CropLife Foundation
Crop Protection Research Institute

COMPARING ORGANIC AND CONVENTIONAL APPLE SYSTEMS

CORRECTING A WSU STUDY

Research Note #3

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Introduction

Beginning in 1994, researchers at Washington State University (WSU) conducted an experiment that compared the performance of organic and conventional apple growing systems. This Study (referred to as "The WSU Study") was funded by grants from USDA. WSU received about $700,000 in grants to support this research. The results were first published in *Nature* in 2001 [1]. Several technical documents contain many of the details of the research [2][3]. WSU issued a press release on the research findings [5]. The story produced a "huge publicity bonanza for the College" [18]. Publicity included interviews with the senior author on NPR's *All Things Considered* and on the *Voice of America*. The major wire services all carried stories on the research [13].

Most of the media coverage of the WSU Study focused on the major findings of the research:

> "Our results show that organic and integrated apple production systems in Washington State are not only better for soil and the environment than their conventional counterpart but have comparable yields and, for the organic system, higher profits and greater energy efficiency. The total environmental impact of our conventional system was 6.2 times that of the organic system. Our data indicate that the organic system ranks first in sustainability and the conventional system last"[1].

This conclusion is regularly cited by those who claim that pesticides are not important in crop production [19]. Several advocacy groups have cited the WSU Study in attempting to persuade the EPA to cancel certain insecticides used in apple production. The research article is an important part of classroom teaching at WSU [21]. The authors continue to present the research results at conferences including a *Symposium on Innovations in Organic Marketing, Technology, and Research* whose Proceedings were recently published by the *Plant Management Network* [6].

A critical review reveals that the WSU Study has several major flaws that make its conclusions unsupportable. The WSU Study unjustifiably inflates the costs and risks of the conventional system while systematically favoring the organic system in its calculations and presentation of results. By correcting these biases, the opposite conclusion is supportable.

This critique includes a background discussion of the importance of pest control in Washington State apples and a summary of the WSU experimental methods. The systematic flaws in the WSU Study are then analyzed.

The critique is limited to the conventional and organic system comparison. It does not include the integrated system. It is also limited to the pest control and fruit thinning operations. Fertilizer use and fuel use are not analyzed. The soil analyses, economics, yield and horticultural characteristics of the apples are not considered. The critique focuses on the 1994-1999 experiment.

Washington State Apple Pest Control

Codling moth is the key pest of the apple in Washington. Moths mate and lay eggs on apple leaves and fruit. Newly-hatched larvae bore through the apple skin and feed, depositing large quantities of excrement [23]. 80% of Washington State apples would likely be damaged by the codling moth without control [17]. Control of codling moth has been achieved for thirty years with three to four summer applications of broad spectrum organophosphate insecticides, azinphos-methyl being primary [25]. The use of these insecticides can reduce codling moth damage to zero. Very stringent market standards exist for codling moth damage and the comparative efficacy of insecticides is measured in terms of percent damage with 1-2% constituting failure. High risk orchards are characterized by having codling moth injury greater than 2% the previous year [28].

In the early 1990s research began on the use of pheromones to disrupt the mating of codling moth. The female moth emits a sex pheromone which attracts the male from long distances so that mating can occur [25]. The underlying premise of mating disruption is that high concentrations of the codling moth sex pheromone in the orchard will prevent the males from finding the females so mating does not occur. Dispensers containing the pheromone are placed in trees throughout the orchard. Research demonstrated that mating disruption could provide adequate codling moth control when low densities are present, but was not an effective stand alone tactic under high codling moth densities [26]. In addition, orchard borders had consistently higher levels of fruit damage due to the movement of mated females into the orchard. Leafrollers became a bigger problem where mating disruption was used for codling moth and broad-spectrum insecticides were reduced.

The leafrollers most often found in apple orchards in Washington are pandemic leafroller and obliquebanded leafroller. Both have two generations a year. Larvae of the overwintering generation may eat portions of young fruit in May. Young summer generation leafroller larvae attach leaves to apples in late June and early July and feed. Chlorpyrifos has been the standard chemical insecticide for control of leafrollers. Bacterial insecticides (strains of *Bacillus thuringiensis* [Bt]) have given good control of leafroller larvae when 2 or 3 applications have been made [24].

Powdery mildew is the primary disease of apples in Washington. Spores can be carried great distances by the wind. The fungus grows down twigs which it covers in a gray felt. When apples are infected, their surface is covered with a network of cork cells (russet). Fungicides that are registered to prevent infections include sulfur and myclobutanil.

