that can occur by the presence of reactive free radicals. Many phenolic phytochemicals, routinely consumed in our diet, have shown antioxidant properties by chelating metal ions, inhibiting lipid oxidation, inhibiting radical-forming enzymes, or quenching free radicals. In recent years, active research has been conducted on fruits and vegetables due to their biologically beneficial effects, which are derived from the antioxidant activities of phenolic phytochemicals.

Foods containing various molecules (proteins, lipids, vitamins, and carbohydrates) are vulnerable to attack by reactive free radicals. Free radicals such as superoxide radical anion, hydrogen peroxide, hydroxyl radical, and singlet oxygen, are normally generated during daily physiological metabolic activities. Damage mediated by free radicals results in the disruption of membrane fluidity, protein denaturation, lipid peroxidation, DNA oxidation, and alteration of platelet functions. Oxidative stress caused by an overwhelming amount of free radicals beyond normal defense capacity of antioxidant systems for oxidation, has been considered a link with aging and many degenerative diseases. Phenolics that quench reactive free radicals can prevent the oxidation of other molecules and may, therefore, have health-promoting effects in the prevention of degenerative diseases such as cancers and Alzheimer's disease.

Significant amounts of phenolic compounds (phenolics) are present in fruits, vegetables and beverages where diverse combinations of phenolics exist. Phenolics are found widely as secondary metabolites in the plant kingdom. Among phenolics, flavonoids frequently occur as glycoside forms, whereas hydroxycinnamic acids generally exist as ester forms. The sugars linked to flavonoid aglycons include arabinose, galactose, glucose, rhamnose, rutinose and xylose. The distribution and composition of phenolics in fruits and vegetables are affected by various factors such as maturity, cultivars, horticultural practices, geographic origin, growing seasons, postharvest storage conditions and processing procedures.

Phenolics are routinely consumed as part of our daily diet. They are the most important group among the phytochemicals and they influence the sensory qualities (color, flavor, taste) of fresh fruits, vegetables and their products. In addition, many phenolic phytochemicals possess important biochemical properties including antioxidative, anticarcinogenic, antimicrobial, antiallergic, antimutagenic and anti-inflammatory activities. Recently, interest in the research area of bioactive phenolics has been growing rapidly due to their many possible benefits to human health. Epidemiological observations suggest that dietary intake of natural bioactive compounds including flavonoids through fruits and vegetables may reduce the risk of cancers and heart disease (Potter, 1997; Hertog et al., 1997).

Various fruits such as grapes and apples are well investigated and are known to contain significant amounts of phenolics. Yet plums, which have very high concentrations of phenolic phytochemicals, remain underutilized in the average American diet and under-researched worldwide. We have been working on phenolics and antioxidant capacity of plums using spectrophotometric methods and reversed-phase high-performance liquid chromatography (HPLC). This article describes our results on total phenolics, antioxidant capacity, and identification of individual phenolics in 10 cultivars of fresh plums grown in NY State from the 2001 and 2002 harvest seasons. Phenolics in plums were extracted by the ultrasound-assisted method using aqueous methanol. The ultrasound-assisted method is rapid and efficient for the extraction of phenolics, during which a constant stream of nitrogen gas is introduced to provide an oxygen-free environment to prevent and minimize the browning reactions.

Total Phenolics in Plums

Total phenolics were analyzed by the colorimetric method using the Folin-Ciocalteu's phenol reagent. Total phenolics of 10 different fresh plum cultivars grown in NY State in 2001 and 2002 are presented in Table 1. The cultivars are categorized by skin color as follows: dark blue/purple plums (Beltsville Elite B70197, Castleton, Empress, Longjohn, NY 6, NY 9, and Stanley), red plum (Early Magic), and yellow plums (Mirabellier, and NY 101). There was a significant difference in total phenolics due to different plum cultivars and growing seasons (or crop years). The total phenolics in plums of the 2001 crop varied from 125.0 to 372.6 mg gallic acid equivalents (GAE)/100 g with an average of 192.1 mg GAE/100 g, whereas plums harvested in 2002 showed total phenolics at 138.1 to 684.5 mg GAE/100 g with an average of 285.8 mg GAE/100 g. Beltsville Elite B70197 was found to have the highest total phenolics among plums tested in 2001 and 2002, while NY 9 had the lowest. Plum cultivars with dark blue/purple skin had higher total phenolics compared to plum cultivars with yellow and red skin. There were greater differences in total phenolic content due to cultivar than different crop years. The cultivars having the highest total phenolics had 3.0 and 4.7 times higher levels than the cultivars with the lowest phenolic content in 2001 and 2002, respectively, whereas seasonal variation caused less than 2.1 times the difference of total phenolics for each of the cultivars between 2001 and 2002. Plums were previously shown to have a higher total phenolics content than apple, banana, and orange (Kim et al., 2003; Proteggente et al., 2002).

Antioxidant Capacity of Plums

Antioxidant capacity in plums was expressed as vitamin C equivalent antioxidant capacity (VCEAC). Vitamin C, which is an antioxidant standard, is naturally present as one of major nutrients in fruits and vegetables and has been shown to possess preventive effects on carcinogenesis (Lee et al., 2002). VCEAC was evaluated on the basis of a chemical reaction using blue/green ABTS (2,2¢-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid)) radicals.

The total phenolic content of plums was highly correlated to the VCEAC in fresh plums from 2001 and 2002 crops (Figure1). This suggests that phenolics in plums may play an important role in scavenging free radicals. A good correlation was previously observed between total phenolics and antioxidant capacity in fresh plums (Gil et al., 2002).

The VCEAC of 10 different fresh plum cultivars grown in NY State in 2001 and 2002 is shown in Table 1. Similarly to total phenolics in plums, there was a significant difference in average content of VCEAC due to cultivars and crop years (or growing seasons). Fresh plums in 2001 possessed antioxidant capacities broadly ranging from 204.9 to 567.0 mg/100 g VCEAC, where Beltsville Elite B70197

TABLE 1

Total phenolics and vitamin C equivalent antioxidant capacity (VCEAC) in various fresh plum cultivars grown in NY State in 2001and 2002[a]

Cultivars	Total phenolics (mg GAE/100 g)		VCEAC (mg vit. C equiv./100 g)	
	2001	2002	2001	2002
Beltsville Elite B70197	372.6 ± 7.5	684.5 ± 2.6	567.0 ± 17.6	889.6 ± 3.2
Castleton	176.4 ± 1.8	250.5 ± 1.6	264.3 ± 10.3	337.8 ± 13.2
Early Magic	143.1 ± 2.0	192.1 ± 5.6	204.9 ± 16.7	251.2 ± 6.5
Empress	187.0 ± 2.1	398.7 ± 8.8	269.8 ± 11.8	524.8 ± 3.9
Longjohn	216.2 ± 1.8	398.9 ± 8.4	289.8 ± 38.4	550.4 ± 11.1
Mirabellier	136.8 ± 2.3	215.7 ± 2.9	211.6 ± 20.2	171.1 ± 6.6
NY 6	162.8 ± 1.6	146.6 ± 1.0	262.3 ± 23.7	154.9 ± 6.6
NY 9	125.0 ± 2.3	138.1 ± 2.9	239.1 ± 21.2	144.4 ± 11.2
NY 101	181.9 ± 2.2	196.1 ± 1.5	289.6 ± 17.9	216.2 ± 3.2
Stanley	181.3 ± 4.6	236.7 ± 4.5	249.9 ± 12.5	308.0 ± 5.3

[a]The data are presented with mean ± standard deviation (n = 6). Total phenolics and VCEAC are expressed as gallic acid equivalent (GAE) and vitamin C equivalent, respectively.

