Characterization of Propanil Prune Foliage Residues as related to Propanil Use Patterns in the Sacramento Valley, California

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Abstract

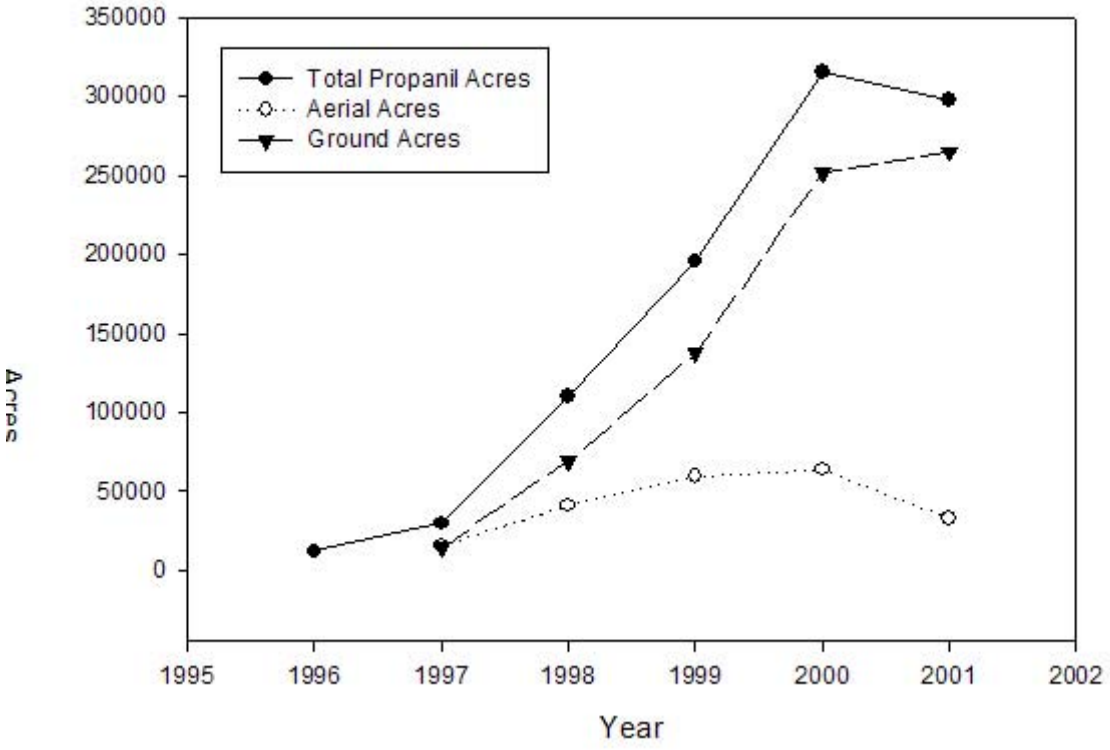
Propanil, a broad-spectrum, post-emergent rice herbicide is a California restricted material due to a history in the 1960's of significant damage to prune orchards. Prior to 2004, regional prune foliage compliance monitoring was a condition of use. This analysis examines patterns of propanil use relative to observed 2001 propanil compliance monitoring residues from sites located throughout the Sacramento Valley. These results suggest aerial applications within 10 miles and ground applications within 4 miles contribute a low, but measurable, level of residues. This appears true on both the West Side where only helicopter applications are allowed, and on the east side in the Butte County Study Area where only fixed wing applications were allowed in 2001. More proximate activities alone appear to produce observed propanil concentration peaks. Important proximate activities include aerial applications within 6 miles and/or ground applications within 1 or 2 miles. In 2001 the two compliance monitoring sites primarily influenced by helicopter applications showed the highest peak residues. Two other sites showed lower peaks likely the result of fixed wing applications. However, ground applications can also produce high peak concentrations. The third highest 2001 compliance monitoring peak residue was most likely the result of ground applications. In 1999, a single 120acre ground application was associated with a residue level of 1.07ppm. In 2000, a single ground application of 154 acres was associated with a residue level of 1.20ppm. These are the highest residues observed in compliance monitoring since the inception of the program in 1986.

Introduction

Propanil is a broad-spectrum, post-emergent rice herbicide that since 1997 has seen significantly increased use in the Sacramento Valley of California. Propanil is a California restricted material as a result of past incidents of significant damage to prune orchards. For example, propanil use was suspended in 1969 following damage in 1967 and 1968 to prune orchards associated with aerial application of the emulsifiable concentrate formulation of propanil. In 1982, limited propanil use was re-introduced following the formation of the Westside Propanil Use Area in Colusa and Glenn Counties. Strict control on the number of acres and application methods was required. Propanil use did not exceed 12,000 acres per year between 1982 and 1986. Based upon work by Akesson (1986) a prune foliage threshold level of 0.1ppm was set in California regulation and prune foliage monitoring (compliance monitoring) was required as a condition of use. Analysis of more recent data indicates that prune leaf spotting begins to occur in the neighborhood of 0.5ppm propanil residue content with spotting of 20% or more of leaves at residue levels of 1.0ppm to 2.0ppm (Barry, 2001a). Through 1997 no prune foliage monitoring results exceeded 0.1ppm.

In 1997 the Expanded Use Area (EUA) was formed, allowing ground applications of propanil throughout the Sacramento Valley and aerial applications under certain conditions in a Butte County Study Area (BCSA). Applications continued to be allowed in the Westside Propanil Use Area. Following the formation the EUA, the use of propanil has increase significantly each year (Figure 1). Beginning in 1998, prune foliage concentrations exceeding the 0.1 ppm threshold have been commonly observed. In 2001 a total of 496,463 acres of rice were planed and propanil was applied to 297,736 acres (60%). Assuming a typical application rate of 4lbs active ingredient per acre, approximately 1,191,000lbs of

Figure 1. Increase in total number of acres applied with propanil between 1996 and 2001. Also shown is a breakdown of total number of acres into acres of aerial and ground applications.



propanil were applied between the middle of May and the middle of June. The total acreage treated with propanil has increased 10-fold relative to 1997, driven primarily by a 20-fold increase in acres treated by ground applications relative to 1997. Growth in acreage treated by air has increased between 2 and 3-fold, depending upon the year. Growth in acreage treated by ground is much greater that that by air because of the strict geographic restrictions associated with aerial propanil applications.

This paper presents analysis of the 2001 Compliance Monitoring results. The objective of this analysis is to characterize patterns of propanil use relative to observed propanil residues at compliance monitoring sites located throughout the Sacramento Valley during the 2001 use season.

