DRAFT
Technical Support Document on
Investigation of Global Exchangeability of Field Trial Residues

for

"Global Zoning & Exchangeability of Field Trial Residues Between Zones"

18 April 2016

Objective and Summary

The objective of this project is to investigate the extent to which systematic overall differences might exist between various global zones in the *residues in supervised field trials* conducted *with the same use patterns.* We compiled a comprehensive database of supervised field trials performed in various countries on a variety of pesticide-crop combinations and used mixed effects models to examine differences in pesticide residue concentrations across trials performed in different zones. We did not find any statistically significant systematic differences between zones among the pesticide/pesticide uses examined. These preliminary findings open the possibility of exploring opportunities for improving harmonization in pesticide regulatory activities, including establishing more globally-aligned Maximum Residue Limits.

Conclusion

The analysis indicates that no significantly systematic differences in field trial residues between the four zones examined (North America, South America, Europe, and Australia & New Zealand). More specifically, both the non-parametric rank sum test (i.e., Kruskal-Wallis test for clustered data) and mixed-effects model indicate that there were no significant systematic differences in the field trial residues between zones (p-value = 0.686 for rank-sum test for clustered data and p-value = 0.285 for mixed model).

Further analysis of the pairwise comparisons from the mixed-effects model shows that the best estimated residue ratios range from a low of 0.724 for AU-NZ vs. EU (indicating that AU-NZ is estimated to have residues that are systematically 27.6% lower than that of the EU) to a high of 1.207 for EU vs. NA (indicating that residue in the EU are estimated to be systematically higher than those in NA by 20.7%). Neither of these differences, however, are statistically significant. The smallest estimated difference between zones is -1.3% representing the difference between NA vs. SA. The smallest and largest bounds among the 95% CIs of the estimated residue ratios are 0.496 (AU-NZ vs.SA) and 1.991 (EU vs. SA), which implies that the estimated ratios at 95% confidence level are within about 2 fold.

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I.   Background and Objective

Background

Global zoning or exchangeability of field trial residues concept relates to the degree to which -- for any given crop-pesticide combination -- pesticide residues following a given application scenario in one geographic, climate, political or other zone differ systematically from those in another zone under those same application practices (e.g., GAP). To the extent that these pesticide residues do not systematically differ, the zone -- however defined – might be said to be inconsequential with respect to establishing MRLs, and crop field trials conducted in one zone could be "exchanged" for those in another with no or minimal consequences for the level of the MRL.

In 2003, OECD published the results of its first evaluation of global zoning using the JMPR residue database [1]. As a follow-on to work conducted earlier in York in 1999 on developing recommendations for field trials, the OECD Working Group on Pesticides and the FAO Pesticide Management Group began work on the concept of a global zoning scheme to define areas in the world where trials could be considered comparable for MRL-setting purposes, irrespective of national boundaries. The objective of the Working group was to "define and design world-wide geographic zones for conducting pesticide residue field trials, where, within each zone, pesticide residue behavior would be expected to be comparable, and therefore, where residue trials data would be considered equivalent and therefore acceptable for regulatory purposes." In this OECD/FAO analysis, zones were defined based on Koppen classification of climate made up of five zones: polar, cold, temperate (wet), temperate (dry), and tropical. The Koppen climate zone classification approach and the ancillary information the Group decided to explore to define zones in this project led to some practical limitations for use. In addition, the decision to include some random factors such as rainfall, temperature, and sunshine hours related to the month of harvest for each crop, etc. as independent variables led to difficulties with developing and supporting a reasonable and practical path forward or any quantitatively supported judgment as to whether field trial residues in zones were comparable. At the end, the OECD/FAO report indicated that "*there was a higher level of residue variability within zones than between zones*" and concluded that "*the differences in residue behaviour between the proposed residue zones were inconsistent and that the use of a residue zoning scheme based on refinements of existing climate maps could not be validated using the available data*."   The analysis did not quantitate estimated differences in field trial residues between zones. And due in part to limitations of the selected statistical approaches, the investigation did not provide relevant conclusions or sufficient information for regulatory agencies to make decisions regarding the exchangeability of field trial residues between zones.

In 2014, OECD again published the results of another investigation of global zoning conducted by Dow Agroscience [2]. In this analysis, residue data of field trials following global Good Agricultural Practices (GAP) of one chemical (sulfoxaflor) conducted in four different continents (North America, South America, Europe, and Australia & New Zealand) for 22 crops during

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[1] http://www.oecd.org/chemicalsafety/pesticides-biocides/2955870.pdf

[2] http://www.oecd.org/chemicalsafety/testing/OECD-draft-CFT-GD-for-review-12-Sept-2014.pdf

2008 – 2010 were analyzed on a crop-by-crop basis using a mixed-effects model. Two major improvements for this analysis were that (i) zones were classified using geographical boundary or continents and (ii) a mixed-effects model was used to analyze the data. The Dow Agroscience conclusion from this analysis was that "*variability within regions was greater than between regions*" which was consistent with the finding of the earlier OECD/FAO analysis in 2003. However, the Dow Agroscience analysis did not quantify estimated ratio differences in the field trial residues concentrations between zones. Furthermore, the approach of performing separate, individual analysis for each crop-pesticide combination would likely lead to power problems and possibly the inability to come to an overall single general conclusion for all crop-pesticide combinations, considered collectively.

Given that limitations of the selected statistical approaches and the findings from previous analyses published by OECD in 2003 and 2014 have not provided sufficient information for regulatory agencies to make decision whether field trial residues from different geographical zones can be combined or used to calculate a global MRL for each crop-pesticide combination, the United States Environmental Protection Agency (US EPA), Pest Management Regulatory Agency of Health Canada (PMRA), and CropLife America (CLA) have collaborated to gather a field trial residue database to better evaluate the concept of global zoning using what we believe to be more suitable statistical methods to investigate the exchangeability of field trial residues between geographical zones and the extent to which, if any, systematic differences may exist in residue concentrations from supervised field trials conducted in different geographic zones.

Objective

The objective of this project is to investigate whether systematic overall differences between various global zones exist in pesticide *residues resulting from supervised field trials* conducted under *the same use patterns* of any crop-pesticide combination (i.e. whether the *residues of field trials with same use patterns* of same crop-pesticide between zones are comparable and exchangeable). The use of appropriate statistical methods should lead to clear conclusions that appropriately reflect confidence bounds, variability, and uncertainty. In this analysis, residue field trial data from six different zones are available, and defined as follows: Africa, Asia, Europe, North America, South America, and Australia & New Zealand.

II.   Database for Global Exchangeability of Field Trial Residues

CropLife America (CLA) has agreed to gather field trial residue data to investigate the global zoning/exchangeability project. CLA has collected field trial residues data from its eight different members and IR-4 and compiled the data into 5 EXCEL files (*Zoning Data 20150112.xlsx; Company F data_Updated treatment rate for compound F2_April 3 2014.xlsx; Zoning Data 20150106 Company B_corrected_April2015.xlsx; Global Zoning_JMP New DAS Data sets by rateXDE-208_Sept 6 2013.xlsx; and FMC Residue Global Zoning Data 17Oct14.xlsx*). The data files were sent to EPA to combine and prepare for the analysis. Due to the sensitivity of business information, the company names were coded as (A, B, C, etc.) and chemical names were coded as (1, 2, 3, etc.).