Weeds can out-compete apple trees for water and nutrients lowering yields. Prior to the use of herbicides, mechanical cultivation and hand weeding were the only tools available [11]. Stuck tractors and soil erosion were common in orchards. Today, the most common system for weed control in Washington apple orchards is a mowed grass cover between rows with an herbicide-treated band under the trees. The area under tree rows cannot be properly mowed and would become a thick tangle of weeds if left to grow [11]. Various methods have been tried for weed control including mulches, flamers, and fabric covers.

The WSU Study: Methodology

Located on a 20-ha commercial, conventional apple orchard in the Yakima Valley, the 1.7 ha study area was planted to Golden Delicious apples in 1994 as a randomized complete block design with four replications of three treatments: conventional, integrated, and organic. (see Figure 1) Each of the twelve experimental plots was .14ha. The research site was bordered on the north and west by the commercial orchard and by pasture on the other two sides. A 2 meter wide weed-free strip in the tree rows was maintained for all systems according to practices described below. The alleyways consisted of mown turf grass. Data were collected and analyzed for the years 1994-1999. In 1999 and 2000 the trees were top-grafted from Golden Delicious to Galaxy Gala and another experiment was begun, which was maintained through 2003[4].

Insect pests, diseases and physiological disorders were monitored throughout each growing season by the farmers and professional consultants. Based on their observations, recommendations were made as to the organic, conventional or integrated treatments for pest control [1]. The cumulative treatments applied over the six year experiment for weed, insect, and disease control and for thinning are listed in Table 1 for the conventional and organic systems. In general, for insect and disease control, the organic plots were treated with pheromones, oil, Bt, and sulfur. The conventional plots were also treated with the same pheromones, insecticides and fungicides as were used in the organic plots. However, additional sprays of insecticides and fungicides were made in the conventional plots. Table 2 lists the sprays made in 1998. For weed control, the organic system utilized bark mulch, landscape fabric, and hand hoeing 1994-1996; thereafter, cultivation and hand hoeing were used in the organic plots. Weeds were controlled with herbicides in the conventional plots. Fruit thinning was by hand in the organic plots and by chemical sprays in the conventional plots.

The researchers report that there were no observable differences in pests or diseases among plots during each growing season and that fruit damage due to pests and diseases were minimal and equal for each of the systems [1].

Yields were reported for each system 1996-1999 and prices were assigned to estimate their value. The organic fruit was assigned a price premium of 50%. The production cost of each system was subtracted from the estimates of gross receipts to determine profitability.

The researchers assigned environmental impact ratings for each application of a pesticide and the pheromones using an index developed by Stemilt Growers of Washington State. This index rates chemicals by combining information on efficacy, dermal LD50 (a proxy for worker exposure), leaching potential, soil sorption index, soil half-life, effect on beneficial organisms, and preharvest interval (a proxy for consumer exposure). The greater the number, the greater the negative impact. Table 3 displays the environmental impact cumulative totals calculated for inputs in the organic and conventional systems. This Table also includes an estimate of the average environmental impact per application (calculated by division).

Critique

The WSU Study's low negative environmental score calculated for the organic system is a result of excluding the negative impacts of organic weed control methods.

The rating system does not include any scores for the negative environmental impacts of cultivation, bark mulch, and fabric covers, or the health problems associated with hand hoeing weeds. 40% of the total negative score for the conventional system comes from the use of herbicides to control weeds which is compared to zero points for the negative effects of cultivation, bark mulch, fabric covers and hand weeding (Table 3). However, the negative effects of cultivation (soil erosion), fabric covers (disposal), bark mulch (respirable dust) and hand weeding (permanent back problems) are well known. Several recent papers at Organic Farm Management Workshops in the Northwest warn about the negative effects of cultivation: depletion of soil organic matter, exposure of soil to wind and water erosion, soil compaction, and damage to tree roots [14] [15]. Hand weeding has been banned in California due to damage to workers backs. The fabric covers are made of plastic and are typically disposed of in landfills. The WSU researchers are not forthcoming on where they disposed of the plastic. To simply ignore the negative effects of one system predetermines the outcome.

The WSU researchers greatly over-applied herbicides in the conventional plots which resulted in very high treatment costs and very high negative environmental scores.

More treatments were made with the herbicide glyphosate (23) than any other pesticide (Table 1). The glyphosate use accounts for 35% of the overall negative score of the conventional system (Table 3). On average, 3.8 glyphosate applications were made per year. In four of the years, five glyphosate applications were made. The WSU Study's number of glyphosate applications is much higher than listed in other sources of data. Surveys of Washington apple farmers have consistently shown that they typically make two glyphosate applications [22]. A cost of production budget for conventional Washington apple growers (prepared by one of the WSU coauthors [Hinman]) lists two glyphosate applications as the typical practice [20]. The "conventional" treatment in the WSU Study was greatly exaggerated in comparison to actual practices.