Methods

Residue and Use Data. Seven counties are in the EUA: Butte, Colusa, Glenn, Placer, Sutter, Yolo, and Yuba counties. For the 2001 Propanil Use Season Compliance Monitoring the California Propanil Task Force (CPTF) selected 16 prune orchards throughout the Westside and EUA (Figure 2). Ten of the orchards (Zumwalt, Meyers, Strains, Weems, Sprulock, Farmland, Bains, Dale, Faye, and Thiara) were part of the routine Compliance Monitoring Program, four orchards (North Island, Ramada, Kullar, and Sundial) were part of the Butte County Aerial Study (BCAS) and two orchards (Gorrill and Argo) were part of both programs. This analysis examines patterns in propanil residues measured in prune foliage collected during the 2001 Compliance Monitoring program (Table 1) and the propanil levels in prune foliage measured at additional orchards included in the 2001 BCAS (CRRB 2001) (Table 2). Details of

Figure 2. GIS map of rice region of the Sacramento Valley, California.

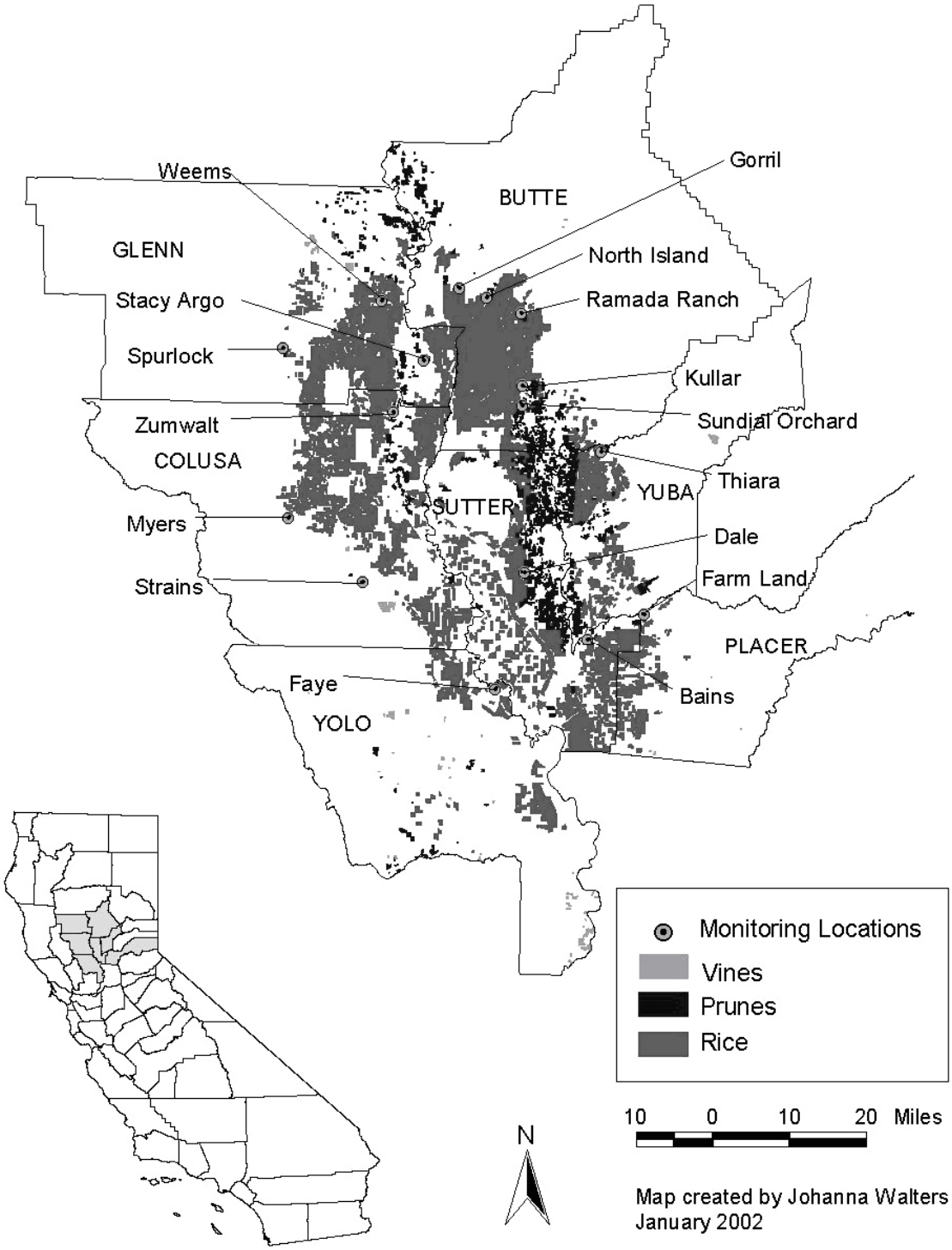


Table 1. Compliance monitoring results for the 2001 Propanil Use Season. Propanil prune foliage residue levels (ppm) by site and collection date.

County	*Site*	*Collection Date*							
		5/22	*6/3*	*6/11*	*6/18*	*6/25*	*7/2*	*7/9*	*7/16*
Butte	*Gorrill*	*ND†*	*ND*	*0.32*	*0.20*	*0.18*	*0.11*	*0.08*	*0.10*
Colusa	*Zumwalt*	*ND*	*0.12*	*0.18*	*0.14*	*0.14*	*0.09*	*0.11*	*0.08*
Colusa	*Meyers*	*ND*	*0.12*	*0.61*	*0.24*	*0.16*	*0.08*	*0.06*	*0.06*
Colusa	*Strains*	*ND*	*ND*	*ND*	*0.06*	*0.05*	*0.04*	*ND*	*ND*
Glenn	*Weems*	*ND*	*0.11*	*0.17*	*0.17*	*0.28*	*0.29*	*0.15*	*0.08*
Glenn	*Argo*	*ND*	*0.10*	*0.12*	*0.18*	*0.22*	*0.17*	*0.11*	*0.08*
Glenn	*Spurlock*	*ND*	*0.15*	*0.23*	*0.20*	*0.54*	*0.31*	*0.27*	*0.14*
Placer	*Farmland*	*ND*	*ND*	*0.08*	*0.11*	*0.09*	*0.05*	*0.05*	*0.08*
Sutter	*Bains*	*ND*	*ND*	*0.07*	*0.11*	*0.18*	*0.07*	*0.09*	*0.09*
Sutter	*Dale*	*ND*	*ND*	*0.08*	*0.11*	*0.11*	*0.08*	*0.07*	*0.09*
Yolo	*Faye*	*ND*	*ND*	*ND*	*0.06*	*0.06*	*0.09*	*0.07*	*0.09*
Yuba	*Thiara*	*ND*	*ND*	*0.12*	*0.06*	*0.07*	*0.04*	*0.06*	*0.06*

† ND = non-detect. Detection Limit = 0.01ppm

Table 2. 2001 Butte County Study Area (BCSA) results. Prune foliage Propanil residues (ppm) at collection sites. Note: Gorrill and Argo served as both Compliance Monitoring sites and BCSA sites. Therefore, prune foliage results for those sites are reported in both Table 1 and Table 2.