Since a crop or commodity may be named or labeled differently for different field trials, the crop labels and commodity labels were reviewed and potentially renamed by EPA such that there is consistency within each crop-pesticide combination. The following decisions were made during the process of QA/QCing and preparing data for the analysis by EPA statisticians:

- CLA database + IR-4 blueberry data:
  o Crop = *Cabbage*: with commodities labeled as *cabbage* and *cabbage head* are assumed to be the same commodity
  o Crop = *Leaf Lettuce* with commodities labeled as *leaves*, *leaves (escarole)*, and *plant* are assumed to be the same commodity
  o Crop = *Lettuce Head* with commodities labeled as *head*, *leaves*, and *plant* are assumed to be the same commodity
  o Crop = *Leaf lettuce* and crop = *open leaf lettuce* are assumed to be the same *leaf lettuce* crop
  o Crop = *Blueberry high bush* and crop = *blueberry low bush* are assumed to be the same *blueberry* crop
  o Crop = *wheat*, crop = *winter wheat*, crop= *spring wheat*, etc. are assumed to be the same *wheat* crop
  o Crop = *barley* and crop = *winter barley* are assumed to be the same *barley* crop
  o Crop = *grape* and crop = *wine grape* are assume to be the same *grape* crop

- DAS:
  o There were 4 commodities (forage, straw, hay, and grain) that were sampled for each wheat field trial, either on PHI = 7 or PHI = 14. Only the grain data on PHI = 14 were included in the analysis.
  o DAS database included data of only 1 chemical with parental residues and metabolite residues. Majority of the metabolites are < LOD or LOQ; so the metabolite residues were not included in the analysis.

- IR-4 tomato
  o There were 4 chemicals (coded as 1, 2, 3, and 4) applied to each IR-4 tomato field trial, and there were 3 PHIs (0, 1, and 3 days). Since the residue data of these chemicals and PHIs are correlated and thus not independent, only data of chemical = 4 on PHI = 3 were included in the final analysis. The selection of chemical 4 and PHI = 3 is due to the lowest proportion of residues <LOD or <LOQ.

It is acknowledged that supervised field trial residue concentrations are strongly associated with some factors such as application rates, number of applications, post-harvest intervals (PHIs), and methods of applications, and that substantive differences in the agricultural practices for a given crop-pesticide combination between zones would necessitate eliminating that crop-pesticide data set. To account for the systematic differences in residues due to the different <u>application rates</u> among the field trials of same crop-pesticide combination, we took advantage of the proportionality principle to adjust the residues of field trials that have different application rates.

In addition, EPA established a number of inclusion criteria: in order for data of a given crop-pesticide combination to be included in the analysis, the crop-pesticide combination must have supervised field trial data from at least 2 zones, the associated residue data are required to have similar use patterns (such as same number of application and similar PHIs), and the proportion of residues <LOD or LOQ of a given crop-pesticide combination should not be too high (1 or close to 1). Note that only a few crop-pesticide combinations with a small number of field trials and higher percent LOD or LOQ were excluded from the analysis on this basis. If residue data resulting from different numbers of applications of a crop-pesticide combination are available, the data from the applications with the larger number of field trials and lower proportion of residues < LOD or <LOQ were selected to be included in the analysis. If a crop-pesticide combination has multiple PHIs, then the PHIs that are closer to labeled (or common use pattern) PHIs, have larger number of field trials, and have a lower proportion of residues < LOD or < LOQ are selected to include in the analysis.

Given the above EPA exclusions, Table 1 below presents the number of field trials that remained in the analysis for each zone and each type of pesticide (herbicide, insecticide, etc.). Note that, after removing from the database the data sets that did not meet the above-stated inclusion criteria, only a small number of herbicide trials remained, and the majority of remaining field trials were associated with fungicide and insecticide applications.

Table 1: Number of field trials per type of chemicals included in the analysis

Pest Type	Number of field trials					
	AF	ASIA	EU	NA	SA	AU_NZ
H			1	5		
F		(1)	73 (24)	55	12	
I	(5)	(7)	222	211	28	93
Numbers of supervised trials NOT used in the assessment are indicated in parentheses. These field trials were not included in the final analysis due to small number of crop-pesticide in Africa and Asia						

Table 2 presents more detailed information than in Table 1, cross tabulated by the crop-pesticide combination. The final analysis included data of 700 field trials, 23 crops, 11 chemicals (3 fungicides, 1 herbicide, and 7 insecticides), and 36 different crop-pesticide combinations for which field trials existed in 2 or more zones among Europe, South America, North America, and Australia & New Zealand. Due to the small number of crop-pesticide combinations in Africa and Asia, the data from Africa and Asia were not included in the analysis. The regions of Europe and North America have the largest numbers of crop-pesticide combinations (34 combinations for each zone) while the Australia & New Zealand region has data of 20 different crop-pesticide combinations. The South America region has data from only 9 crop-pesticide combinations.

Table 2: Distribution of number field trials (included in the final analysis) by zone and Crop-Pesticide

PestType	CropPest	AF	ASIA	EU	SA	NA	AU_NZ
F	B-1-APPLE	.	(1)	(24)	.	.	.
F	B-3-APPLE	.	.	14	12	.	.
F	B-3-WHEAT-GRAIN	.	.	8	.	12	.
F	B-6-HOPS-DRIEDCONES	.	.	6	.	4	.
F	D-3-GRAPE	.	.	17	.	17	.
F	D-3-STRAWBERRY	.	.	18	.	10	.
F	D-3-TOMATO	.	.	10	.	12	.
H	B-4-SOYBEAN	.	.	1	.	5	.
I	B-8-CABBAGE	.	.	2	.	2	.
I	D-1-BLUEBERRY	.	.	5	3	13	5
I	D-1-HOPS-DRIEDCONES	.	.	8	.	3	.
I	D-2-AVOCADO	.	.	.	3	2	.
I	DAS-1-APPLE	.	.	4	.	6	6
I	DAS-1-BARLEY-SEED	.	.	13	.	6	5
I	DAS-1-BROCCOLI	.	.	7	.	6	2
I	DAS-1-CABBAGE	.	.	6	.	6	2
I	DAS-1-CANOLA-SEED	.	.	7	.	8	4
I	DAS-1-CHERRY	.	.	6	.	6	2
I	DAS-1-COTTON-SEED	.	.	8	4	6	4
I	DAS-1-CUCUMBER	.	.	13	.	6	2
I	DAS-1-GRAPE	.	.	12	.	9	12
I	DAS-1-HEADLETTUCE	.	.	6	.	4	4
I	DAS-1-LEAFLETTUCE	.	.	6	.	8	4
I	DAS-1-MELON	.	.	6	4	6	.
I	DAS-1-ORANGE	.	.	.	4	12	10
I	DAS-1-PEACH	.	.	6	.	6	8
I	DAS-1-PEAR	.	.	6	.	6	2
I	DAS-1-PEPPER	.	.	6	.	8	6
I	DAS-1-TOMATO	.	.	18	4	12	6
I	DAS-1-WHEAT-GRAIN	.	.	12	4	11	5
I	F-1-LEAFLETTUCE	.	.	7	.	12	.
I	F-1-LETTUCE,HEAD	.	.	3	.	12	.
I	F-1-ORANGE	.	.	2	.	13	.
I	F-2-APPLE	.	.	22	.	5	.
I	F-2-GRAPE	.	.	11	.	.	2
I	F-2-LEAFLETTUCE	.	.	15	.	11	.
I	IR4-TOMATO	(5)	(7)	5	2	6	2
Numbers of supervised trials NOT used in the assessment are indicated in parentheses. These field trials were not included in the final analysis due to small number of crop-pesticide in Africa and Asia						