The WSU Study misrepresents the importance of pesticides in the organic plots.

The published WSU articles refer to controlling pests "naturally" using "biological" controls including applications of *Bacillus thuringiensis* in the organic plots while the conventional plots were treated with "pesticides." The fact is the organic plots were sprayed with pesticides too. *Bacillus thuringiensis* is a pesticide sprayed to kill insects by rupturing their stomach linings. The articles summarizing the WSU Study do not mention the spraying of sulfur in the organic plots for killing the powdery mildew fungus. And yet, the technical appendices make it clear that sulfur was sprayed in the organic plots.Bt and sulfur are EPA-registered FIFRA-regulated pesticides The same type of blast sprayers are listed as being used in both the conventional and organic plots. The public should not be misled into thinking that organic growers do not use “pesticides” when, as in the WSU Study, they clearly do.

The WSU Study’s conclusion that the organic system is more sustainable than the conventional system is not supportable due to the reliance on laborers for hand hoeing weeds.

According to the published articles, weeds were controlled in the WSU organic plots with bark mulch, landscape fabric, cultivation and mowing .No mention is made of the forty-eight hours of labor employed annually per acre for hand hoeing weeds out of the organic plots. This important labor input is identified only in the detailed budgets for the organic operations [2]. Labor is in critically short supply for agricultural work in Washington State. Herbicides substitute for labor. The dependence on labor for hand weeding makes the potential sustainability of organic systems questionable. Such an important input into the organic system should not be hidden from the public and policymakers.

The basis of the negative environmental impact ratings assigned to pesticides is subjective and cannot be determined or defended scientifically.

The WSU Study uses a negative pesticide environmental rating system which was developed by the largest commercial packer of apples in the US, Stemilt Growers, as a marketing tool for their “Responsible Choice” label. Consumers Union tried to evaluate the Stemilt System and noted that the rating system is confidential and concluded that:” It is impossible to determine the clarity, meaning, verification, and consistency of the Responsible Choice label.”[12] The WSU researchers state that the Stemilt rating system is “similar” to Cornell University’s Environmental Impact Quotient (EIQ). They fail to note that when the Cornell researchers applied the EIQ to apple production systems in New York, that the negative score for the organic system was double the negative score of the conventional system [9]. There are significant differences between the Stemilt commercial rating system and Cornell University’s. The Stemilt system drops out a measure for risks to aquatic organisms and adds a factor for the efficacy of a pesticide in controlling a pest. It is not clear that there is general agreement that control efficacies have any appropriate place in an index measuring environmental effects. A recent analysis by Alex Avery of the Hudson Institute reveals that by substituting the EIQ ratings for the Stemilt ratings that the negative impact of the conventional WSU system is reduced from 520% higher than the organic score to 32% higher [10]. The details of the Stemilt scoring system have not been published or reviewed; they are secret. They are a marketing tool for a large commercial company. The ratings are easily manipulated and have no appropriate role in a scientific study.

The WSU Study does not contain any measurements of pest infestation or damage. The relative performance of the systems cannot be judged.

Not a single measurement of codling moth, leafroller, or powdery mildew incidence or control has been released for the 1994-1999 experiment. The authors merely state that the pest levels were equal and minimal. What do they mean by "minimal?" As noted above, codling moth damage in excess of 2% is considered a failure in commercial orchards. What the codling moth pressure was like in the WSU Study plots is impossible to determine. There was no untreated plot. As noted above, pheromones can only provide effective control as a stand alone treatment if codling moth pressure is low. The WSU plot may have had very low codling moth pressure which would have favored the organic system. The WSU Study cannot be used for broad scale generalizations and evaluation since the pest pressure level is not revealed. They present no data on the pest infestation levels that guided the application of sprays. How did the pest levels change following the sprays? It is impossible to judge whether the systems worked equally well as the WSU researchers claim. In three of the years, only one Bt spray was made in the organic plots. Did one Bt spray provide leafroller control equivalent to a chlorpyrifos spray in the conventional plots? As noted above, generally two to three Bt sprays are needed for equivalency. There are no scientific measurements of pest damage in the WSU Study 1994-1999 and this makes it impossible to evaluate the Study.

The location of the plots greatly favored the performance of the organic system.