Site	***May 22***	***Week1*** 5/29–6/3	***Week2*** 6/4–6/10	***Week 3*** 6/11–6/18	***Week 4*** 6/19-6/25	***Week 5*** 6/26-7/2
Gorrill	*ND†*	*ND*	*0.32*	*0.20*	*0.18*	*0.11*
North Is.	*ND*	*0.11*	*0.17*	*0.23*	*0.34*	*0.15*
Ramada	*ND*	*0.10*	*0.20*	*0.13*	*0.44*	*0.13*
Argo	*ND*	*0.10*	*0.12*	*0.18*	*0.22*	*0.17*
Kullar	*ND*	*0.11*	*0.34*	*0.25*	*0.24*	*0.12*
Sundial	*ND*	*0.08*	*0.16*	*0.15*	*0.17*	*0.15*

† ND = non-detect. Detection Limit = 0.01ppm

the prune foliage sample collection and analytical procedures are available in the Compliance Monitoring Protocol (CPTF 2001) and in the 2001 BCAS (CRRB 2001).

During the 2001 Propanil Use Season, the Department of Pesticide Regulation (DPR) received a total of 4590 application records consisting of 3896 ground and 694 aerial applications from the seven county Westside and EUA. For most applications, these records have a resolution of location to the section (1 mile square area) and a resolution of time to the day. However, in Butte County, aerial applications were allowed only as part of the 2001 BCAS conducted in the BCSA. The aerial applicators in the BCSA were required to complete accurate aerial applicator logs with location of each application to the parcel level, and the time of application to the hour within the day the application occurred.

Weather data. A weather station was located in the BCSA as part of the BCAS (CRRB 2001), measuring wind speed and wind direction at 10 meters. Hardcopy and electronic records of 15-minute average weather data for the duration of the study was submitted with the study results.

GIS methods. The 4590 application records were used to develop a database with the following fields: county, application date, total acres, air acres, ground acres, section township, range, and COMTRS (county, meridian, township, range section). A query summed the total acres applied, acres applied by air, and applied by ground. This query was then used to produce the daily summed-by-section tables that were subsequently used to create propanil acreage maps in ArcView 3.2. Data themes included the Public Land Survey (PLS) system grid for the seven counties and digitized points

using GPS coordinates along with visual identification using satellite imagery and roads for the monitoring locations. The daily acreage tables were imported into ArcView and were individually joined to the PLS attribute table based on the COMTRS field. The PLS theme was then selected to show only sections with total acres greater than zero. For each day of the study, the resulting sections were added as a new theme to the project. Circular buffers at distances of 0.5, 1, 2, 4, 6, 8, and 10 miles were created around each monitoring location. The daily acreage totals were made active on an individual basis to determine acreage totals within the buffer distances. The acreage totals for air and ground were calculated separately and were reported as totals for each buffer distance. To resolve instances were use in a section fell across the boundary between two buffers, the centroid of the PLS theme was made active and the acreage of that section was included in the total for the buffer distance in which the centroid was located.

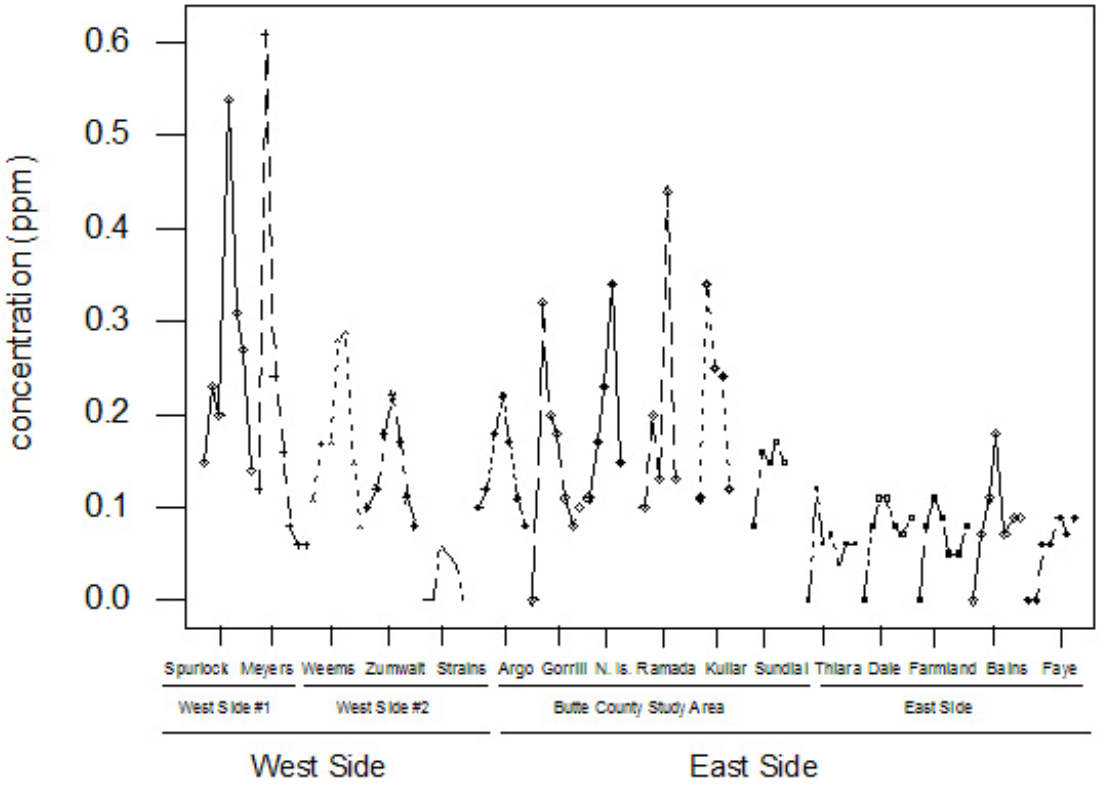
Statistical Analysis. Statistical analysis was conducted using MINITAB V12.1 (Minitab Inc. 1997), SigmaPlot V7.0 (SPSS Inc. 2000), and MicroSoft Excel 2000. Analysis techniques included simple correlation and stepwise multiple regression. Analysis focused on 1) the first week of Compliance Monitoring representing baseline resides and use patterns without carryover from applications made during the previous week, and 2) peak week concentrations and use patterns present only during the monitoring week that produced the peak concentration at each compliance monitoring site. By focusing on patterns present during the peak week, conditions of use can be identified that might be modified to mitigate the magnitude of the peaks to desired risk management levels.

Results and Discussion

Use Season Summary. Figure 3 shows monitoring results for the entire 2001use season presented in an order reflecting geographic relationships between the compliance monitoring orchards. Each location is presented separately with results of each week of the use season shown in chronological order for that location. The “West Side” area is comprised of five compliance monitoring orchards: Spurlock, Meyers, Weems, Zumwalt, and Strains, located along the western side of the Sacramento Valley (Figure 2). Spurlock and Meyers sit on low hills just above the rice fields located in Glenn and Colusa Counties. The remaining West Side sites (Weems, Zumwalt, and Strains) are on the valley floor. These three sites are presented in north to south order. The “East Side” sites include one site in eastern Colusa County (Argo) and all the sites in Butte, Sutter, Yuba, Placer, and Yolo Counties (Figure 2). The “East Side” sites are shown in north to south order beginning with the western most site, Argo, and progressing through Gorrill, North Island, Ramada, Kullar, Sundial, Thiara, Dale, Farmland, Bains, and Faye.