Table 3 presents the distribution of PHIs of the crop-pesticide combinations included in the final analysis.

Table 3: Distribution of average PHI (average of PHIs within each crop-pesticide combination)

Distribution of average PHI	Number of Crop-Pesticide combinations	Cumulative Frequency
0	2	2
1	10	12
2	1	13
3	8	21
7	7	28
14	5	33
21	1	34
35	1	35
72	1	36

III.   Statistical Methods

Different crop-pesticide combinations are expected to differ in their residue distributions, and therefore residues in field trials from same crop-pesticide combination are expected to be more similar to each other than the residues in field trials from different crop-pesticide combinations. To account for the similarity of residues from same crop-pesticide combination in the database – this intraclass correlation - methods for nested/clustered data were used to analyze the data. Here, two different statistical methods were used:

- The first approach is a non-parametric statistical method, called "Rank-Sum Test for Clustered Data" [3]. This approach has advantages that it correctly accounts for the nesting of residues within each crop-pesticide combination and it does not make any assumption about the distribution type of the residue data within each crop-pesticide combination. The method allows different numbers of field trials between crop-pesticide combinations and different numbers of field trials (within each crop-pesticide combination) between the zones. However, the method only detects whether there is (or is not) a significant difference between zones, but does not determine which zones are different and does not estimate the magnitude of these differences. Also, the method is not able to identify the crop-pesticide combinations that have extreme residue ratios between zones.

  The rank-sum test for clustered data method allows only 1 residue data point for each field trial. To simplify the data structure, the average of replicates was used if a field trial had 2 or more residue values (i.e. replicates).

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[3] Rank-Sum Tests for Clustered Data. S. Datta, G. Satten. 2005, Vol. 100, No. 471, *Journal of the American Statistical Association*.

- • The second statistical method used to compare the residues between zones were mixed effects models for unbalanced incomplete block study design, where each Crop-Pesticide combination was considered as a random block in the study design. The residue distributions were assumed to be lognormal (or near lognormal) so log-transformation was applied to the residue prior to the analysis. Crop-Pesticide combination and Trial nested into Crop-Pesticide combination were set as random effects in the model. Zone effect on each crop-pesticide combination was set as random since the model has a lower AIC value than the model with common zone effect. The random effects (residue ratios between zones for each crop-pesticide combination) and the "*average*" of differences (i.e. median residue ratios) between zones were estimated from the mixed-effects models and presented.

It was recognized that there might be substantial variation in residues between crop-pesticide combinations (e.g., apples vs. rice for a given pesticide). The substantial variation between crop-pesticide combinations will influence the decision of which statistical methods for estimating zone effect might be most appropriate. Fortunately, the selected mixed-effects model for an unbalanced incomplete block study design was able to separate the total variation of residues in the database into the variation between zones (fixed effects), variation of zone effect between crop-pesticide combinations (random effect), variation between crop-pesticide combinations (i.e., blocks, random effect), and variation within crop-pesticide combinations (summation of variation between trials and variation within trials, random effect). In the analysis using a mixed-effects model for an unbalanced incomplete block study design, the variation between crop-pesticide combinations has a negligible or almost no impact on the estimates and the significance of zone effects (Appendix D).

IV.   Results of Global Exchangeability of Field Trial Residue Analysis

Table 4 summarizes the results of comparisons in both analyses using rank-sum test for clustered data (in blue) and mixed-effect models (in red).

Table 4: Results of comparisons from rank-sum test and mixed-effects model

Method	Comparison	# crop-pesticide combinations have data in both zones	Ratio (95% CI)	p-value	ANOVA p-value Zone Effect
Rank Sum Test				0.686	
Mixed-effects model	AU-NZ vs.EU	19	0.724 (0.507, 1.033)	0.074	0.285
	AU-NZ vs.NA	19	0.874 (0.613, 1.246)	0.449	
	AU-NZ vs.SA	5	0.862 (0.496, 1.499)	0.593	
	EU vs.NA	32	1.207 (0.919, 1.585)	0.172	
	EU vs.SA	7	1.191 (0.713, 1.991)	0.498	
	NA vs.SA	8	0.987 (0.591, 1.649)	0.959	

The result of analysis using non-parametric (Rank Sum Test) indicates that there were no significant differences in the field trial residues between zones (p-value = 0.686). However, this analysis cannot estimate the pairwise estimated residue ratios between zones nor the confidence limits of the differences. Another disadvantage of the analysis using this non-parametric approach is that it cannot identify the crop-pesticide combinations that have extreme estimated residue ratios.

The analysis using a mixed-effects model results in a conclusion consistent with the analysis of using the non-parametric method, with no significant differences found between zones (p-value =0.285). The mixed effects model, however, is able to provide further information concerning the estimated ratios in the residue concentrations between zones. As seen in Table 4, the point estimate ratios range from a low of 0.724 for AU-NZ vs. EU (indicating that AU-NZ is estimated to have residues that are systematically 27.6% lower than that of the EU) to a high of 1.207 for EU vs. NA (indicating that residue in the EU are estimated to be systematically higher than those in NA by 20.7%). Neither of these differences, however, are statistically significant. The smallest estimated systematic difference between zones is -1.3% representing the difference between NA vs.SA. The smallest and largest values among the 95% CIs of the estimated residue ratios are 0.496 (AU-NZ vs.SA) and 1.991 (EU vs. SA), which implies that **the estimated ratios at 95% confidence level are within about 2 fold**.

The mixed effect model is also able to estimate the variances and covariance estimated from the data and provide estimates of within- and between zone variations. This information is provided in Table 5 below.

Table 5: Variance and covariance estimated from the mixed-effects model

Covariance Parameter Estimates		
Cov Parm	**Subject**	**Estimate**
Intercept	CropPest	3.0788
Zone	CropPest	0.1925
Field Trial (CropPest)		0.7077
Residual		0.0672

Regression diagnostics

An important "next step" in evaluating the above model is to test and evaluate the model validity. Regression diagnostics can be an important set of procedures for assessing the validity of a model. Typically – and of most relevance here -- this can involve investigating the model's

underlying statistical assumptions and investigating data points that are outliers and are poorly represented by the model. Such diagnostics are often done graphically.