The plots were surrounded on two sides by a commercial conventional orchard where, presumably, chemical insecticides were used to keep codling moth pressure low. This location favored the organic plots in two ways. First, codling moth pressure in the plots was probably low because the population in the surrounding orchard was kept low by insecticide use. Secondly, the lack of effectiveness of pheromones in managing codling moth at field edges was minimized. As noted above, mated females often fly into pheromone plots and damage apples on the edges of the field. There was little chance of this happening in the WSU plots because of its location. This plot location was not an independent site free of outside controlling effects.

The WSU researchers greatly over-applied insecticides and fungicides in the conventional plots which resulted in very high treatment costs and very high negative environmental scores in comparison to the organic plots.

In 1994, no insecticide or fungicide sprays were made in the organic plots while three insecticide and fungicide sprays were made in the conventional plots. There is no explanation for this difference in treatment in the year that the trees were planted. In succeeding years (1995-99), the conventional and organic plots were treated at the same time with pheromones and with the same type of spray (insecticide, fungicide) up to a certain date after which there were no more organic sprays but additional sprays were made in the conventional plots in succeeding months. For three of the years, the organic sprays were stopped in May while the conventional sprays continued into July or

September. In the other two years, the organic sprays were stopped in June while the conventional sprays continued through August. Table 2 displays the spray timings for 1998. There is no explanation of why these additional sprays were made.

For example, in 1998 an application of the fungicide myclobutanil was made in June, but no corresponding sulfur spray was made in the organic plot. Was the myclobutanil spray made because spores were detected? If so, were no spores detected in the adjacent organic plots? The researchers do say that pest incidence was similar in the plots. If pest incidence was similar , why were additional sprays made in the conventional plots and not in the organic plots? It is impossible for the WSU researchers to answer these questions with data because, as noted above, they present no data on pest infestations.

Why were azinphos-methyl sprays made in June and July in the conventional plots which had pheromones in place? Was it because of high codling moth incidence? If so, then codling moth damage must have been high in the nearby organic plots where no sprays were made to supplement the pheromones. If that was the case, then the apples in the organic plot would have shown more codling moth damage at the end of the season. But the researchers state that pest damage was equal in all plots which implies that the conventional plots received no additional benefits from the additional sprays. It appears that the plots were regarded differently when control recommendations were being made. The organic treatments stop with low incidence of pests, but the conventional sprays continue even with low incidence of pests, as if on a calendar basis, and not on the basis of scouting for pests as the WSU researchers claim. Was a separate set of standards used for the organic plots? Did the same personnel apply exactly the same standards for spraying pesticides on both the organic and conventional plots?

One of the WSU Study coauthors wrote an independent report which concluded that adoption of the organic insect control method would lead to widespread losses in Washington apple production.

In 1999 one of the WSU Study's coauthors (Hinman) coauthored a paper estimating the impacts of eliminating carbamate and organophosphate insecticides in Washington apple production [20]. The 1999 paper concluded that pheromone dispensers could control codling moth when pressure is light, but that codling moth damage could approach 75% with heavier infestations. The WSU Study does not cite this paper by one of its own coauthors. The 1999 paper is consistent with other reports that conclude that pheromone use alone would lead to large losses at higher pressures from codling moth. The WSU Study has no such caveats.

The organic insect controls were not sustainable and failed completely in the 2002 continuation of the WSU Study

The only data on codling moth damage to be released as part of the WSU Study were for the 2002 and 2003 continuation years of the experiment. In 2002, the researchers once again relied only on the pheromone ties for codling moth control. In 2002, 10% of the organic apples had codling moth damage while 3% of the conventional apples showed codling moth damage [27].In the 2003 experiment the WSU researchers doubled the number of pheromone ties used per acre and made five insecticide sprays (oil, spinosad) in the summer in the organic plots which reduced codling moth damage to 2% in the organic plots while the conventional plots had 1% damage in 2003. Did the WSU plot have low codling moth incidence 1994-1999, which made pheromones a feasible stand alone treatment? The pheromone treatments alone are not sustainable as the WSU Study clearly shows.

The WSU Study failed to effectively control weeds with the organic methods.

The WSU authors write that weeds were "controlled" in the organic system using bark mulch, landscape fabric, cultivation and mowing. They admit to no problems with weed control in their articles. However, in their progress reports and technical documents it is clear that they never effectively controlled weeds in the organic systems. In an early project description [29], the following summary was made:

> "We found that the conventional system produced about twice the yield of the other systems in the first cropping year. This difference was probably due to the extra weed competition in the organic and integrated systems shortly after planting."

The following summary was made of the multi-year experiment [27]

> "In over ten years of experiments at this study site, researchers have attempted to control weeds in the organic system with bark mulches, landscape fabric, a surface weed cultivator, mowing, a weed burner, a rototiller, and hand hoeing. None have proved to be as reliable as the chemical herbicides used in the conventional treatments."