Spurlock and Meyers sites show the highest concentrations throughout the season. These two orchards are located in areas of heavy local use of propanil by both ground and air (helicopter only). The remaining West Side orchards show a north to south pattern of residues reflecting the geographic distribution of propanil applications. Weems is surrounded by a high density of ground applications. In contrast, Zumwalt has no rice cultivation for several miles to the east. The Strains site is in an area of light propanil use. The East Side orchards show a generalized north to south trend that is likely influenced by the density of local ground applications and the proximity to aerial applications. Six sites, Argo, Gorrill, North Island, Ramada, Kullar, and Sundial surround the BCSA where, in 2001, only fixed wing aerial applications were allowed. The remaining orchards in the East Side area had no aerial applications within approximately 10 miles. Two mechanisms are likely producing these residue patterns: 1) long-range (miles), low-level drift deposition from many applications in the general area surround a particular compliance site. Measurable long-range drift most likely originates from aerial applications and amounts to a background level that constitutes a baseline to which residue contribution from more proximate ground applications (and/or aerial applications) is then added. 2) The second mechanism is relatively large deposition from single or a few more proximate applications. Drift from proximate

Figure 3. Propanil compliance monitoring results for the 2001 use season presented in an order that reflects the locations of the compliance monitoring orchards. The curve for each site shows compliance monitoring orchard foliage concentration results for each of the seven weeks from May 29, 2001 to July 9, 2001. For tabular presentation of the compliance monitoring orchard foliage concentration results see Table 1.



applications can be from ground or aerial applications and are like responsible for the highest residues observed. However, proximate is generally not closer than 4 miles for aerial applications and ½ mile for ground applications. California propanil regulations dictate that unless expressly authorized by the Agricultural Commissioner, aerial applications cannot be made within four mile of prune orchards. During the 2001 use season, with the exception of Colusa County where helicopter applications were allowed between 2 and 4 mile from the Meyers, no aerial applications were made closer than four miles from any compliance monitoring site. Also during the 2001 season, permit conditions dictated that unless expressly authorized by the Agricultural Commissioner, ground applications were not allowed within ½ mile of a prune orchard.

Compliance Monitoring Week 1. The first week of compliance monitoring (5/29/01 – 6/03/01) allows examination of baseline conditions. Background samples taken on 5/22/01 showed no detections at any of the compliance monitoring sites. With the exception of Glenn and Colusa County, no use occurred prior to 5/29/01. In Glenn County only 28 acres were applied between ½ and 1 mile from the Weems site. However, in Colusa County 2533 acres were applied by air countywide between 5/22/01 and 5/28/01. It is possible that some of these earlier aerial applications contributed to residues measured 6/03/01. However, the half-life of propanil in prune foliage is approximately 7 days (Barry, 2001b) so the influence of those earlier residues would likely be small relative to residues from activities during the week of 5/29/01 – 6/03/01.

Figure 4. Week 1 Compliance Monitoring results. Sites separated according to four groups: West Side #1 (air/ground), West Side #2 (ground), Butte County Study Area (air/ground), and East Side (ground).

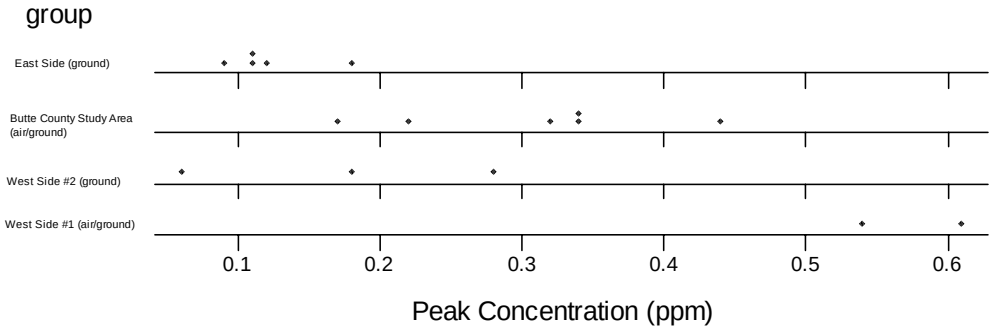


Figure 4 shows the Week 1 residues grouped by location and application type. Tthe West Side #1 and BCSA sites (air/ground) show generally higher residues than the West Side #2 and East Side sites (ground only). Seven of the 8 air/ground influence sites showed propanil residue detections in Week 1. Of these 8 air/ground influence sites, only Gorrill showed a non-detect. Very little propanil application activity occurred in the vicinity of Gorrill during Week 1 – only 70 acres of ground applied between 2 miles and 4 miles away and 179 acres of air applied between 6 miles and 10 miles away (Table 3). In contrast, only 2 of the 8 ground only sited showed detections for Week 1. Those two sites were Weems and Zumwalt on the West Side #2 where ground applications where 75 to 80 acres were treated with propanil between ½ mile and 1 mile from each site (Table 4). At the remaining sites, with the exception of Thiara, no ground applications were made closer than 2 miles.

Stepwise multiple linear regression was used to estimate the relative importance of aerial and ground application acreage to the observed residues. The dependent variable was Week #1 foliage concentration (ppm) and the potential independent variables were air acres within 4, 6, 8, and 10 miles (air4, air6, air8, and air10 respectively) and ground acres within 1, 2, and 4 miles (ground1, ground2, and ground4, respectively). The resulting best fit regression equation is shown below:

$$\text{Week 1 conc (ppm)} = 0.0031 + 0.000083\text{air10} + 0.000048\text{ground 4}$$

The R^2 value of this equation is 78%. The intercept is not significantly different from zero, indicating that, for a particular compliance monitoring orchard, if there were no aerial applications within 10 miles and no ground applications within 4 miles, the expected residue is zero. The acres applied by air within 10 miles (air10) explained 56%of the variation observed in foliage residues while the acres applied by ground within 4 miles (ground 4) explained 22%. In addition, on both the standardized and the original scale, the regression coefficient for air10 was about twice the size of the coefficient for ground4. This regression equation is not intended to predict residue levels for other weeks. Instead, it is intended to illustrate the relative importance of the aerial and ground applications to the observed Week 1 propanil residues. These regression results indicate that aerial and ground applications contribute low, but measurable, levels of propanil residue to prune orchards within a wide area. CPTF (2000a) large scale

Table 3. Compliance Monitoring and use at Air/Ground site during baseline Week #1 (5/29/01 – 6/3/01).
Week 1 Concentration Results