TABLE 2

Hydroxycinnamic acids in various fresh plum cultivars grown in NY State in 2001 and 2002[a]

Cultivars	neochlorogenic acid(mg/100 g)		chlorogenic acid(mg/100 g)	
	2001	2002	2001	2002
Beltsville Elite B70197	215.4 ± 7.6	184.6 ± 12.0	9.5 ± 0.5	10.4 ± 0.7
Castleton	73.1 ± 8.5	66.8 ± 2.2	7.1 ± 1.0	8.0 ± 0.3
Early Magic	18.1 ± 5.4	19.1 ± 0.1	0.9 ± 0.5	3.0 ± 0.0
Empress	127.7 ± 13.7	155.7 ± 13.3	8.0 ± 1.0	7.3 ± 0.7
Longjohn	128.0 ± 19.9	121.8 ± 4.4	16.4 ± 1.3	11.5 ± 0.4
Mirabellier	63.9 ± 7.3	44.1 ± 2.4	16.4 ± 2.7	15.9 ± 0.9
NY 6	67.9 ± 11.1	35.5 ± 2.2	8.8 ± 1.4	4.3 ± 0.3
NY 9	49.7 ± 4.1	28.1 ± 1.7	3.7 ± 0.4	3.3 ± 0.3
NY 101	179.4 ± 20.2	78.8 ± 6.1	21.0 ± 2.6	5.8 ± 0.4
Stanley	104.2 ± 16.4	108.6 ± 4.3	7.8 ± 1.5	9.2 ± 0.3

[a]The level of hydroxycinnamic acids are reported as mean ± standard deviation (n = 6 for 2001; n = 4 for 2002). The concentration of neochlorogenic acid is described as chlorogenic acid equivalents.

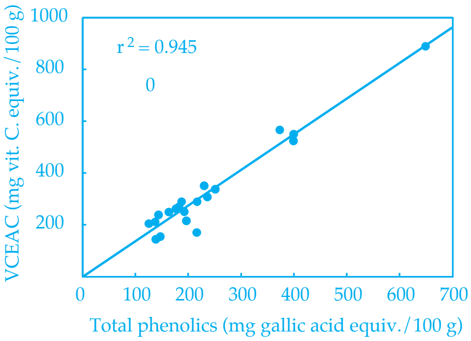

Figure 1. Relationship between total phenolics and vitamin C equivalent antioxidant capacity (VCEAC) in various fresh plum cultivars.

showed the highest VCEAC among 10 plum cultivars and carried 2.8 times higher VCEAC than Early Magic which had the lowest VCEAC. For the 2002 crop, VCEAC varied from 144.4 to 889.6 mg/100 g. Beltsville Elite B70197 also was found to have the highest VCEAC among plums tested in 2002, while NY 9 had the lowest. Compared to plums with yellow and red skins, plums with dark blue/purple skin showed higher antioxidant capacity. As with total phenolics, the difference due to cultivars was greater than the difference observed due to growing seasons. Plum cultivars having the highest antioxidant capacity had ~ 2.8 and 6.2 times higher level than cultivars with the lowest level for 2001 and 2002 respectively, whereas there was a difference of only 1.9 times between the 2001 and 2002 crops. Based on the results reported in Table 1, plums may be used as good sources of natural antioxidants. It was previously reported that plums possessed higher antioxidant capacity than apple, banana, lettuce, orange and tomato (Kim et al., 2003; Proteggente et al., 2002). Another use of plums would be their utilization in commercial food processing which may efficiently prevent lipid oxidation and therefore rancidity and production of undesirable by-products resulting in shelf life extension of foods. The antioxidant components in plums, mainly phenolics, could be a natural way to replace the use of synthetic antioxidants (BHA, BHT, etc.) by the addition of plum in food formulations.

Identification of Phenolics in Plums

Individual phenolic compounds in plums were tentatively identified and quantified using a High Pressure Liquid Chromatograph. Hydroxycinnamic acids in 10 plum cultivars grown in NY State in 2001 and 2002 are shown in Table 2. The main acids found were neochlorogenic and chlorogenic acids. There was a significant difference in the content of hydroxycinnamic acids due to plum cultivars and growing seasons. Irrespective of skin color, all the plum cultivars commonly had chlorogenic and neochlorogenic acids. For the 2001 crop, neochlorogenic acid ranged from 18.1 to 215.4 mg chlorogenic acid equivalents (CAE)/100 g, whereas chlorogenic acid values were between 0.9 and 21.0 mg/100 g. Plums harvested in 2002 had neochlorogenic acid content from 19.1 to 184.6 mg CAE/100 g and chlorogenic

TABLE 3

Flavonols in various fresh plum cultivars grown in NY State in 2001 and 2002[a]

Cultivars	rutin (mg/100 g)		quercetin 3-galactoside (mg/100 g)		quercetin 3-glucoside (mg/100 g)		quercetin derivatives (mg/100 g)	
	2001	2002	2001	2002	2001	2002	2001	2002
Beltsville Elite B70197	4.3 ± 0.3	6.1 ± 0.4	nd[b]	nd	nd	nd	nd	0.4 ± 0.0
Castleton	3.8 ± 0.5	3.8 ± 0.2	nd	nd	nd	0.8 ± 0.0	nd	nd
Early Magic	6.3 ± 0.6	8.3 ± 0.1	nd	1.2 ± 0.0	2.2 ± 0.3	1.5 ± 0.0	2.7 ±áf3 0.3	1.8 ± 0.0
Empress	3.3 ± 0.4	3.7 ± 0.5	nd	nd	nd	nd	nd	nd
Longjohn	7.7 ± 1.3	6.2 ± 0.3	nd	0.7 ± 0.0	nd	0.4 ± 0.0	nd	0.5 ± 0.0
Mirabellier	6.7 ± 0.5	7.2 ± 0.4	3.5 ± 0.4	0.6 ± 0.0	1.2 ± 0.1	0.5 ± 0.0	nd	nd
NY 6	2.8 ± 0.3	1.4 ± 0.1	nd	nd	nd	nd	nd	nd
NY 9	4.3 ± 0.3	2.7 ± 0.2	nd	nd	nd	nd	nd	nd
NY 101	5.0 ± 0.6	1.0 ± 0.1	nd	nd	nd	nd	nd	nd
Stanley	3.8 ± 0.6	3.3 ± 0.1	nd	nd	nd	nd	nd	nd