Figures 1 and 2 present the histogram and Q-Q plot of the residuals of log(residue) of zones by crop-pesticide combination where a residual was estimated by the mixed-effects model = the estimated log(residue) of each zone per crop-pesticide combination minus the estimated log(residue) of each crop-pesticide combination all zones together. Since one of the assumptions of mixed-effects models is that the errors follow a normal distribution, the histogram of the random effects in Figure 1 is expected to have a bell shape, and all the data points in the Q-Q plot in Figure 2 are expected to be on or close to the line in the figure. A residual of a zone-crop-pesticide combination that is located on the left tail or right tail of the normal curve in Figure 1 (or, equivalently, not close to the regression line in Figure 2) is an outlier. As shown, the histogram in Figure 1 follows a bell shape and the majority of data points in Figure 2 are located close to or on the line in the figure except for four data points (outliers or extreme residue values). This provides some confirmation that the selected mixed-effects model provides a reasonable fit to the data and that gross violations are not present.

Figure 1: Histogram of estimated residuals of Zone by crop-pesticide combination
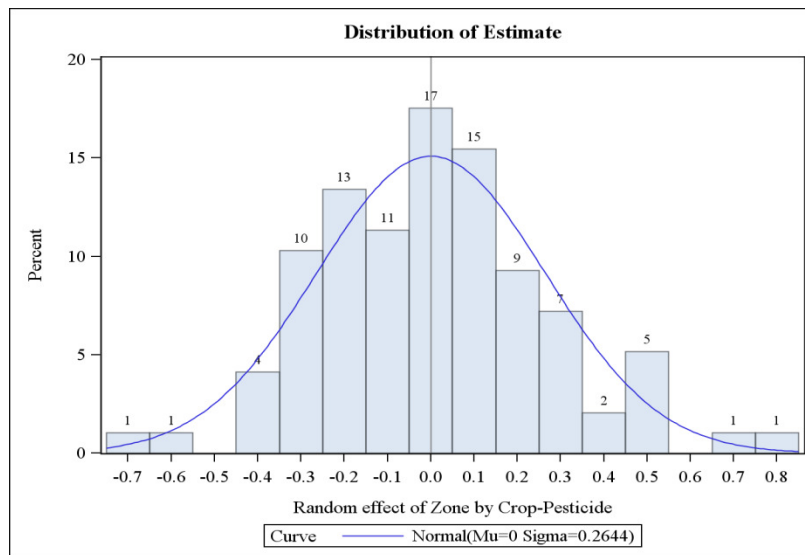
Note: residual = estimated log(residue) of each zone per crop-pesticide combination – estimated log(residue) of each crop-pesticide combination all zones together

Figure 2: Q-Q plot of estimated residuals of Zone by crop-pesticide combination
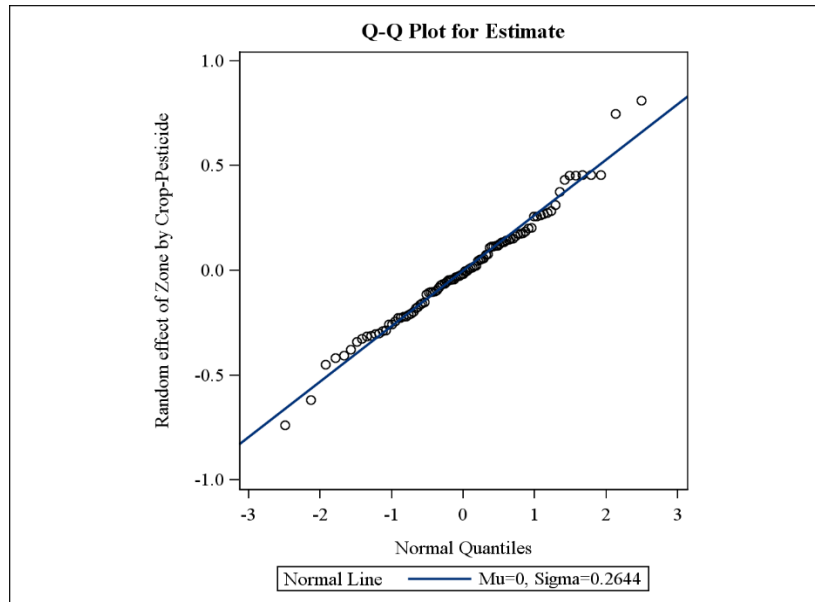
Note that the residuals in Figures 1 and 2 are not independent since the data are clustered by crop-pesticide combination. For example, if a crop-pesticide combination has data in 2 zones and the residual of one zone is far to the left of the normal curve in Figure 1, the residual of other zone is likely far to the right of the normal curve. Therefore, outliers or extreme residual values are used to identify the crop-pesticide combinations that have extreme residue ratios among zones. The outliers or extreme residue values are identified in the following table:

CropPest	Zone	Estimated residual*
F-2-LEAFLETTUCE	EU	-.7375
DAS-1-HEADLETTUCE	NA	-.6174
DAS-1-HEADLETTUCE	EU	0.7483
F-2-LEAFLETTUCE	NA	0.8104

*:   the estimated random zone effects on log(residue) by crop-pesticide level. Each residual is estimated by the mixed-effects model = the estimated log(residue) of each zone per crop-pesticide combination minus the estimated log(residue) of each crop-pesticide combination all zones together.

Figures 3 through 14 (in the section "Additional Tables and Figures for Regression Diagnostics") present the histograms of random effects of ratio (i.e. zone effect) in the log-scale (Figures 3

through 8) and actual scale (Figures 9 through 14) by pairwise comparison. The log-scale ratios were calculated using the estimated residuals outputting from the mixed-effects model. As one of the assumptions of mixed-effects models is the errors follow a normal distribution, the histograms of the random effects in log scale of ratios in Figures 3-8 are expected to have bell shapes or be symmetrical. If there was no difference between a pair of zones, a comparison of the centers of the histogram of log scale ratios should be 0 and the centers the histograms of ratio in actual scale (Figures 9-14) should be 1. However, since the sample sizes (number of crop-pesticide combinations that have data in both zones of a pairwise comparison) are generally small in this analysis and bell shaped histograms or log-normal shaped histogram can be difficult to discern, such criteria are less useful in evaluating the model , and the histograms are instead used as a tool to detect and identify extreme ratio values that may be present in a series of pairwise comparison, i.e. to identify crop-pesticide combinations that have ratios substantially smaller than 1 or greater than 1.

Table 6 below is based on Figures 3 through 8 (log scale) and 9 through 14 (actual scale) and Table 7, and summarizes the crop-pesticide combinations that were found to have extreme estimates of between zone residue ratios (subjectively pick at >2 for convenience) arranged by zonal comparison), with additional details on the number of trials in each region and observations added. Estimates that are greater than 2 are shown in yellow while those that are greater than 3 are shown in brown.