West Side #1						
Site (peak week)	**Propanil Concentration (ppm)**	**Nearest Ground**		**Nearest Air**		**Acres Air 4 –10 miles away**
		Distance Range	**Total Acres**	**Distance Range**	**Total Acres**	
Spurlock	0.15	2 – 4 miles	174	4 – 6 miles	585	877
Meyers	0.12	2 – 4miles	590	2 – 4 miles	553	1092
Butte County Study Area						
Site (peak week)	**Propanil Concentration (ppm)**	**Nearest Ground**		**Nearest Air**		**Acres Air 4 –10 miles away**
		Distance Range	**Total Acres**	**Distance Range**	**Total |Acres**	
Gorrill[†]	0.00(ND*)	2 – 4 miles	70	6 – 8 miles	179	280
North Island	0.11	2 – 4 miles	238	4 – 6 miles	100	633
Ramada	0.10	2 – 4 miles	340	4 – 6 miles	100	479
Argo	0.10	2 – 4 miles	375	4 – 6 miles	660	1384
Kullar	0.11	1 – 2 miles	200	4 – 6 miles	199	1284
Sundial	0.08	2 - 4 miles	226	4 – 6 miles	199	1205

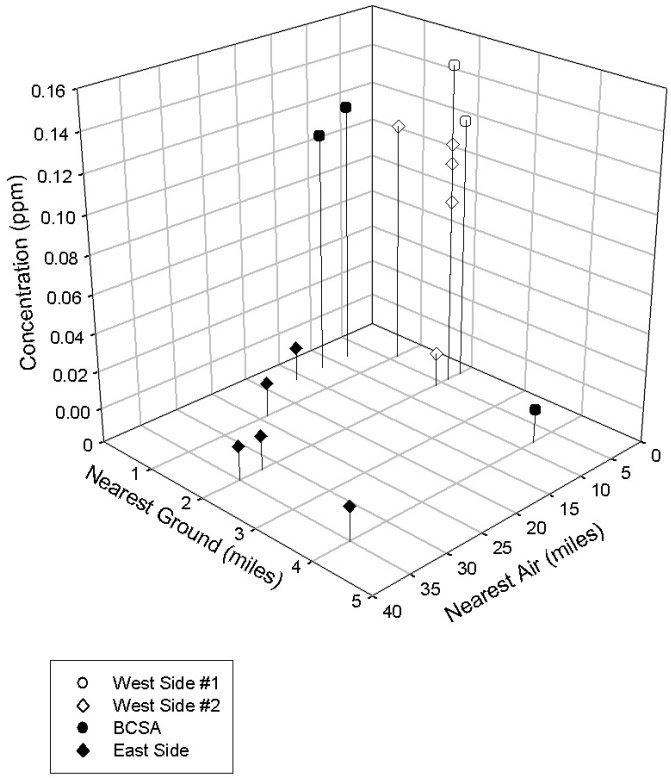
[†] The north boundary of the Butte County Study Area is 6 miles from Gorrill
[*] ND = no detection, Detection Limit = 0.01ppm. For analysis purposes 0.0 has been substituted for ND.

Table 4. Compliance Monitoring and use at Ground sites during baseline Week #1 (5/29/01 – 6/3/01).
First Week Results

West Side #2				
Site	**Propanil Concentration (ppm)**	**Nearest ground**		**Acres ground ½ – 4 miles**
		Distance Range	**Total Acres**	
Weems	0.11	½ - 1 mile	75	2294
Zumwalt	0.12	½ - 1 mile	80	850
Strains	0.00 (ND[*])	> 4 miles	-	0
East Side				
Site	**Propanil Concentration (ppm)**	**Nearest ground**		**Acres ground ½ – 4 miles**
		Distance Range	**Total Acres**	
Thiara	0.00 (ND)	½ – 1 miles	71	249
Dale	0.00 (ND)	> 4 miles	0	0
Farmland	0.00 (ND)	2 – 4 miles	80	80
Bains	0.00 (ND)	> 4 miles	-	0
Faye	0.00 (ND)	2 – 4 miles	0	0

[*] ND = no detection, Detection Limit = 0.01ppm. For analysis purposes 0.0 has been substituted for ND

Figure 5. Week 1 propanil concentration (ppm) versus distance to the nearest aerial application (miles) and distance to nearest ground application (miles).



aerial study measured residues of 0.55ppm 4 miles from applications. Analysis of CPTF ground studies (CPTF 2000b) indicates that a single 40 acre ground application has the potential to deposit propanil residues of 0.1ppm at a distance of 1 mile from the field edge (Barry, 2002). Figure 5 illustrates the pattern quantified in the multiple regression analysis.

Compliance Monitoring Peak Week. Peak week analysis examines application events associated with the peak concentrations observed at each site (Tables 5 and 6). Note that the peak week dates vary by site. For example, the peak week for Meyers, Gorrill, and Kullar sites is Week 2, while the peak week for the remainder of the air/ground sites is Week 4. The peak week in shown in parentheses next to the site names in Tables 5 and 6. Figure 6 suggests continued separation between the air/ground and the ground only sites. Peak concentration is significantly correlated with air acres applied within 6 miles ($r = 0.75$, $p = 0.001$) and air acres applied within 8 miles ($r = 0.682$, $p = 0.009$). However, the correlation of peak concentration with air acres applied within 10 miles is only marginally significant ($r = 0.47$, $p = 0.066$). These results suggest that more proximate aerial applications are associated with peak concentrations. The two highest peak concentrations were observed at Meyers and Spurlock of the West Side #1 group. These two peaks appear to be associated most closely with aerial applications (helicopter) made within 6 miles. There was no significant simple correlation between peak concentrations and acres applied by ground within 1, 2, or 4 miles.

Stepwise multiple linear regression was used to further characterize the relative importance of aerial and ground application acreage in relation to the observed residues. The dependent variable was Peak Week foliage concentration (ppm) and the potential independent variables were air acres within 4, 6, 8, and 10 miles (air4, air6, air8, and air10, respectively) and ground acres within 1, 2, and 4 miles (ground1, ground2, and ground4, respectively). The resulting best fit regression equation is shown below:

$$\text{Peak Conc (ppm)} = 0.146 + 0.000384\text{air6} + 0.000408\text{ground1}$$

Table 5. Peak concentration week Compliance Monitoring and use at Air/Ground sites. Number in parentheses following the site name is Peak Week number.
Peak Concentration Week Results