[a]The level of flavonols are reported as mean ± standard deviation (n = 6 for 2001; n = 4 for 2002). The concentration of quercetin derivatives is described as quercetin equivalents.
[b]nd = non detected

TABLE 4

Anthocyanins in various fresh plum cultivars grown in NY State in 2001 and 2002[a]

Cultivars	cyanidin derivative (mg/100 g)		cyanidin 3-glucoside (mg/100 g)		cyanidin 3-rutinoside (mg/100 g)		peonidin 3-glucoside (mg/100 g)		peonidin derivative (mg/100 g)	
	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002
Beltsville Elite B70197	nd[b]	nd	3.9 ± 0.3	7.4 ± 0.4	25.7 ± 1.0	33.0 ± 1.9	nd	1.5 ± 0.2	11.5 ± 0.5	16.2 ± 1.0
Castleton	nd	nd	7.0 ± 0.9	14.2 ± 0.3	16.1 ± 1.9	22.1 ± 0.7	1.2 ± 0.2	2.3 ± 0.2	5.0 ± 0.7	6.9 ± 0.4
Early Magic	3.1 ± 0.3	nd	6.7 ± 0.6	4.1 ± 0.1	18.9 ± 1.9	23.4 ± 0.5	nd	0.3 ± 0.0	1.9 ± 0.3	3.1 ± 0.1
Empress	nd	nd	1.9 ± 0.8	1.4 ± 0.4	17.5 ± 2.2	22.4 ± 2.8	nd	nd	2.0 ± 0.3	3.1 ± 0.4
Longjohn	nd	nd	5.3 ± 0.9	7.2 ± 0.2	33.0 ± 2.0	41.1 ± 0.6	nd	0.7 ± 0.0	5.4 ± 0.8	9.1 ± 0.2
Mirabellier	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
NY 6	nd	nd	13.5 ± 2.0	3.8 ± 0.7	23.8 ± 3.5	8.9 ± 0.5	1.1 ± 0.2	0.3 ± 0.0	4.4 ± 0.6	2.1 ± 0.1
NY 9	nd	nd	3.9 ± 0.4	2.6 ± 0.2	24.2 ± 2.1	17.4 ± 1.1	nd	0.3 ± 0.0	8.3 ± 0.7	7.1 ± 0.4
NY 101	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Stanley	nd	nd	2.1 ± 0.3	3.4 ± 0.1	21.5 ± 3.9	25.5 ± 0.9	nd	0.3 ± 0.1	5.2 ± 0.9	6.1 ± 0.4

[a]The level of anthocyanins are reported as mean ± standard deviation (n = 6 for 2001; n = 4 for 2002). Concentrations of cyanidin and peonidin derivatives are described as cyanidin and peonidin equivalents, respectively.
[b]nd = non detected

acid from 3.0 to 15.9 mg/100 g. Beltsville Elite B70197, which had the highest content of neochlorogenic acid among various plums tested in 2001 and 2002, had more than 9.7 times higher neochlorogenic acid than Early Magic, which had the lowest. Longjohn, Mirabellier and NY 101 had chlorogenic acid at relatively high levels. Neochlorogenic acid was always in higher concentration than its isomer, chlorogenic acid, in all the cultivars of plums studied. There was no effect of crop year on hydroxycinnamic acid content. Neochlorogenic acid was previously reported to be the major hydroxycinnamic acid derivative, whereas chlorogenic acid the minor (Tomas-Barberan et al., 2001).

Flavonols in 10 plum cultivars grown in NY State in 2001 and 2002 are shown in Table 3. The flavonols found in plums were the derivatives of quercetin. Rutin (quercetin 3-rutinoside) was the most common and predominant among flavonols present in 10 plum cultivars tested, with concentrations ranging from 2.8 (NY 6) to 7.7 (Longjohn) mg/100 g for the 2001 crop, and from 1.0 (NY 101) to 8.3 (Early Magic) mg/100 g for the 2002 crop. Hyperoside (quercetin 3-galactoside) and isoquercitrin (quercetin 3-glucoside) were found in a few plum cultivars such as Castleton, Early Magic, Longjohn, and Mirabellier. One or two additional quercetin derivatives was present in Beltsville Elite B70197, Early Magic, and Longjohn.

Anthocyanins in 10 plum cultivars grown in NY State in 2001 and 2002 are presented in Table 4. Among flavonoids identified in fresh plums, anthocyanins were found to be the principal group. As expected, there were no anthocyanins found in yellow plums (Mirabellier and NY 101). A previous report (Tomas-Barberan et al., 2001) found no anthocyanins in the yellow plum Wickson. Anthocyanins of red and purple plum cultivars possessed the glycosides of cyanidin and peonidin such as keracyanin (cyanidin 3-rutinoside), kuromanin (cyanidin 3-glucoside) and peonidin derivatives. Keracyanin was the predominant anthocyanin in anthocyanin-containing plums. Longjohn had the highest amount of keracyanin among plum cultivars tested in both crop years. The highest level of peonidin derivative was found in Beltsville Elite B70197 among plums harvested in 2001 and 2002.

The average concentration of hydroxycinnamic acids (neochlorogenic and chlorogenic acids) in 10 plum cultivars was 112.7 mg/100 g for the 2001 crop and 92.2 mg/100 g for the 2002 crop. The common flavonol, rutin, in 10 plums was found at the average of 4.8 and 4.4 mg/100 g for 2001 and 2002 crops, respectively. For anthocyanin-containing plums, the sum of 3 common anthocyanins (keracyanin, kuromanin, peonidin derivative) averaged 33.6 and 36.4 mg/100 g for 2001 and 2002, respectively. Compared with the plums harvested in 2001, plums of the 2002 crop had 18.2% and 8.3% less hydroxycinnamic acids, and flavonol rutin while there was an 8.3% increase in three common anthocyanins. It indicates that the growing season may affect hydroxycinnamic acids content more than levels of flavonol rutin and common anthocyanins.

Conclusions

Plum cultivars showed significant differences in total phenolics and antioxidant capacity. There was a positive linear relationship between antioxidant capacity and total phenolics. Individual phenolics identified by reversed-phase HPLC analysis were neochlorogenic acid, chlorogenic acid, rutin, quercetin 3-glucoside, quercetin 3-galactoside, cyanidin 3-glucoside, cyanidin 3-rutinoside, peonidin 3-glucoside, and derivatives of cyanidin, peonidin, and quercetin. Plum cultivars exhibited diverse composition and different concentrations of phenolics. Plums contained copious amounts of phenolics and may be good sources of natural antioxidants through our diet, providing health-promoting effects in humans and preventing diseases. Plums are reported to have higher VCEAC than apples, the latter being one of the most commonly consumed fruit in our diet (Kim et al., 2003). Therefore, an increased consumption of plums is recommended in our diet.