Table 6: Crop-pesticide combinations that have extreme estimated residue ratios

CropPest	comparisons	LogRatio	Ratio	Inversed Ratio	N1	N2	Notes/Observations
DAS-1-HEADLETTUCE	AU_NZ vs. EU	-1.27	0.28	3.56	4	6	Residues of EU field trials are higher than in NA and AU&NZ
	EU vs. NA	1.55	4.73	0.21	6	4	
DAS-1-LEAFLETTUCE	AU_NZ vs. NA	-0.89	0.41	2.44	4	8	
DAS-1-ORANGE	AU_NZ vs. NA	0.73	2.07	0.48	10	12	
DAS-1-GRAPE	EU vs. NA	0.70	2.02	0.49	12	9	
DAS-1-CUCUMBER	EU vs. NA	0.73	2.07	0.48	13	6	
DAS-1-PEPPER	EU vs. NA	0.74	2.09	0.48	6	8	
DAS-1-BROCCOLI	EU vs. NA	0.79	2.20	0.45	7	6	
DAS-1-TOMATO	AU_NZ vs. EU	-0.94	0.39	2.56	6	18	
F-2-LEAFLETTUCE	EU vs. NA	-1.36	0.26	3.90	15	11	Crop =Leaf lettuce in NA, Crop = open leaf lettuce in EU
IR4-TOMATO	AU_NZ vs. EU	-0.84	0.43	2.32	2	5	
	EU vs. NA	0.71	2.03	0.49	5	6	

V.   Additional Tables and Figures of Regression Diagnostics

Table 7: Estimated Zone Random Effects per pairwise comparison

Comparisons	CropPest	LogRatio	Ratio	1/Ratio	N1	N2
AU_NZ vs. EU	DAS-1-HEADLETTUCE	-1.27	0.28	3.56	4	6
	DAS-1-TOMATO	-0.94	0.39	2.56	6	18
	IR44-TOMATO	-0.84	0.43	2.32	2	5
	DAS-1-CANOLA-SEED	-0.67	0.51	1.96	4	7
	DAS-1-WHEAT-GRAIN	-0.63	0.53	1.88	5	12
	DAS-1-PEACH	-0.63	0.54	1.87	8	6
	DAS-1-PEPPER	-0.58	0.56	1.79	6	6
	DAS-1-BROCCOLI	-0.58	0.56	1.79	2	7
	DAS-1-CHERRY	-0.55	0.58	1.73	2	6
	DAS-1-LEAFLETTUCE	-0.54	0.58	1.72	4	6
	DAS-1-GRAPE	-0.41	0.66	1.51	12	12
	DAS-1-APPLE	-0.38	0.68	1.46	6	4
	DAS-1-CUCUMBER	-0.35	0.70	1.42	2	13
	DAS-1-CABBAGE	-0.31	0.73	1.36	2	6
	D-1-BLUEBERRY	-0.19	0.83	1.21	5	5
	DAS-1-COTTON-SEED	-0.16	0.85	1.17	4	8
	DAS-1-BARLEY-SEED	-0.14	0.87	1.16	5	13
	DAS-1-PEAR	0.04	1.05	0.96	2	6
	F-2-GRAPE	0.58	1.79	0.56	2	11
AU_NZ vs. NA	DAS-1-LEAFLETTUCE	-0.89	0.41	2.44	4	8
	DAS-1-CHERRY	-0.46	0.63	1.59	2	6
	DAS-1-TOMATO	-0.34	0.71	1.40	6	12
	DAS-1-BARLEY-SEED	-0.31	0.73	1.37	5	6
	DAS-1-CANOLA-SEED	-0.20	0.82	1.22	4	8
	DAS-1-CABBAGE	-0.17	0.84	1.19	2	6
	DAS-1-WHEAT-GRAIN	-0.17	0.84	1.18	5	11
	DAS-1-PEAR	-0.17	0.84	1.18	2	6
	D-1-BLUEBERRY	-0.14	0.87	1.15	5	13
	IR44-TOMATO	-0.14	0.87	1.15	2	6
	DAS-1-COTTON-SEED	-0.13	0.88	1.14	4	6
	DAS-1-PEACH	0.04	1.04	0.96	8	6
	DAS-1-PEPPER	0.15	1.17	0.86	6	8
	DAS-1-APPLE	0.18	1.20	0.83	6	6
	DAS-1-BROCCOLI	0.21	1.23	0.81	2	6
	DAS-1-HEADLETTUCE	0.28	1.33	0.75	4	4
	DAS-1-GRAPE	0.29	1.34	0.75	12	9
	DAS-1-CUCUMBER	0.38	1.46	0.68	2	6
	DAS-1-ORANGE	0.73	2.07	0.48	10	12
AU_NZ vs. SA	DAS-1-TOMATO	-0.47	0.62	1.60	6	4
	D-1-BLUEBERRY	-0.45	0.64	1.57	5	3

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Comparisons	CropPest	LogRatio	Ratio	1/Ratio	N1	N2
	IR44-TOMATO	-0.22	0.80	1.25	2	2
	DAS-1-WHEAT-GRAIN	-0.08	0.92	1.08	5	4
	DAS-1-COTTON-SEED	-0.00	1.00	1.00	4	4
	DAS-1-ORANGE	0.35	1.42	0.70	10	4
EU vs. NA	F-2-LEAFLETTUCE	-1.36	0.26	3.90	15	11
	F-2-APPLE	-0.61	0.55	1.83	22	5
	F-1-LEAFLETTUCE	-0.61	0.55	1.83	7	12
	D-1-HOPS-DRIEDCONES	-0.56	0.57	1.75	8	3
	DAS-1-LEAFLETTUCE	-0.35	0.70	1.42	6	8
	D-3-STRAWBERRY	-0.30	0.74	1.35	18	10
	DAS-1-PEAR	-0.21	0.81	1.24	6	6
	B-3-WHEAT-GRAIN	-0.19	0.83	1.21	8	12
	DAS-1-BARLEY-SEED	-0.17	0.84	1.19	13	6
	B-8-CABBAGE	-0.16	0.85	1.18	2	2
	DAS-1-COTTON-SEED	0.03	1.03	0.97	8	6
	D-1-BLUEBERRY	0.05	1.05	0.95	5	13
	DAS-1-CHERRY	0.09	1.09	0.92	6	6
	DAS-1-CABBAGE	0.14	1.15	0.87	6	6
	F-1-ORANGE	0.21	1.24	0.81	2	13
	B-6-HOPS-DRIEDCONES	0.25	1.28	0.78	6	4
	D-3-GRAPE	0.35	1.42	0.70	17	17
	DAS-1-MELON	0.36	1.43	0.70	6	6
	F-1-LETTUCE,HEAD	0.44	1.56	0.64	3	12
	DAS-1-WHEAT-GRAIN	0.46	1.59	0.63	12	11
	B-4-SOYBEAN	0.47	1.60	0.62	1	5
	DAS-1-CANOLA-SEED	0.48	1.61	0.62	7	8
	D-3-TOMATO	0.55	1.73	0.58	10	12
	DAS-1-APPLE	0.57	1.76	0.57	4	6
	DAS-1-TOMATO	0.60	1.82	0.55	18	12
	DAS-1-PEACH	0.67	1.95	0.51	6	6
	DAS-1-GRAPE	0.70	2.02	0.49	12	9
	IR44-TOMATO	0.71	2.03	0.49	5	6
	DAS-1-CUCUMBER	0.73	2.07	0.48	13	6
	DAS-1-PEPPER	0.74	2.09	0.48	6	8
	DAS-1-BROCCOLI	0.79	2.20	0.45	7	6
	DAS-1-HEADLETTUCE	1.55	4.73	0.21	6	4
EU vs. SA	B-3-APPLE	-0.38	0.69	1.46	14	12
	D-1-BLUEBERRY	-0.27	0.77	1.30	5	3
	DAS-1-COTTON-SEED	0.16	1.17	0.86	8	4
	DAS-1-TOMATO	0.47	1.59	0.63	18	4
	DAS-1-MELON	0.53	1.70	0.59	6	4
	DAS-1-WHEAT-GRAIN	0.55	1.73	0.58	12	4
	IR44-TOMATO	0.62	1.85	0.54	5	2
NA vs. SA	DAS-1-ORANGE	-0.38	0.69	1.46	12	4
	D-1-BLUEBERRY	-0.31	0.73	1.37	13	3
	DAS-1-TOMATO	-0.13	0.87	1.14	12	4
	IR44-TOMATO	-0.09	0.92	1.09	6	2