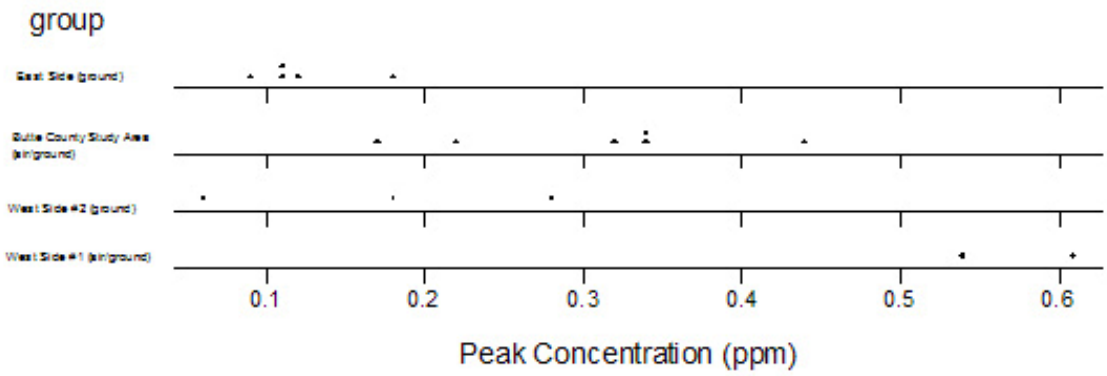
West Side #1						
Site (peak week)	**Propanil Concentration (ppm)**	**Nearest Ground**		**Nearest Air**		**Acres Air 4 –10 miles away**
		Distance Range	**Total Acres**	**Distance Range**	**Total Acres**	
Spurlock (4)	0.54	1 – 2 mile	435	4 – 6 miles	507	1196
Meyers (2)	0.61	< ½ mile	59	2 – 4 miles	378	2397
Butte County Study Area						
Site (peak week)	**Propanil Concentration (ppm)**	**Nearest Ground**		**Nearest Air**		**Acres Air 4 –10 miles away**
		Distance Range	**Total Acres**	**Distance Range**	**Total |Acres**	
Gorrill† (2)	0.32	2 – 4 miles	158	6 – 8 miles	425	1671
North Island (4)	0.34	1 - 2 miles	987	4 – 6 miles	508	2862
Ramada (4)	0.44	½ - 1 mile	334	4 – 6 miles	307	2972
Argo (4)	0.22	1 – 2 miles	477	4 – 6 miles	809	3887
Kullar (2)	0.34	1 – 2 miles	802	4 – 6 miles	451	4196
Sundial (4)	0.17	½ - 1 mile	194	4 – 6 miles	80	3597

† Closest Aerial Application to Gorrill is 6 miles

Table 6. Peak concentration week Compliance Monitoring and use at Ground sites. Number in parentheses following the site name is Peak Week number.
Peak Concentration Week

West Side #2				
Site (peak week)	**Propanil Concentration (ppm)**	**Nearest ground**		**Acres of ground ½ mile – 4 miles**
		Distance Range	**Total Acres**	
Weems (4)	0.28	½ - 1 mile	348	1700
Zumwalt (2)	0.18	1 - 2 miles	188	2901
Strains (3)	0.06	1 – 2 miles	180	1119
East Side				
Site (peak week)	**Propanil Concentration (ppm)**	**Nearest ground**		**Acres of ground ½ mile – 4 miles**
		Distance Range	**Total Acres**	
Thiara (2)	0.12	2 – 4 miles	672	672
Dale (3)	0.11	½ - 1 mile	99	2293
Farmland (3)	0.11	1 - 2 miles	95	870
Bains (4)	0.18	1 - 2 miles	150	981
Faye (5)	0.09	1 – 2 miles	93	338

Figure 6. Peak Week Compliance Monitoring results. Note that the peak week varies according to site. See text for further discussion. Sites separated according to influence of aerial applications and geographic area within the air influence groups.



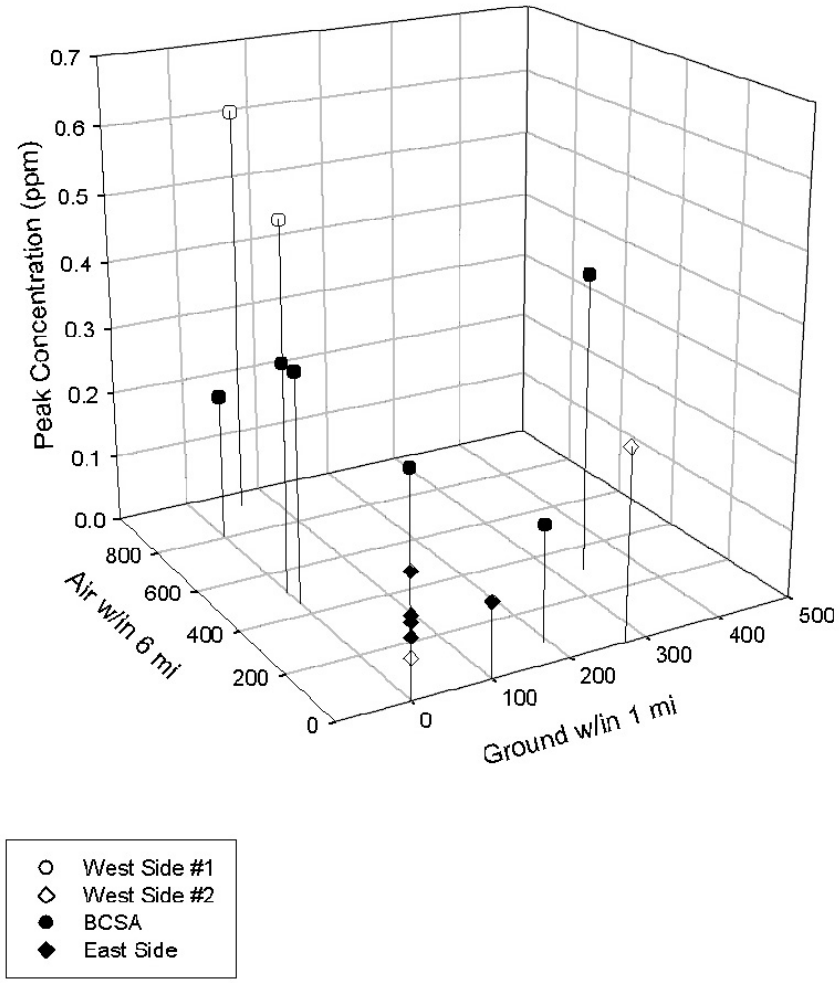
The R^2 value of this equation is 60%. The intercept is significantly different from zero indicating that, as the use season progresses, compliance monitoring sites will tend to show residues above the detection limit independent of peak week use patterns. The percent variation explained by acres applied by air within 6 miles is 52% and the percent variation explained by acres applied by ground is 8%. The unstandardized regression coefficients for air6 and ground1 are about the same size. However, standardized regression coefficient for air6 is approximately 3 times the size of the standardized regression coefficient for ground1. This indicates that for the dataset as a whole, the number of air acres applied within 6 miles tends to have about 3 times the influence on peak residue levels relative to the number of acres applied by ground within 1 mile. This is likely because the highest peak concentrations were in the areas influenced by aerial applications.