The WSU Study authors never make clear why they spent $1000 per acre to install plastic covers in 1995 and $200 per acre to remove the plastic only two years later in 1997. These covers are supposed to last 5-7 years. Were the covers a total failure? The use of plastic covers for weed control is probably not a "sustainable" practice. The WSU Study authors should have highlighted the weed control failures in the organic plots. Policymakers and the public are likely to be led to the false conclusion that weeds were "controlled" when, in fact, they were not.

Correcting the WSU Study

As noted above, the WSU Study greatly overestimated the environmental impacts of the conventional system by over applying pesticides in the conventional system. One correction that is straightforward to make is to subtract out the environmental impacts of conventional sprays that were made after the organic sprays were stopped. For this calculation, insecticide and fungicide sprays were subtracted out when they were made in the conventional program in months after the month in which insecticide and fungicide sprays were stopped in the organic plots. Glyphosate sprays in the conventional plots in excess of two per year were also subtracted out. The exact sprays subtracted out of the conventional program are listed in a footnote to Table 4. Table 4 summarizes the total environmental impact points calculated for the conventional system after subtracting out the over-applications. The points assigned per spray are the same as used in the WSU Study. The total environmental score for the conventional system is lowered by 38%.

As noted above, the WSU Study underestimates the negative environmental effects of the organic system by ignoring the negative effects of tillage, bark mulch, fabric covers, and hand weeding. The negative effects of hand thinning (ladder accidents) are also not included. Another straightforward correction is to assign negative environmental ratings to the organic weed control and thinning practices. The following negative environmental points have been assigned: cultivation (100), hand hoeing (10), hand thinning (5), bark mulch (1), and landscape fabric (0.5).These environmental impact scores are from the CropLife Foundation's Weed Management Index (WMI). The effect of adding these negative impacts is to raise the negative environmental impact score of the organic system by a factor of 15. (See Table 4)

Table 4 presents the results of these corrections to the WSU Study. As can be seen, the result of these two corrections is to decrease the environmental score of the conventional system to 1803.8 and increase the negative environmental score of the organic system to 7130.6 which is four times higher than the negative score of the conventional system.

By correcting the WSU Study, the large bias in favor of the organic system is removed with the result showing that the organic system used in the WSU Study was far more harmful (four times more)to the environment than the conventional system.

Summary

The WSU Study cannot be used to generalize about the relative merits of organic versus conventional apple growing since no data on pest infestations were presented. Washington State apple growers are not likely to be misled by the WSU Study because they have very high standards for the data that they expect to see from researchers. They would never accept statements like the damage was “minimal” and “equal.” The growers would want to see the data, unlike the editors of *Nature*. The danger with the WSU Study is that an unsuspecting public and media may not read all the technical material to detect the systematic favoring of the organic system in their calculations.

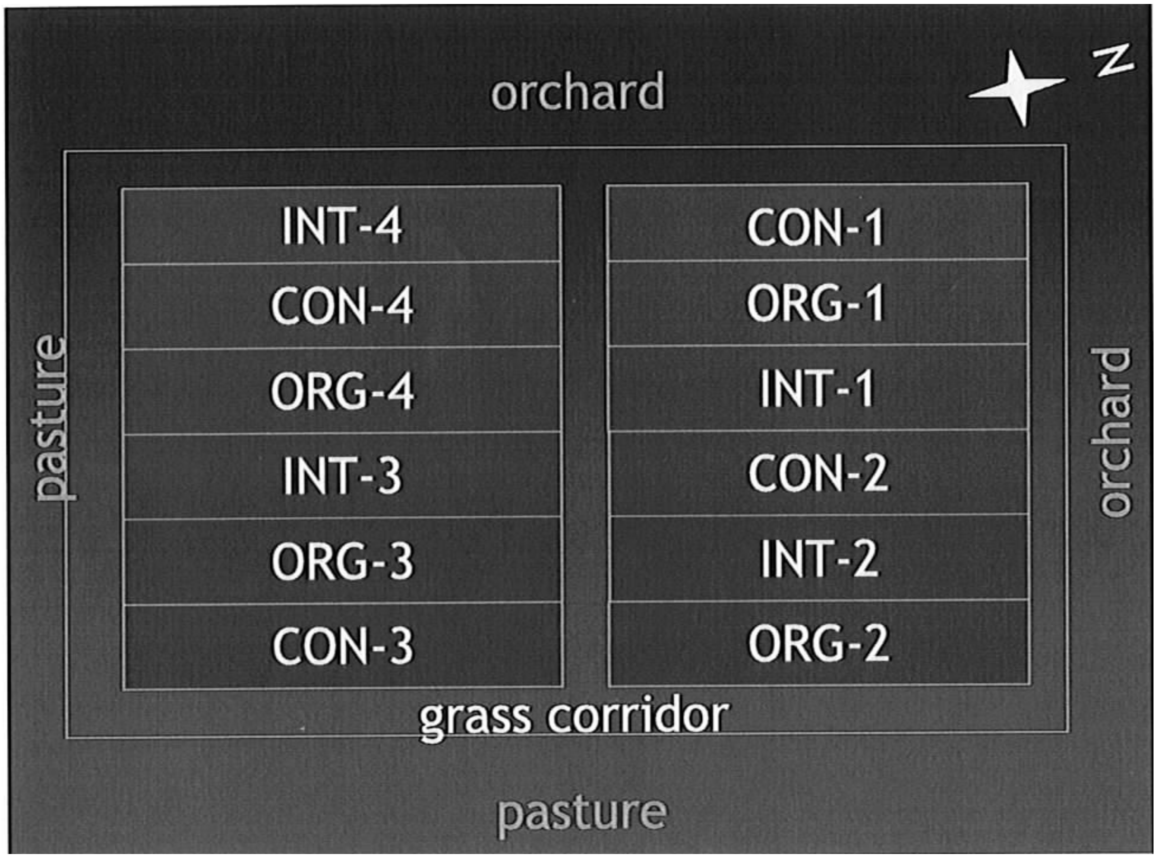
The WSU researchers inflated the risk calculations for the conventional system by making unnecessary sprays. The WSU researchers have no defense on this point. They simply say that consultants and farmers made the decisions on when to spray. Without access to the data that guided the decisions, no outside evaluation of the WSU Study can be made. If they are taken at their word that everything was equal, then the extra sprays were not called for.