Comparisons	CropPest	LogRatio	Ratio	1/Ratio	N1	N2
	DAS-1-WHEAT-GRAIN	0.09	1.09	0.91	11	4
	D-2-AVOCADO	0.10	1.10	0.91	2	3
	DAS-1-COTTON-SEED	0.13	1.14	0.88	6	4
	DAS-1-MELON	0.17	1.19	0.84	6	4
This presents the estimated random zone effects by crop-pesticide combination in each zonal pairwise comparison. These estimated ratios were calculated using the estimated residuals outputting from the mixed-effects model. Note that these estimated residue ratios of crop-pesticide combinations in log-scale and actual scale were used to create the histograms appearing in Figures 3 through 14.						

Figures 3-8: Histograms of random effects (log(ratio)) by pairwise comparison
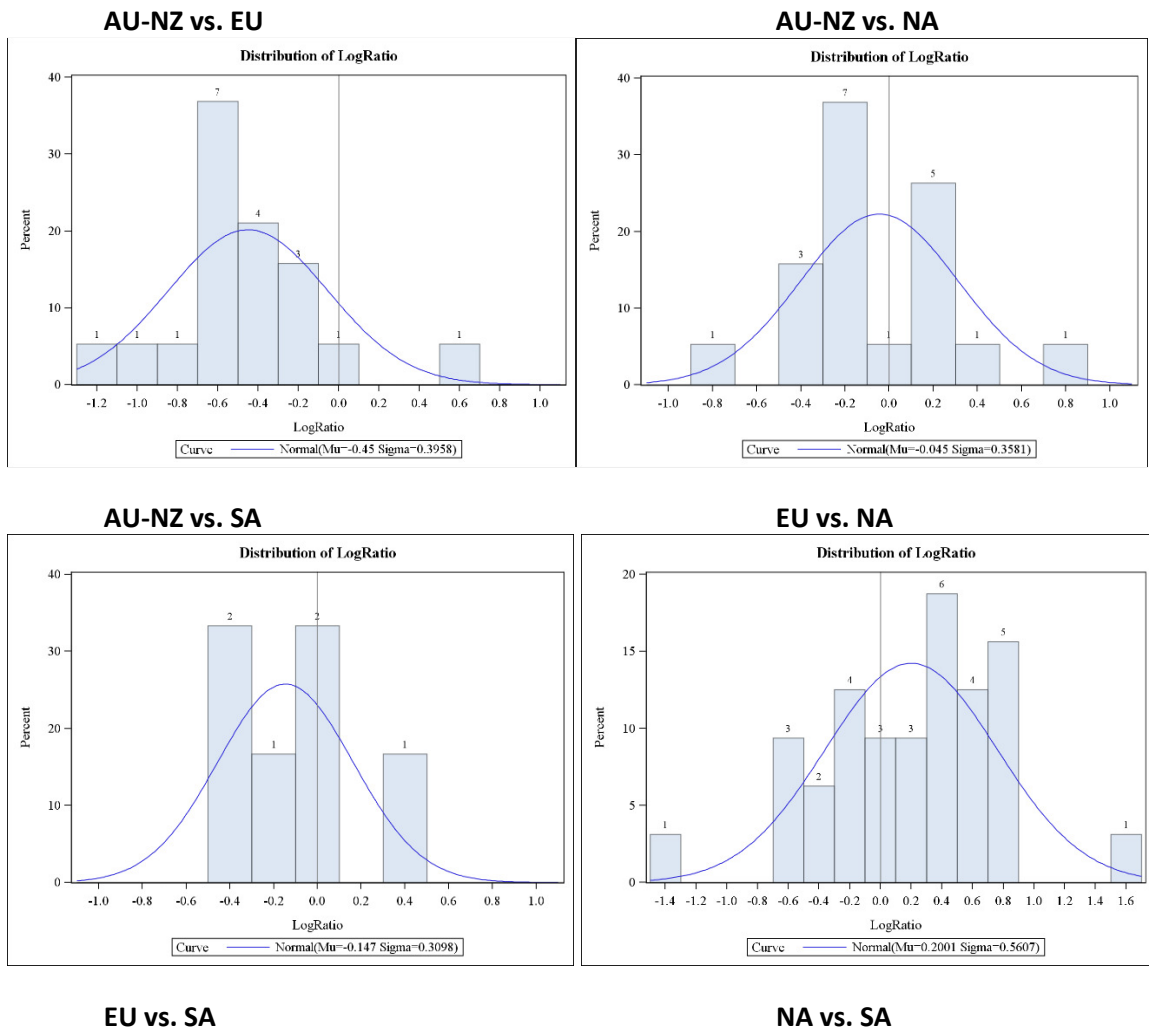
AU-NZ vs. EU   **AU-NZ vs. NA**