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Economic Impact of the Two-Spotted Spider Mites (*Tetranychus Urticae*) on Strawberries Grown as a Perennial

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Currently, an economic threshold of 5 mites per leaf has been recommended for perennial strawberries grown in New York; however, it is not clear if this threshold is valid during the establishment year. Moreover, the threshold of 5 mites per leaf may be conservative for established plantings during the vegative growth stage (mid-summer to fall). Our current research suggests that June-bearing strawberries are tolerant of mite damage during the establishment year. We could not detect an impact on yield when infestation reached 10 mites per leaf and we suspect that thresholds could be raised to at least that number before treatment is warranted. Similarly, established plantings can likely tolerate 20 mites per leaf during late summer without reducing yield the next season.

Two-spotted spider mite (TSSM) *Tetranychus urticae*, can be a serious pest of strawberries. This appears to be especially true in regions where strawberries are grown in an annual production system as is used in California (Strand 1994). In fact, research over the past 20 years has concentrated on the impact of TSSM on strawberry grown as an annual (Sances et al. 1982, Gimenez-Ferrer et al. 1994, Walsh et al. 1998), while information on the impact of spider mites on strawberry grown as a perennial has received little recent attention. Currently, an economic threshold of 5 mites per leaf has been recommended for perennial strawberries grown in New York (Kovach et al. 1993), although this estimate is based mostly on anecdotal observations rather than manipulative experiments. It is unclear whether this threshold should vary with the year of planting or the time of season. For this project we assessed the impact of *T. urticae* on strawberries grown using a perennial production system, the system predominantly used in the Northeast.

The majority of strawberries that are grown in the Northeast are June-bearing varieties. These cultivars undergo different developmental processes depending on whether day lengths are getting longer or shorter (Pritts and Handley 1998). Thus, as day lengths shorten (summer and fall) plants initiate flower buds and produce vegetative runners. The following spring, when days are lengthening, plants flower and fruit mature. Mite feeding at these different developmental periods may have different effects on subsequent yield. Age of the planting may also influence the impact of spider mite damage. In particular, first year plants, due to their smaller size, may be less tolerant of spider mite injury than older plants. Moreover, the matted row system typically used in the Northeast relies on vigorous growth the first year, with the production of an abundance of runners in order to maximize yields in the second growing season. Mite injury may reduce growth and runnering. The purpose of this three-year project was to develop baseline data on the impact of TSSM on June-bearing strawberries grown in New York, data which can be used to refine economic thresholds. Our objectives were:

1. To assess the impact of *T. urticae* on perennial strawberry during the year of establishment.
2. To assess the impact of *T. urticae* on established perennial strawberry as a function of time of season.

This report focuses on results from the third year in which we evaluated the impact of previous injury on yield.

Methods

A new planting of June-bearing strawberries was established in late May 2001 at the New York State Experiment Station in Geneva, New York. The planting consisted of 30 rows approximately 22 meters in length with four-foot spacing between rows using three rows of the cultivar 'Honeoye' followed by three rows of the cultivar 'Jewel' across the planting. This plot was used to assess impact of TSSM damage on established strawberries. During 2001 plants showed some symptoms

We divided the 2002 planting into 25 plots (six rows [three Earliglow and three Cavendish] by 4.5 m) and assigned them to one of five treatments: 1) No spider mite damage; 2) Low level of mite damage during growth and sexual reproductive phase (June to August, 2002, although plants were not allowed to mature fruit), 3) High level of mite damage during growth and sexual reproductive phase; 4) Low level of mite damage during vegetative reproductive phase (runnering, August through mid-October, 2002); 5) High level of mite damage during vegetative reproductive phase. Each treatment was replicated five times for each cultivar. Miticide (Kelthane 35 WP at 3 lb/A rate in 50 to 100 gallons of water) was applied once at borders of each replicate plot (down edge rows) and a two-foot section between replicate plots (across rows) to maintain treatment integrity.

Approximately three weeks after planting (18 June 2002), TSSM were added to treatments two and three (early-season damage). Mites were obtained from a laboratory colony and reared on strawberry. Each plant of the center four rows of each plot assigned to treatment two (early season, low impact) was infested with from 10 to 20 large motile TSSM plus eggs. Similarly, each plant of the central four rows of plots assigned to treatment three (early season, high impact) was infested with 30 to 40 motile TSSM plus eggs. We treated control plots (treatment one) and plots assigned to late-season damage treatments (four and five) with a miticide (Kelthane 35WP, 2.5 lb/A, 75 gallons per A of water) on 11 July to kill TSSM. Control plots were again treated with Kelthane on 5 August 2002. All plots were treated with a pyrethroid insecticide (Asana [esfenvalerate]) at a rate of 1.5 to 7 fl. oz./A several times during the season to reduce populations of predatory mites.

Plants in our 2001 planting were kept mite free in 2001. At the start of the 2002 season we divided it into 25 plots (six rows [three Honeoye and three Jewel] by 4.5 m) which were assigned to one of five treatments: 1) No spider mite damage; 2) Low mite damage during vegetative reproductive phase (runnering, August through mid-October, 2002); 3) High mite damage during vegetative reproductive phase; 4) Low level of mite damage during growth and sexual reproductive phase (May-June 2003); and 5) High level of mite damage during growth and sexual reproductive phase. Each treatment was replicated five times for each cultivar. TSSM from our laboratory colonies were released on plants in the center four rows of plots assigned to late-season damage (treatments two and three) on 8 August, after regrowth of plants following renovation. Plots assigned to low mite damage (treatment two) received approximately 350 motile mites plus eggs while plots assigned to high mite damage (treatment three) received 700 motile mites plus eggs. We treated control plots (treatment 1) and plots assigned to early-damage in 2003 (treatments four and five) with a miticide (Kelthane 35WP, 2.5 lb/A, 75 gallons per A of water) on 22 August 2002 and 18 September 2002 to kill TSSM. All plots were treated with a pyrethroid insecticide (Asana [esfenvalerate]) at a rate of 7 fl. oz./A once during August to reduce populations of predatory mites. In the spring of 2003 TSSM from our laboratory colonies were released into plots assigned to receive a low or high level of mite damage during the growth and fruiting period (treatments four and five, respectively). Treatment four plots received approximately 600 motile mites plus eggs while treatment five plots received approximately 1,200 motile mites plus eggs on 27 May.

Mite populations in each planting were estimated approximately every week from 26 June through September in 2002 and in the established planting during June of 2003. Census data were used to estimate accumulated mite days for each cultivar in each plot during the season. Accumulated mite days provides a quantitative assessment of mite injury to plants and is determined by multiplying the number of days between two successive censuses by the average number of mites per leaflet between the same two successive censuses. Yield was assessed in 2003 in all plots of both plantings by collecting, counting and weighing ripe fruit from one meter sections systematically placed within each cultivar of each plot over about a three week period (until fruit was small and not marketable).