While inflating the risk calculations of the conventional system by making unnecessary sprays, the WSU Study underestimated the risks of the organic system by ignoring the negative effects of the organic weed control practices.

Correcting for these two biases leads to the conclusion that the organic system is potentially far more damaging to the environment and human health than the conventional system.

There are no caveats to the WSU Study. Everything favors the organic system. The WSU researchers suppress unpleasant facts about the organic system such as the need for hours of drudgery in hand hoeing and the failures of the organic systems to effectively control weeds. The WSU Study was not a scientific experiment; it was an exercise in advocacy.

Figure 1
Plot Layout: WSU Study



15 foot grass buffer between research plots and commercial orchard.

CON: conventional
INT: integrated
ORG: organic

Table 1
Cumulative Pest-Control/Thinning Operations: WSU Study
(1994-1999)

Type[2]		**# of Applications**[1]
	Organic	
I	Bt	5
I	Pheromone	4
F	Sulfur	11
I	Oil	5
W	Hand Hoeing	154 hours
T	Hand Thinning	139 hours
W	Cultivation	24 trips
W	Bark Mulch	205 cubic yards
W	Landscape Fabric	3650 feet
	Conventional	
F	Captan	1
I	Bt	4
T	Ethephon	7
I	Azinphos methyl	16
I	Pheromone	4
I	Chlorpyrifos	7
F	Sulfur	9
I	Imidacloprid	3
F	Triflumizole	4
F	Myclobutanil	7
W	Glyphosate	23
F	Fenarimol	1
W	Simazine	3
T	Carbaryl	2
W	Norflurazon	3
I	Oil	5

1. From [2][3].
2. I: Insect Control
   F: Fungal Control
   W: Weed Control
   T: Thinning

Table 2
Apple Insect/Mildew Applications- WSU Study 1998

	Organic		Conventional	
	(Per Acre)	($/A)	(Per Acre)	($/A)
Dormant Spray: March	2.1 gallons of oil	5.46	2.1 gallons of oil	5.46
	10.0 lbs sulfur	9.30	10.0 lbs sulfur	9.30
			4.0 pts chlorpyrifos	24.76
Mildew Spray: April	10.0 lbs sulfur	9.30	10.0 lbs sulfur	9.30
			0.5 lbs triflumizole	25.95
Insect: Pheromones	400 ties	110.00	400 ties	110.00
Insect Spray: May	2.0 lbs Bt	17.00	1.05 pts chlorpyrifos	6.50
Mildew Spray: May	10.0 lbs sulfur	9.30	10.0 lbs sulfur	9.30
Mildew/Insecticide Spray: May			5.0 oz myclobutanil	26.00
			2.0 lbs Bt	17.00
Mildew/Insecticide Spray: June			2.0 lbs azinphos methyl	16.04
			5.0 oz. myclobutanil	26.00
Insecticide Spray: July			2.0 lbs azinphos methyl	16.04
Total		$160.36		$291.65

Source [2].