AU-NZ vs. SA   **EU vs. NA**

EU vs. SA   **NA vs. SA**
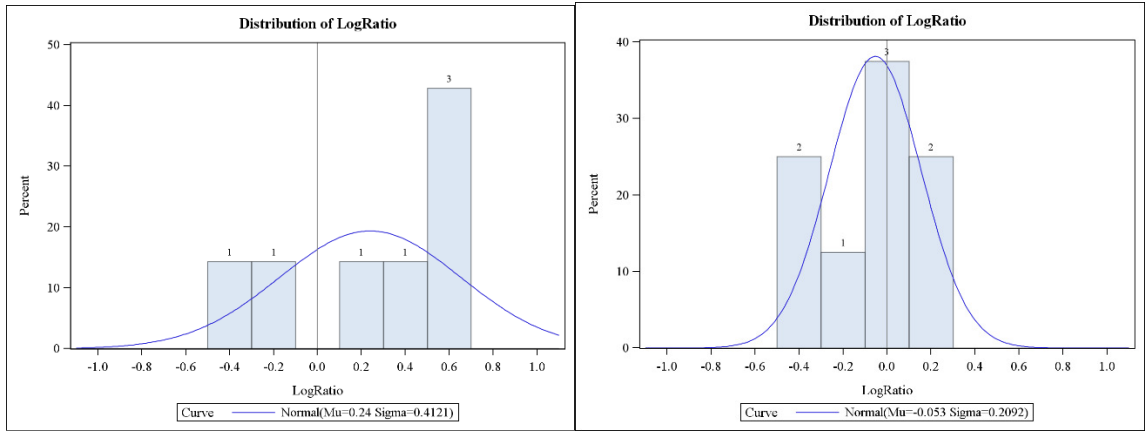
Figures 9-14: Histograms of random effects (ratio) by pairwise comparison
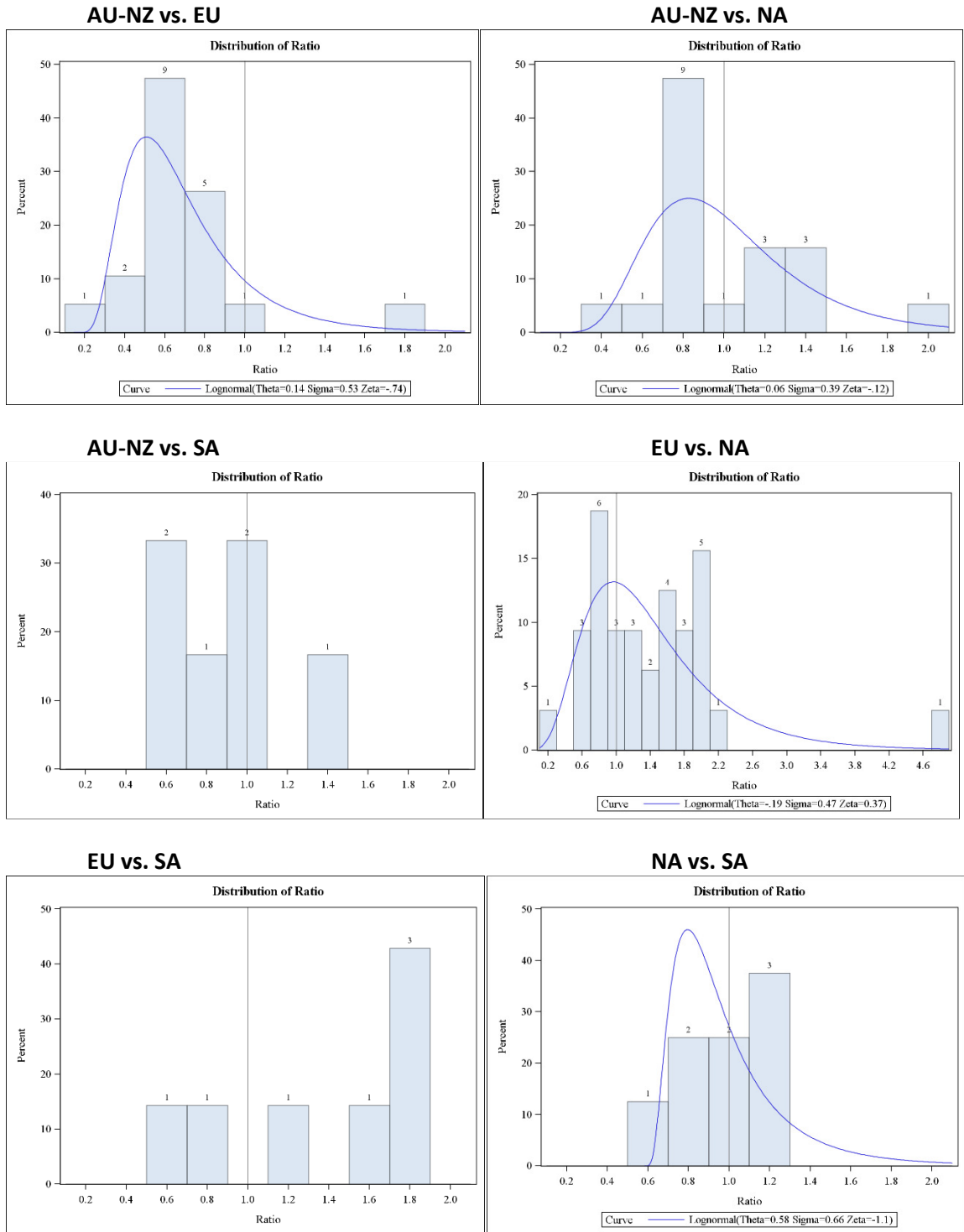
Figure 15: Scatter plot of residuals vs. predicted value by Zone
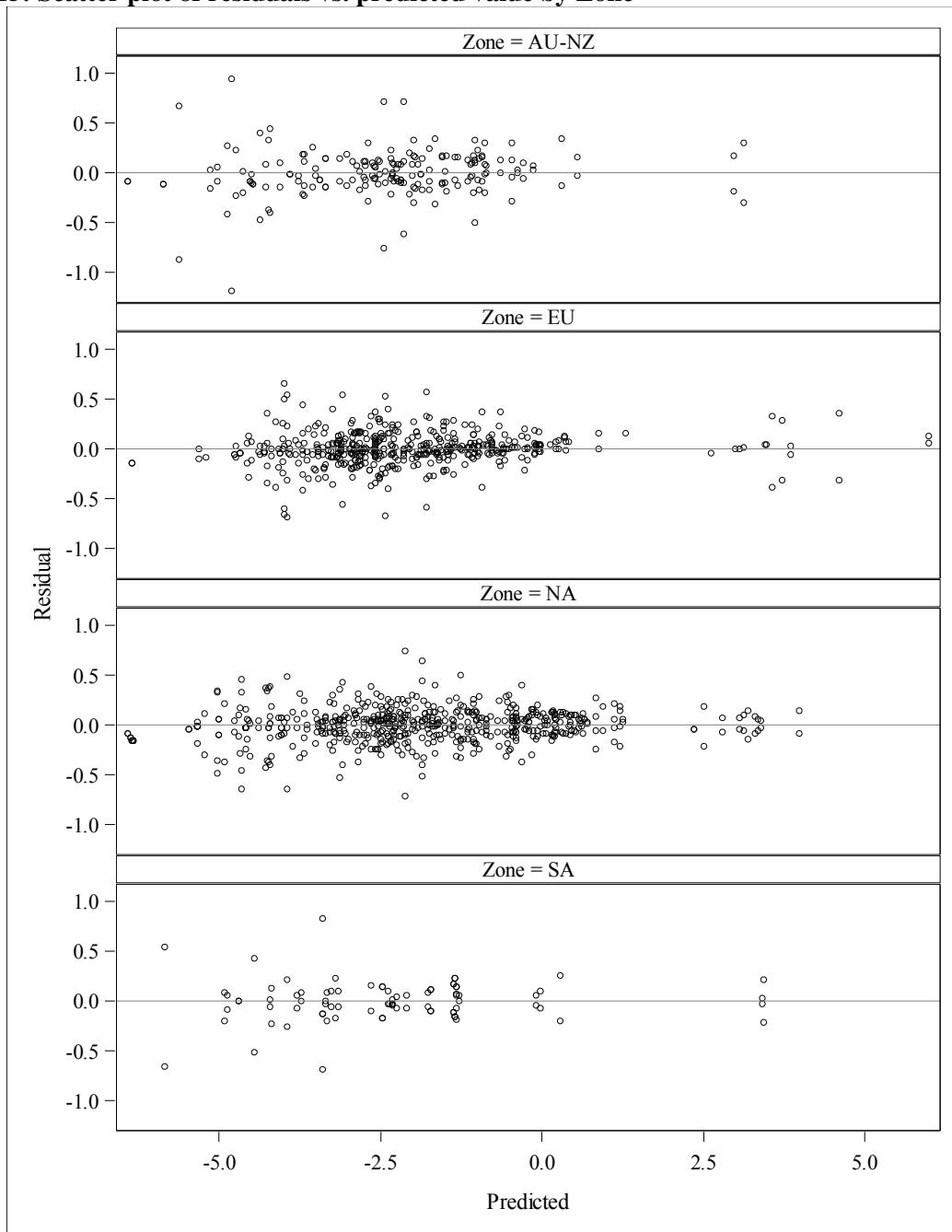
Note that the residuals in the scatter-plot above are not independent since some field trials may have 2 or more replicates, and trials were nested into crop-pesticide combinations. The scatter-plot above indicates there may be some potential outliers and this is expected in a large sample size of 700 field trials. It is expected that the results of analysis would not substantially change if some of these potential outliers are removed.