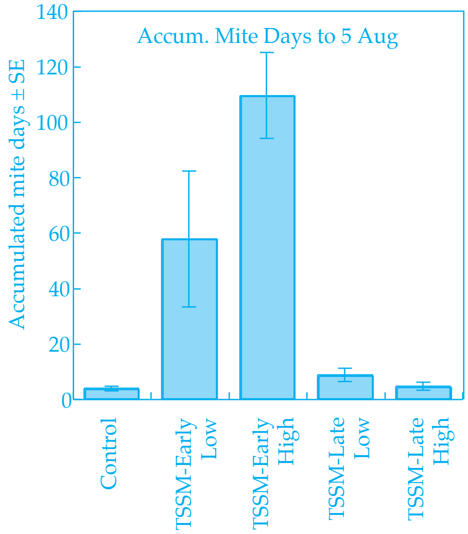

Figure 1. Accumulated mite days (± standard error) from 21 June to 5 August 2002 for strawberry plants assigned to different levels and timings of feeding injury from Two-spotted Spider Mite (TSSM).

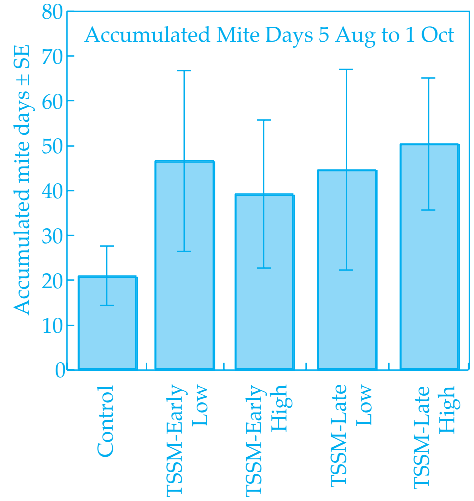

Figure 2. Accumulated mite days (± standard error) from 5 August to 1 October 2002 for strawberry plants assigned to different levels and timings of feeding injury by Two-spotted Spider Mite (TSSM).

Results

Effects of Mite Abundance in the Establishment Year. We were successful in establishing TSSM in plots of our 2002 planting assigned to the early-season treatments, although accumulated mite days (AMD) were not as high as we had originally desired (Figure 1). AMD were generally low in control plots and plots assigned to the late-season treatments. Moreover, high impact plots had about 1.5 more AMD than low impact plots (Figure 1). TSSM densities per leaf peaked between 16 July and 23 July with an average of 6.8 motile mites per leaf (SE = 1.5) on plants assigned to the high mite impact treatment and 4.3 motile mites per leaf (SE = 2.2) for plants assigned to low mite impact treatment. Our currently recommended economic threshold is 5 mites per leaf. AMD during the second half of the experiment was less than achieved during the first half and was similar among the four treatments infested with

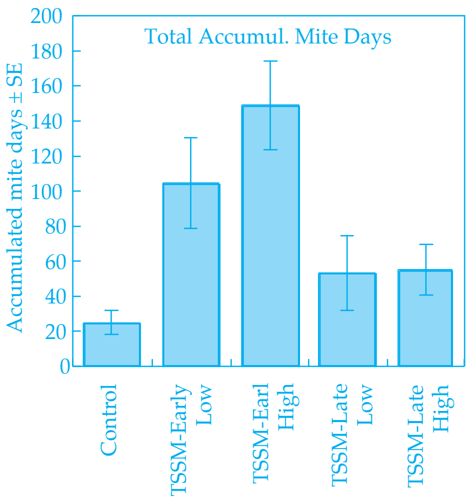

Figure 3. Accumulated mite days (± standard error) from 21 June to 1 October 2002 for strawberry plants assigned to different levels and timings of feeding injury by Two-spotted Spider Mite (TSSM).

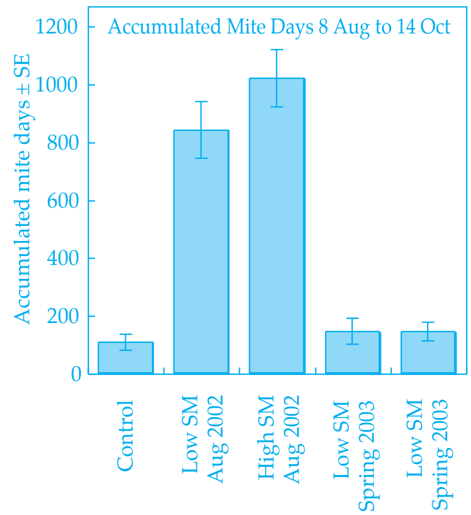

Figure 4. Accumulated mite days (± standard error) from 8 August to 14 October 2002 in plots of a second year planting of strawberries assigned to different levels and timings of injury from two-spotted spider mite (TSSM).

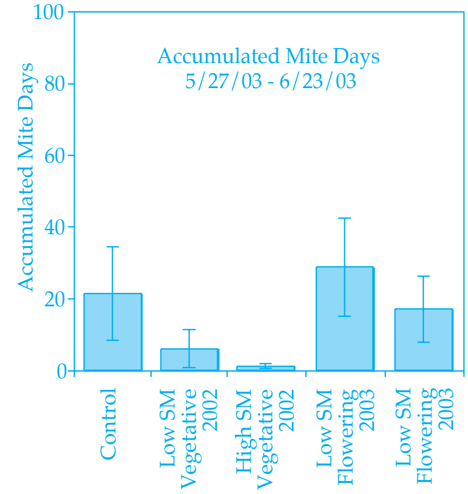

Figure 5. Accumulated mite days (± standard error) from 27 May to 23 June 2003 in plots of a third year planting of strawberries assigned to different levels and timings of injury from two-spotted spider mite (TSSM).

mites (Figure 2). Thus, AMD during the full season was somewhat greater for treatments two and three, that had mites for the entire season, compared to treatments four and five, that only had TSSM during the second half of the season (Figure 3). Peak mite densities in the second half of the season were about the same among treatments and all were below 3 mites per leaf.

The moderate densities of TSSM we achieved during the establishment year (2002) had no impact on either yield ($F_{4,36}$ = 0.165, P = 0.5) nor weight per berry ($F_{4,36}$ = 0.36, P = 0.83) in 2003. Yield did not differ between Earliglow and Cavendish ($F_{1,36}$ = 1.3, P = 0.25), although weight per berry, not surprisingly, was almost twice as much for Cavendish compared to Earliglow (9.8 g/berry vs. 5.5 g/berry; $F_{1,36}$ = 134, P < 0.001).

Effect of Mite Abundance on Established Strawberry Beds. As planned, abundance of TSSM in all plots in our 2001 planting was very low during the flowering and fruiting period of the 2002 season (data not shown). However, mites became quite abundant during the second half of the season in plots assigned to receive mites, reaching a maximum density of 63 motile mites per leaf on 9 September for the high-release plots, and 52 mites per leaf on 23 September for the low-release plots. AMD exceeded 1000 for the high-release plots and over 800 for the low-release plots (Figure 4). Toward the end of the season mite numbers in control plots and plots assigned to receive mites in the spring of 2003, began to build and reached maximum densities of around 6 motile mites per leaf before declining. AMD were below 150 in theses plots.