Table 3
Cumulative Environmental Impact Ratings: WSU Study
(1994-1999)

Type		# of Applications[1]	Total Points[3]	Points/Application[2]
	Organic			
I	Bt	5	81.5	16.3
I	Pheromone	4	59.3	14.5
F	Sulfur	11	285.3	26.0
I	Oil	5	39.5	7.9
W	Hand Hoeing	154 hours		
T	Hand Thinning	139 hours		
W	Cultivation	24 trips		
W	Bark Mulch	205 cubic yards		
W	Landscape Fabric	3650 feet		
	Total		465.6	
	Conventional			
F	Captan	1	56.3	56.3
I	Bt	4	65.2	16.3
T	Ethephon	7	34.2	4.9
I	Azinphos methyl	16	632.3	39.5
I	Pheromone	4	59.2	14.8
I	Chlorpyrifos	7	86.5	12.4
F	Sulfur	9	244.5	27.0
I	Imidacloprid	3	57.8	19.3
F	Triflumizole	4	41.9	10.5
F	Myclobutanil	7	323.7	46.2
W	Glyphosate	23	1022.6	44.5
F	Fenarimol	1	33.4	33.4
W	Simazine	3	57.8	19.3
T	Carbaryl	2	47.4	23.7
W	Norflurazon	3	90.8	30.3
I	Oil	5	39.5	7.9
	Total		2893.2	

1. From [2][3].
2. By Division
3. From [3].

Table 4
Cumulative Environmental Impact Ratings: WSU Study (Corrected)
(1994-1999)

Type		**# of Applications[1]**	**Total Points**	**Points/Application[2]**
	Organic			
I	Bt	5	81.5	16.3
I	Pheromone	4	59.3	14.5
F	Sulfur	11	285.3	26.0
I	Oil	5	39.5	7.9
W	Hand Hoeing	154 hours	1540.0	10.0
T	Hand Thinning	139 hours	695.0	5.0
W	Cultivation	24 trips	2400.0	100.0
W	Bark Mulch	205 cubic yards	205.0	1.0
W	Landscape Fabric	3650 feet	1825.0	0.5
	Total		7130.6	
	Conventional			
F	Captan	1	56.3	56.3
I	Bt	4	65.2	16.3
T	Ethephon	7	34.2	4.9
I	Azinphos methyl	6	237.0	39.5
I	Pheromone	4	59.2	14.8
I	Chlorpyrifos	7	86.5	12.4
F	Sulfur	9	244.5	27.0
I	Imidacloprid	0	0	19.3
F	Triflumizole	3	31.5	10.5
F	Myclobutanil	5	231.0	46.2
W	Glyphosate	11	489.5	44.5
F	Fenarimol	1	33.4	33.4
W	Simazine	3	57.8	19.3
T	Carbaryl	2	47.4	23.7
W	Norflurazon	3	90.8	30.3
I	Oil	5	39.5	7.9
	Total		1803.8	

1 From [2][3]. The following applications were subtracted out of the conventional treatments:
1994: Myclobutanil (-1), Triflumizole (-1), Imidacloprid (-1)
1995: Azinphos methyl (-3)
1996: Glyphosate (-3), Azinphos methyl (-2), Imidacloprid (-1)
1997: Glyphosate (-3), Azinphos methyl (-2)
1998: Glyphosate (-3), Azinphos methyl (-2), Myclobutanil (-1)
1999: Glyphosate (-3), Azinphos methyl (-1), Imidacloprid (-1)

2. See Table 2 and text.

Reference List

1. Reganold, John P., Jerry D. Glover, Preston K. Andrews, and Herbert R. Hinman, "Sustainability of Three Apple Production Systems," Nature, Volume 410, April 19, 2001.

2. Glover, Jerry, et al., A Cost of Production Analysis of Conventional vs. Integrated vs. Organic Apple Production Systems, Washington State University, Agricultural Research Center Publication XB1041.

3. Reganold, J.P., et al., "Supplementary Information," available on Nature's World Wide Web site (http://www.nature.com).

4. Peck, Gregory, et al., "Apple Orchard Productivity and Fruit Quality Under Organic, Conventional, and Integrated Management," HortScience, 41(1): 99-107, 2006.

5. Washington State University, "WSU Study Shows Organic Apple Orchards Competitive, Sustainable," College of Agriculture and Home Economics, available at http://www.cahenews.wsu.edu/RELEASES/2001/01024.htm. April 18, 2001.