Figure 7 shows the Peak Concentration (ppm) plotted against the acreage of aerial applications within 6 miles and the acreage of ground applications within 1 mile. This figure suggests splitting compliance monitoring sites into three groups: 1) peak concentrations associated with proximate aerial applications (Spurlock, Meyers, North Island, Kullar, and Argo), 2) peak concentrations associated with proximate ground applications (Ramada, Sundial, Weems,and Dale), and 3) peak concentrations association with more remote applications (Gorrill, Zumwalt, Strains, Thiara, Farmland, Bains, and Faye).

In the first group, peak concentrations associated with proximate aerial applications (Spurlock, Meyers, North Island, Kullar, and Argo), with the exception of Meyers, the sites showing peaks associated with proximate aerial applications had no ground applications within 1 mile (Table 5). Those sites showed peak residues of 0.54ppm (Spurlock), 0.34ppm (North Island), 0.34ppm (Kullar), and 0.22ppm (Argo). Meyers showed a peak residue of 0.61ppm but had both very close air (helicopter between 2 and 4 miles) and very close ground (less than ½ mile). For the Meyers site, on-site weather data was unavailable so it is difficult to separate the relative contribution of the two application methods.

In the second group, peak concentrations associated with proximate ground applications (Ramada, Sundial, Weems,and Dale), all sites had ground applications made between ½ mile and 1 mile away. Ramada (0.44ppm) and Sundial (0.17ppm) had 344 acres and 194 acres applied by ground within 1 mile, respectively (Table 6). These two sites also had aerial applications made between 4 and 6 miles away. However, examination of the weather data from the BCSA suggests these peaks are most closely

Figure 7. Peak Week concentration (ppm) versus acres applied by air within 6 miles and acres applied by ground within 1 mile. Note that the peak week varies according to site. See text for further discussion.



associated with the ground applications alone. Weems (0.28ppm) and Dale (0.11ppm) had no aerial applications closer than 12 and 24 miles, respectively. Therefore, the peak residues at these two sites are most likely from the more proximate ground applications.

The third group, sites with peak concentrations that appear to be associate with more remote applications (Gorrill, Zumwalt, Strains, Thiara, Farmland, Bains, and Faye), have generally lower peak concentrations relative to the other compliance monitoring sites. The highest residue level in this group is 0.32ppm observed at Gorrill. Examination of the weather data from the BCSA and the timing of this application suggests the Gorrill peak concentration is most closely associated with aerial applications between 6 and 8 miles away in the BCSA. Of the remaining sites, Zumwalt (0.18ppm) had 1487 acres of aerial applications made between 8 and 10 miles away and 2901 acres of ground applications within 4 miles, 188 acres of which were between 1 and 2 miles away. Thiara (0.12ppm), Farmland (0.11ppm), Baines (0.18ppm), and Faye (0.09ppm) had no aerial applications closer than 16, 17, 12, and 11 miles, respectively. With the exception of Thiara, all these sites had ground applications made within 2 miles (Table 6). Since there is such a large distance between any aerial applications and these sites, it is most likely that the residues at these sites originated largely from ground applications.

Atmospheric Loading analysis. The phenomenon of "atmospheric loading" is presented as a use season long persistent regional build-up of residue in the atmosphere from many propanil applications (Akesson, 1999). This atmospheric loading is then assumed to produce the peaks routinely observed in compliance monitoring concentrations each use season. However, there has been little actual data demonstrating the phenomenon. The half-life of propanil in the atmosphere is unknown.

One method to explore the possible existence of atmospheric loading is to examine the season long compliance monitoring concentrations at individual monitoring sites together with the daily acreage totals in the surronding county. If atmospheric loading is indeed a significant contributor to peak residues observed at compliance monitoring sites, then the residues measured each week should follow at least approximately the patterns of application volume (acreage) in the county because

atmospheric loading as it is presented is a large scale phenomenon. In addition, compliance monitoring locations in the same general region should show approximately similar patterns.

Figures 8 through 10 show for Colusa, Glenn, and Butte counties the daily acreage applied within each compliance monitoring week throughout the use season and the foliage concentration (ppm) measured at the end of each week. The figures also show a proposed cap for aerial and ground applications combined of 3% per day of the total rice acres in a county (CRRB 2001). All graphs are on the same scale to facilitate comparisons between counties and sites. There is no consistent regional pattern evident in these graphs between residues and county-wide applications. Peak concentrations at the various sites occur during different weeks and at significantly different magnitudes. These graphs suggest local effects during each week are driving the residues levels measured at a particular orchard on a particular date. With the exception of North Island in Butte County, there is no general trend of residues with the range of daily acreage applied each week. There is also a wide range of residue level observed for sites even within the same county where the use level is necessarily the same.

Figure 8. Colusa County compliance monitoring concentrations (ppm) and daily acreage (sum of ground and air) versus week.

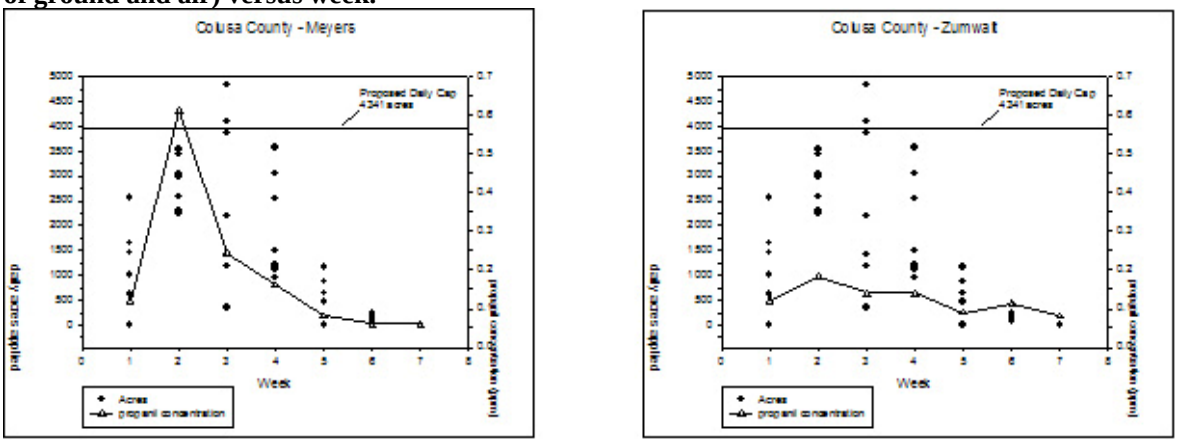


Figure 9. Glenn County compliance monitoring concentrations (ppm) and daily acreage (sum of ground and air) versus week.