In the spring of 2003 mite abundance was quite low in all plots despite the release of large number of laboratory-reared mites into plots at the end of May (Figure 5). Average peak densities remained below 2 mites per leaf for all treatments. There was no clear explanation for why mite numbers did not increase during this time period.

High accumulated mite densities in the fall of the proceeding year in an established strawberry planting had no impact on yield the next season nor did very low accumulated mite densities in the current year ($F_{4,36}$ = 0.73 P = 0.58). There was a significant difference between the two cultivars with Honeoye out producing Jewel in 2003 (3,854 g/2m for Honeoye and 2,645 g/2m for Jewel, $F_{1,36}$ = 14.6, P < 0.001). Similarly, we found no treatment effect on weight per berry ($F_{4,36}$ = 1.1, P = 0.38) but berry weight for Jewel was slightly higher than Honeoye (9.3 g/berry for Jewel vs. 8.1 g/berry for Honeoye, $F_{1,36}$ = 15.0, P < 0.001).

Discussion

Our objective for this project was to examine the impact of TSSM on yield parameters of June-bearing strawberries in the Northeast when damage accumulates during different growth periods. Specifically, we were interested in determining to what extent damage during the year of establishment negatively impacted yield the second year and to what extent damage during the vegetative period or damage during the flowering period negatively impacted yield of an established planting. We were only partially successful in accomplishing these objectives primarily because we had difficulty maintaining sufficiently high mite densities in some plots at certain times of the year. We were most successful at developing large populations and damage during the vegetative growth period of an established planting (Figure 4). Average peak densities greatly exceeded the current threshold of 5 mites per leaf, yet we could not detect an impact on yield the next season. This suggests that June-bearing strawberries are very tolerant of mite damage during the vegetative phase, at least for Honeoye and Jewel, the two cultivars we worked with in this project.

We were unsuccessful, however, in assessing the impact of TSSM during the flowering phase of an established planting (Figure 5). Mite numbers never really developed despite a large release in the spring. The 2003 growing season was cool and wet and this undoubtedly helped suppress populations, although other factors were probably important as well. Average peak densities were below current thresholds for all but a few plots where they briefly exceeded 5 mites per leaf. Thus, it is difficult to draw any definitive conclusions regarding the suit ability of our current threshold based on our results. It is probably conservative for a healthy planting, but by how much is unclear.

We also had difficulty developing adequate mite populations during the establishment year, especially in the second part of the season.
Part of the reason for the difficulty was that predatory mites colonized the field and reduced population growth. Several applications of a pyrethroid insecticide known to be very toxic to predatory mites were only marginally successful.

Summary

During the establishment year with June bearing strawberries we imposed average peak TSSM densities during the first part of the growing season that exceeded the common threshold of 5 mites per leaf, yet this did not translate into a yield reduction the following season. Thus, five mites per leaf is a conservative threshold for June-bearing strawberry during the establishment year. Given the fact that we could not detect a yield impact for several plots that exceeded 10 mites per leaf, we suspect that thresholds could be raised to at least 10 before treatment is warranted. For established strawberry plantings, our results indicated that plants can tolerate substantial mite feeding later in the summer without causing significant economic injury.

Acknowledgments

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Mortality of Obliquebanded Leafroller Due to Natural Enemies in Orchards Treated with Conventional or Reduced-Risk Insecticides

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Obliquebanded leafroller (OBLR) [*Choristoneura rosaceana* (Walsh)] is a serious pest of apple in several regions of New York, and is of increasing importance in Washington, California, Michigan, British Columbia, Ontario, and Quebec. The pest status of OBLR is in part due to its development of resistance to insecticides. Populations of OBLR from commercial apple orchards show varying resistance to organophosphate insecticides (Guthion, Imidan), synthetic pyrethroids (Asana), and even newer insecticides such as Confirm and Intrepid. Currently, treatments of Intrepid and Spinosad provide adequate control of OBLR; however, more integrated management strategies are desirable to counter the problem of insecticide resistance and to lower management costs.

OBLR is native to North America and is widely distributed on many uncultivated species of trees and shrubs. In New York, OBLR are found throughout the state on uncultivated apple trees and in thickets of gray dogwood. Casual observations suggest the dynamics of OBLR in these uncultivated habitats is very different from those observed in commercial orchards. Although OBLR populations appear to be persistent in wild habitats, densities apparently are very low, particularly during the summer. In contrast, OBLR populations in commercial orchards appear to persist at damaging levels from year to year, even when treated with insecticides. Commercial apple orchards are excellent food sources for leafrollers, and treatments of some insecticides, such as organophosphates, are not highly toxic to OBLR but will destroy natural enemies (parasitoids and predators) that help regulate OBLR densities. In native habitats, vegetation may be less concentrated and nutritious for OBLR, and a diverse array of plant species may provide habitats that allow high densities of natural enemies to limit leafroller numbers (Figure 1).

Obliquebanded leafroller is a serious pest of apple in part due to its development of resistance to common insecticides. Although OBLR populations appear to be persistent in wild habitats, densities apparently are very low, particularly during the summer. This is due to high natural predation and parasitism; however, in commercial orchards insecticides kill most predators and parasites. Therefore, it should be possible to develop biologically based management programs for OBLR in commercial apple orchards if selective insecticides that are not toxic to indigenous natural enemies can be developed. It is therefore important to test newer more selective insecticides for toxicity to OBLR predators and parasites.

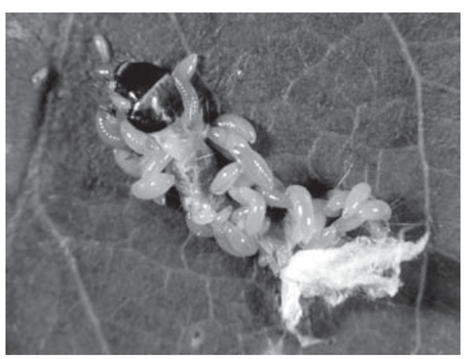

Figure 1. Two natural enemies of Obliquebanded leafroller larvae. A parasitoid, (*Colpoclypeus florus*), on the left and a predator, an immature reduviid bug (*Phymata fasciata*) .

In 2002 and 2003, studies were conducted to identify factors that limit an abundance of OBLR in habitats devoid of insecticides. Our intent was to use this information to develop a more biologically-based management program in commercial apple orchards. These studies confirmed that although low numbers of OBLR larvae consistently occur on gray dogwood plants in the spring, it was impossible to find larvae from the subsequent summer generation during July and early August. Similar results were observed on apple trees that had not been treated with insecticides. Concurrent laboratory studies showed that OBLR larvae could develop equally well on foliage from apple trees and dogwood plants, which suggested that the nutritional quality of apples and dogwood plants was similar and not a factor limiting OBLR populations.