6. Reganold, John, "Sustainability of Organic, Conventional, and Integrated Apple Orchards," available at http://www.plantmanagementnetwork.org/pub/cm/symposium/organics/Reganold/

7. Reed, A. Nathan, "Responsible Choice: A Systems Approach to Growing, Packing and Marketing Fruit," Michigan State Horticultural Society, 125th Annual Report, 1995.

8. Reed, A. Nathan and P. Nelson, "Responsible Choice- An IFP Approach," Acta Horticulturae: International Conference on Integrated Fruit Production 422,

9. Kovach, J., et al., "A Method to Measure the Environmental Impact of Pesticides," New York's Food and Life Sciences Bulletin, New York State Agricultural Experiment Station, Number 139, 1992.

10. Avery, Alexander A., "Organic Pesticide Use: What We Know and What We Don't Know About Use, Toxicity, and Environmental Impacts" in Crop Protection Products for Organic Agriculture: Environmental, Health, and Efficacy Assessment. Felsot, A. S., K. D. Racke (ed.), American Chemical Society Symposium Series 947, 2006.

11. Smith, Timothy J., "Weed Management in Orchards," Washington State University, available at: http://www.ncw.wsu.edu/treefruit/weeds2.htm.

12. Consumers Union, "Guide to Environmental Labels," available at http://www.eco-labels.org/labelPrint.cfm?LabelID=99.

13. "Apple Study Backs Organic Methods," Seattle Post-Intelligencer. April 19, 2001.

14. Mullinix, Kent, "Pacific Northwest/Colorado/British Columbia- Regional Report," in Proceedings of the 3rd National Organic Tree Fruit Research Symposium, 6-8 June 2005, Campbell's Resort, Chelan, WA.

15. Machado, Stephen, Christopher D. Humphreys, and Brian Tuck, "Allelopathic Effects of Different Plant Species on Downy Brome (Cheat grass) and What Seed Germination: Implications for Weed Control in Organic Farming," in Ecological and Organic Farm Management Workshop Proceedings, 25 February 2004, Wilsonville, Oregon.

16. Brunner, Jay F., et al., "Organic Management of Codling Moth with Pheromones, Entrust, and CM Virus," in Proceedings of the 3rd National Organic Tree Fruit Research Symposium, 6-8 June 2005, Campbell's Resort, Chelan, WA.

17. "No Coddling for This Moth," Agricultural Research, November 2001.

18. Washington State University, AgEcHo, Department of Agricultural Economics, Fall 2001, available at: http://www.ses.wsu.edu/Announcements/Agecho/agecho-sept.pdf.

19. Duram, Leslie A., Good Growing: Why Organic Farming Works, University of Nebraska Press, 2005.

20. Williams, Kathleen and Herbert Hinman, Impacts of the Elimination of Organophosphates and Carbamates from Red Delicious Apple Production in Washington, AFPC Policy Research Report 99-1, April 1999, available at: http://www.afpc.tamu.edu/pubs/2/171/rr99-1.pdf.

21. Washington State University, "Orchard Sustainability," available at: http://classes.hortla.wsu.edu/hort310/hort%20310%20-%20documents/Orchard%20Sustainability.pdf.

22. USDA, Agricultural Chemical Usage, 2005 Fruit Summary, National Agricultural Statistics Service July 2006.

23. Beers, Elizabeth, et al., Orchard Pest Management: A Resource Book for the Pacific Northwest, Good Fruit Grower,1993.

24. Brunner, Jay F. and L.O. Smith, "Apple, Pandemis Leafroller Control Test #1," in Proceedings of the 66th Annual Western Orchard Pest & Disease Management Conference, 8-10 January 1992, Portland, Oregon.

25. Brunner, J.F., “Pheromone-based IPM in Washington,” Washington State University, Tree Fruit Research & Extension Center.

26. Brunner, Jay, et al., “Mating Disruption of Codling Moth: A Perspective from the Western United States,” in Use of Pheromones and Other Semiochemicals in Integrated Production, IPBC wprs Bulletin Vol. 25, 2002.

27. Peck, Gregory Michael, Orchard Productivity and Apple Fruit Quality of Organic, Conventional, and Integrated Farm Management Systems, MS Thesis, Washington State University, May 2004, available at: http://dspace.library.cornell.edu/handle/1813/2720.

28. Gut, Larry J., Jay F. Brunner, and Alan Knight, “Implementation of Pheromone-based Pest Management Programs in Washington,” Washington State University, Tree Fruit Research and Education Center.

29. “Project Description, Sustainability of Three Apple Production Systems:Organic, Conventional, and Integrated,” available at: http://classes.hortla.wsu.edu/preston/mydocs/proposals/usda-nricgp/usda96.doc