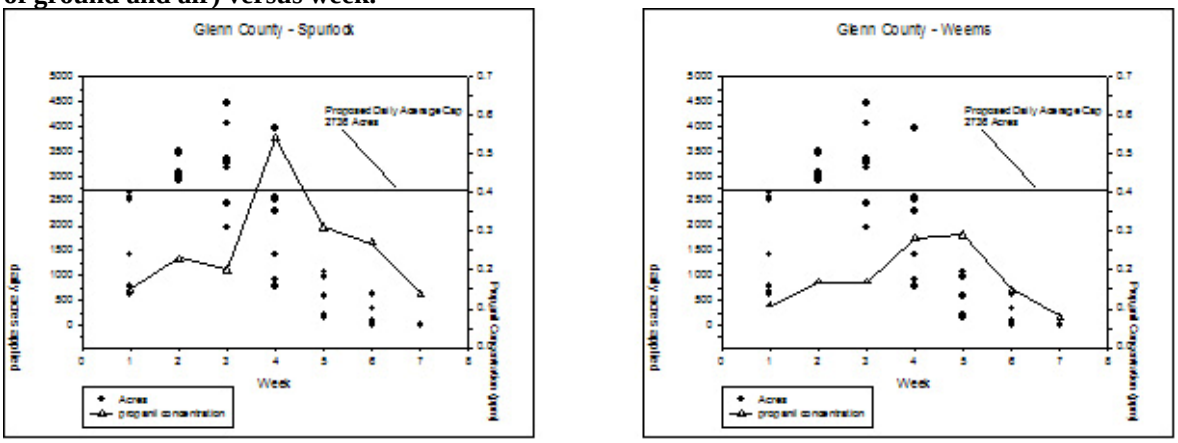
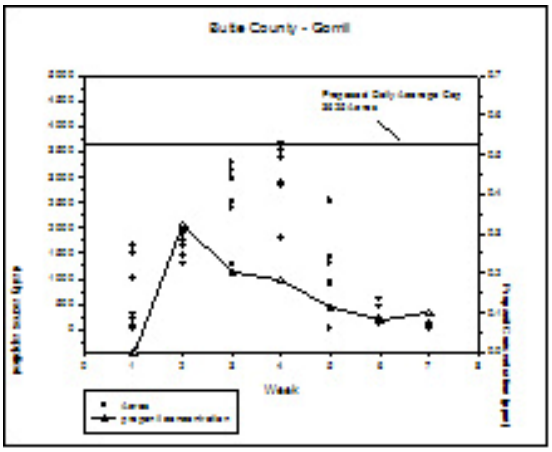
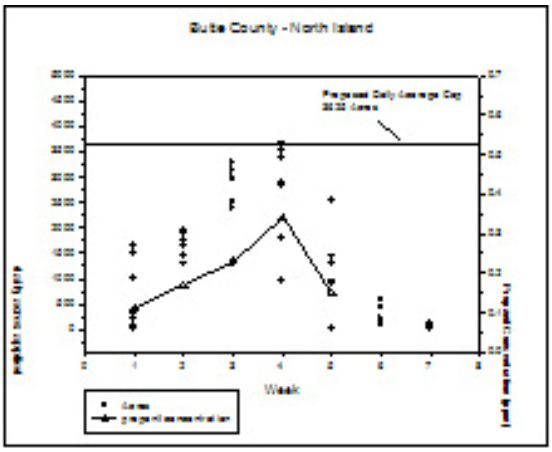
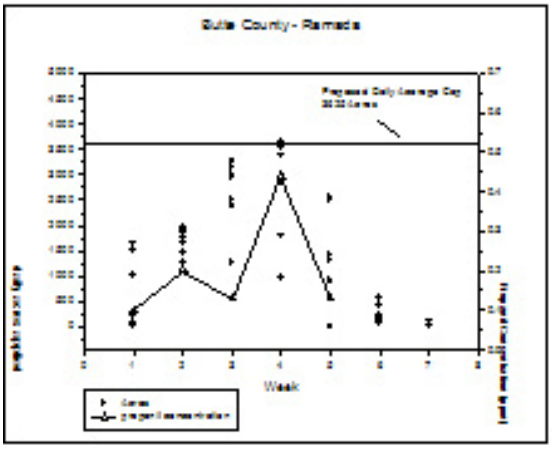
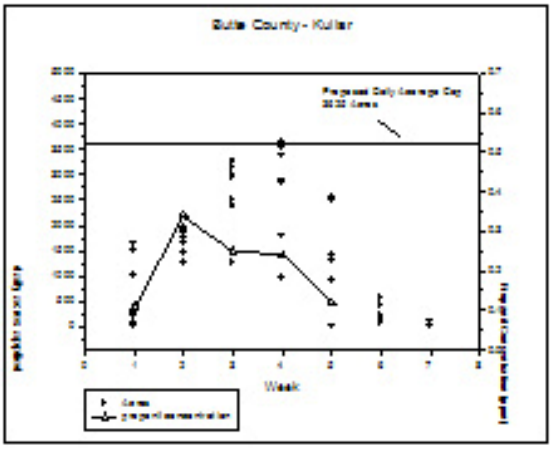


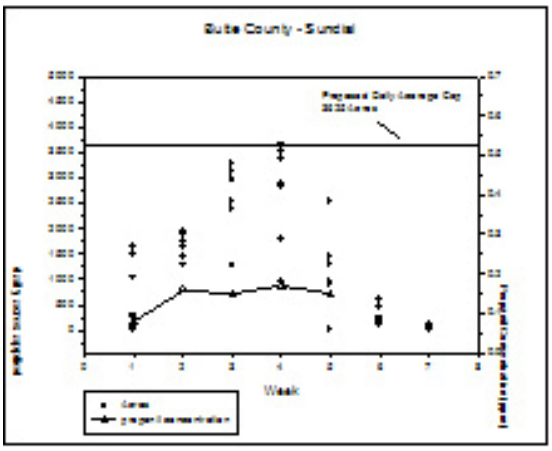
Figure 10. Butte County compliance monitoring concentrations (ppm) and daily acreage (sum of ground and air) versus week.


Butte County - Gorrill
Week


Butte County - North Island
Week


Butte County - Ramada
Week


Butte County - Kuller
Week


Butte County - Sundial
Week

The potential effectiveness of the proposed a daily acreage cap is questionable. A 3% per day acreage cap would substantially reduce the daily applications only in Glenn County.

Conclusion

These results suggest aerial applications within approximately 10 miles contribute a low level of residues. This appears to be the case both on the West Side where only helicopters are allowed, and on the east side in the Butte County Study Area where only fixed wing applications were allowed in 2001. More proximate activities appear to produce observed propanil concentration peaks at compliance monitoring orchards. Important proximate activities include aerial applications within about 6 miles and/or ground applications within 1 mile. In 2001 the two compliance monitoring sites influenced by helicopter applications show the highest peak residues. However, helicopter applications were allowed closer than 4 miles at one of those two sites. Ground applications alone can produce very high peak concentrations. In 2001, the third highest peak observed was most likely from ground applications. In 1999, a single 120 acre ground application was directly associated with a peak concentration of 1.07ppm. In 2000, a single ground application of 154 acres was associated with a residue level of 1.20ppm. These are the highest residues observed in compliance monitoring since the inception of the program in 1986.

Clearly, both air and ground applications must be considered when designing and implementing a mitigation plan. The appropriate mix of air and ground controls will depend upon desired mitigation goals.

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