Experiments were also conducted to compare the abundance and diversity of natural enemies in uncultivated dogwood habitats and in orchards not treated with insecticides. Small potted apple trees infested with OBLR larvae were placed in the orchards and in thickets of dogwood. Larvae were recollected after 96 hours, reared in the laboratory, and emerging parasitoids were identified. We found that levels of parasitism and the species composition of parasitoids were similar in unsprayed apple orchards and in dogwood thickets and that parasitism rates were as high as 72 percent.

These studies suggested that natural enemies could substantially contribute to the control of OBLR in commercial orchards if the deleterious effects of insecticides on OBLR natural enemies could be reduced. More selective, reduced-risk insecticides are currently being tested to replace organophosphates, carbamates and pyrethroids (see details in Agnello et al., 2004). We made use of these trials to determine whether these reduced risk compounds (Table 1) allow for greater natural enemy-caused mortality of OBLR.

Methods

The objective of the investigation was to determine whether predators and parasitoids caused greater mortality of OBLR larvae in orchards treated with reduced-risk insecticides compared to orchards treated with conventional insecticides. This required a methodology that would allow placing large numbers of larvae in orchards and exposing them to natural enemies therein. Following exposure, remaining larvae needed to be retrieved to monitor development and emergence of parasitoids. We accomplished this by placing laboratory-reared larvae on insecticide-free apple foliage and then placed the foliage and accompanying larvae into experimental plots. Following exposure, we recollected the larvae and reared them on artificial diet. With this procedure, which we termed outsourcing, we could determine the proportion of larvae that were parasitized. We could also estimate the proportion of larvae that were lost during the exposure period, a reduction in larvae that was due to the additive effects of dispersal and predation. If an estimate of dispersal loss was known, then predation loss could be determined.

Two outsourcing methods were used. In 2003, two apple leaves were placed in florist waterpicks and a single larva was allowed to develop a feeding site for 24 hours and then the leaves and larva were placed in trees in and around orchards. In 2004, a one meter long apple branch was placed in a capped PVC pipe filled with water and two-three larvae were allowed to develop feeding sites for 24 hours and then placed in trees in the research plots. In both years larvae were left in the research plots for 48 hours and then retrieved.

Dispersal loss of larvae from the leaves in waterpicks and from branches was estimated in the absence of any predators. This was done so that loss due to predation could be separated from loss due to dispersal. To preclude predators, the experiment was conducted in a screenhouse, which did however allow air movement. Larvae were placed on either the two leaves in waterpicks or on branches and allowed to develop feeding sites. The foliage and larvae were then placed in a screenhouse for 48 hours and subsequently examined to determine the proportion of larvae that had dispersed away. The experiment was repeated several times and overall, 550 larvae on leaves in waterpicks and 300 larvae on branches were used. Dispersal loss was very consistent among replicates and between the two placement methods, averaging 7 percent from foliage in

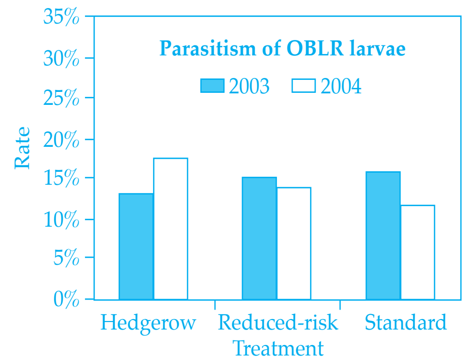

Figure 2. Percentage of OBLR larvae placed in plots in orchards that were killed by parasitoids. Percentages are based on 5 replicate orchards and 50 larvae per treatment plot outsourced 3 times each year. Treatments were wild habitats on the edge of orchards (hedgerow), approximately 10 acre plots treated with reduced-risk insecticides (reduced risk), and 10 acre plots treated with conventional insecticides (organophosphates, carbamates and pyrethroids) (standard).

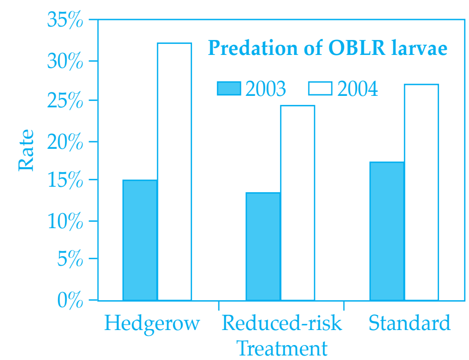

Figure 3. Percentage of OBLR larvae placed in plots in orchards that were killed by predators. Percentages are based on 5 replicate orchards and 50 larvae per treatment plot outsourced 3 times each year. Treatments were wild habitats on the edge of orchards (hedgerow), approximately 10 acre plots treated with reduced-risk insecticides (reduced risk), and 10 acre plots treated with conventional insecticides (organophosphates, carbamates and pyrethroids) (standard).

TABLE 1

Selective insecticides and their proposed target pests.

Insecticide	Target Pest(s)
Actara	rosy apple aphid, spotted tentiform leafminer, plum curculio
Avaunt	spotted tentiform leafminer, internal lepidoptera, plum curculio, Apple maggot, white apple leafhopper
Dipel	obliquebanded leafroller
Intrepid	internal lepidoptera, obliquebanded leafroller
Provado	aphids, spotted apple leafminer
Spinosad	codling moth, obliquebanded leafroller, apple maggot

waterpicks and 8.5 percent from branches.

An experiment was also conducted to determine whether the outsourcing methods would bias estimates of parasitism or predation. Bias might occur if the placement method influenced searching by natural enemies. While knowledge of bias is useful, the occurrence of bias would not invalidate the methods because they were to be used to compare relative estimates of predation and parasitism among treatments and not to obtain absolute estimates of mortality. The experiment was conducted in an insecticide-free orchard. Leafroller larvae were placed in trees two ways. The first by using one of the two outsourcing methods previously described and the second by placing larvae directly on foliage of trees. In the latter case, larvae were caged on the trees and allowed to develop feeding sites for 24 hours before being exposed to natural enemies. These trials were repeated three times each year in 2003 and 2004. We found that the waterpick and PVC pipe placement methods resulted in a 55 and 30 percent underestimation of predation loss, respectively. The waterpick method resulted in about a 50 percent underestimation of parasitism whereas the PVC pipe methods underestimated parasitism by ca. 20 percent.

The experiment to compare the mortality of OBLR larvae from parasitoids and predators was conducted in five orchards each of which contained three plots; one treated with conventional insecticides, one treated with reduced-risk insecticides, and a habitat (e.g., hedgerow) adjacent to the orchard that was not treated with insecticides. Fifty larvae were placed into each of these habitats using the outsourcing methods previously described (waterpick in 2003, PVC pipe in 2004). Larvae were left in the orchards for 48 hours, and those remaining were retrieved and reared. This process was repeated three times each year. Data were analyzed using a mixed models analysis of variance.

To determine the abundance and diversity of potential arthropod predators, collections were made from 50 randomly chosen branches in each orchard plot (15) four times in 2004 [7/13 (daytime collection); 7/19 (day & night collection); 8/3 (daytime collection)]. Two-foot-long branch-tips were vacuumed for three seconds each using an insect vacuum. All the collected insects were identified and predators were separated into seven groups: lacewing larvae, tree crickets, ants, spiders, predacious flies, predacious true bugs and lady beetles. An additional study verified that vacuuming provided a representative sample of the predators present on the branches.

Results

Parasitism of OBLR larvae was not significantly different among the hedgerows, reduced-risk treatments and plots treated with conventional insecticides during 2003 or 2004 (Figure 2). Rate of parasitism in all three treatments was remarkably similar during both years of the study (13,16 & 15 percent in 2003 and 17, 12, & 14 percent in 2004, respectively in the hedgerows, reduced risk, and standard).

Wasps and flies parasitized the outsourced larvae. In 2003, wasps parasitized a higher percentage of OBLR larvae in the hedgerows and reduced-risk pesticide treatments than in the standard plots, but rates of parasitism were similar in all plots in 2004. Parasitoid flies parasitized the same proportion of larvae in all three treatments in both years. The relative importance of the two parasitoid groups (wasps and flies) varied between two regions in which the experiment was conducted. In the two orchard sites located in one of these regions (Lafayette), flies (Tachnidae) were the most important parasitoids, and in one orchard 50 percent of larvae were parasitized by this group of insects. Wasps were less active in the Lafayette orchards, parasitizing a range of 0-16 percent of the larvae in different treatments. In contrast, flies were considerably less active in the three orchards in the second region (Wayne), and the rates of larval parasitization ranged from 0- 9 percent. In these orchards, wasps were relatively more important parasitoids and larval parasitization reached a maximum of 22, and 30 percent, respectively in 2003 and 2004.

Larval mortality from predators was higher than that from parasitoids during both years of the study in all of the treatments (Figure 3). The estimated levels of predation in hedgerows, reduced-risk treatments, and standard plots were similar in both years of the study, although the average estimated percentages of larval loss from predation were higher in all treatments in 2004 than in 2003. This difference may be attributed to the use of branches in pipes for outsourcing larvae in 2004, which resulted in higher estimates because it may have more closely mimicked larval infestations on actual tree branches.

Nine parasitoid species were recorded from the research sites, but only three of them, the ichneumonid wasp *Exochus albifrons*, the tachinid fly *Actia interrupta* and the braconid wasp *Oncophanes americanus* parasitized rela tively high numbers of larvae in both years. *O. americanus* was present in all three treatments. This parasitoid was collected from late June until mid-August, parasitizing every larval stage of OBLR. *E. albifrons* was present only in July, reaching a peak parasitism level in mid-July, and disappearing by August. The only important parasitic fly, *A. interrupta*, was abundant in the two Lafayette orchards, but rare in Western NY sites. This parasitoid fly was present in both July and August in both years.

The most common groups of predators collected were true bugs, ants, and tree crickets. Ants and tree crickets were more commonly collected in hedgerows and true bugs were the most common predaceous species collected in all treatments. Although significantly higher numbers of predators were collected from hedgerows than orchards, this higher population density apparently did not result in a higher predation of OBLR larvae.

Discussion

Levels of mortality inflicted on outsourced OBLR larvae from parasitoids and predators were not significantly higher in our 10 acre orchard plots treated only with selective insecticides for two to three growing seasons compared to nearby plots treated with standard insecticides. The estimates of larval mortality from predation were consistently higher than estimates of mortality from parasitoids. Two factors could account for this pattern. First, it is possible that changes in natural enemy abundance in orchards will not occur as a result of changes in management practices imposed on relatively small acreages. The plots used in this study were approximately 10 acres in size, but were surrounded by many acres of orchard that were treated with conventional insecticides. While 10 acres would seem to be a large area, patterns of natural enemy abundance may be determined by processes that occur on a much larger scale. The fact that estimates of natural enemy-caused mortality of OBLR larvae were not greater in hedgerows is evidence that supports this explanation. It is also possible that some or all of the selective, reduced-risk insecticides are more toxic to natural enemies than currently thought. Plots were treated with several different types of selective insecticides some of which might be toxic to beneficials as conventional insecticides. These variables will have to be investigated more thoroughly in future studies.

Larval mortality from natural enemies in nearby hedgerows that were presumably not treated with pesticides, was also not significantly greater than that observed in the two insecticide-treated plots. It is possible that the population of natural enemies in hedgerows is relatively low because they are a small, localized unsprayed part of the landscape near an extensive acreage of apple orchards and other agricultural land that has repeatedly been treated with pesticides. Perhaps it is necessary to have large unsprayed areas with a diverse plant structure that are geographically isolated from pesticide treated areas to enhance the abundance of natural enemies of leafrollers.

This study also showed that there were differences in the overall levels of activity of beneficials and the species of most important parasitoids associated with OBLR larvae among orchards in different geographical locations. This variability may be due to differences in the overall landscape environment outside of orchards, or variability in the acreage and size of apple orchards within the region. Future studies should be done in more locations to determine if variables associated with regional orchard plantings, or host plant or geographic variables in the external landscape near orchards can be identified that will enhance the likelihood of improving biological control of leafrollers.

Summary

Biological studies conducted in research plots of unsprayed apple trees and thickets of gray dogwood showed that overwintering OBLR larvae were common in these two types of natural habitats, but persisted at relatively low levels. Later during the season, larvae from the summer generation were not usually detectable. Subsequent studies showed that the quality of the two host plants was suitable for the survival of the summer generation of larvae, but high levels of parasitism and a similar composition of parasitoid species were observed when larvae were set out on both host plants in these habitats. These studies suggested that natural enemies can regulate populations of OBLR at low levels on unsprayed apple trees, particularly during the summer when most fruit damage occurs. Therefore, it should be possible to develop biologically based management programs for OBLR in commercial apple orchards treated with more selective insecticides that are not toxic to indigenous natural enemies. Studies were conducted during the 2003 and 2004 growing season to compare the mortality of OBLR larvae from predators and parasitoids in three habitats: (1) Unsprayed hedgerows adjacent to commercial orchards. (2) Plots treated only with reduced-risk insecticides for 2-3 consecutive seasons. (3) Plots treated with conventional insecticides. Larval mortality from both predators and parasitoids was not significantly different among untreated hedgerows, reduced-risk insecticide plots, and standard plots. Estimates of larval mortality from predation were consistently higher during both years of the study in all three treatments than that from parasitoids. This study also showed that there were differences in the species of most important parasitoids associated with OBLR larvae among orchards in different geographical locations. These results suggest that future studies should be done to compare the toxicity of individual reduced-risk insecticides to natural enemies, and to identify variables associated with orchard plantings or the landscape surrounding orchards to determine their effects on populations of predators and parasitoids.

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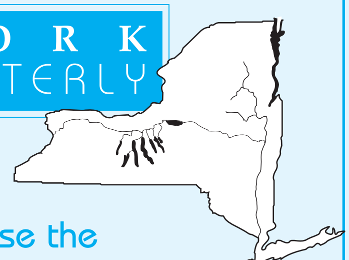

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