VI.   Additional Tables for Database Descriptions

Table 8: Numbers of field trials and Crop-Pesticide combination in DAS Database

Pest Type	Crop-Pest	GAP	Number of field trials				Reason	Excluded
			AU_NZ	EU	NA	SA		
I	DAS-1-APPLE	2x200 PHI 7	6	4	6	.		
I	DAS-1-BARLEY-SEED	2x50 PHI 14	5	13	6	.		
I	DAS-1-BARLEY-STRAW	2x50 PHI 14	5	13	6	.	commodity with same field trials	excluded
I	DAS-1-BROCCOLI	4x100 PHI 3	2	7	6	.		
I	DAS-1-CABBAGE	4x100 PHI 3	2	6	6	.		
I	DAS-1-CANOLA-SEED	2x50 PHI 14	4	7	8	.		
I	DAS-1-CHERRY	2x200 PHI 7	2	6	6	.		
I	DAS-1-COTTON-GINBYPRODUCT	4x100 PHI 14	4	7	6	4	commodity with same field trials	excluded
I	DAS-1-COTTON-SEED	4x100 PHI 14	4	8	6	4		
I	DAS-1-CUCUMBER	4x100 PHI 1	2	13	6	.		
I	DAS-1-GRAPE	4x100 PHI 7	12	12	9	.		
I	DAS-1-HEADLETTUCE	4x100 PHI 3	4	6	4	.		
I	DAS-1-LEAFLETTUCE	4x100 PHI 3	4	6	8	.		
I	DAS-1-MELON	4x100 PHI 1	.	6	6	4		
I	DAS-1-ORANGE	2x200 PHI 1	10	.	12	4		
I	DAS-1-PEACH	2x200 PHI 7	8	6	6	.		
I	DAS-1-PEAR	2x200 PHI 7	2	6	6	.		
I	DAS-1-PEPPER	4x100 PHI 1	6	6	8	.		
I	DAS-1-TOMATO	4x100 PHI 1	6	18	12	4		
I	DAS-1-WHEAT-FORAGE	2x50 PHI 7	2	13	11	4	commodity with same field trials	excluded
I	DAS-1-WHEAT-GRAIN	2x50 PHI 14	5	12	11	4		
I	DAS-1-WHEAT-HAY	2x50 PHI 7	.	14	11	4	commodity with same field trials	excluded
I	DAS-1-WHEAT-STRAW	2x50 PHI 14	5	13	11	4	commodity with same field trials	excluded

Table 9: Number of field trials and Crop-Pesticide combinations CLA database that have data in 1 zone

PestType	CropPest	No_Appli	Number of field trials					Reason	Excluded
			EU	ASIA	SA	NA	AU_NZ		
F	B-1-APPLE	4	46	.	.	.	.	field trials in 1 zone	excluded
F	B-1-APPLE	12	21	.	.	.	.	field trials in 1 zone	excluded
F	B-1-CHERRY	3	26	.	.	.	.	field trials in 1 zone	excluded
F	B-1-GRAPE	3	21	.	.	.	.	field trials in 1 zone	excluded
F	B-1-GRAPE	4	28	.	.	.	.	field trials in 1 zone	excluded
F	B-1-GRAPE	6	8	.	.	.	.	field trials in 1 zone	excluded
F	B-1-GRAPE	8	29	.	.	.	.	field trials in 1 zone	excluded
F	B-1-PEACH	3	12	.	.	.	.	field trials in 1 zone	excluded
F	B-1-PLUM	3	16	.	.	.	.	field trials in 1 zone	excluded
F	B-2-GRAPE	3	16	.	.	.	.	field trials in 1 zone	excluded
F	B-2-GRAPE	6	18	.	.	.	.	field trials in 1 zone	excluded
F	B-3-TOMATO	3	41	.	.	.	.	field trials in 1 zone	excluded
F	C-1-CHERRY,SWEET	2	.	.	.	9	.	field trials in 1 zone	excluded
F	C-1-CHERRY,TART	2	.	.	.	7	.	field trials in 1 zone	excluded
F	C-1-PEACH	2	.	.	.	16	.	field trials in 1 zone	excluded
H	B-4-BARLEY	1	.	.	.	15	.	field trials in 1 zone	excluded
H	B-4-BEAN	1	.	.	.	10	.	field trials in 1 zone	excluded
H	B-4-CANOLA	1	.	.	.	16	.	field trials in 1 zone	excluded
H	B-4-PEA	1	.	.	.	9	.	field trials in 1 zone	excluded
H	B-4-SUNFLOWER	2	.	.	.	12	.	field trials in 1 zone	excluded
H	B-4-WHEAT-GRAIN	1	.	.	.	25	.	field trials in 1 zone	excluded
H	B-5-CANOLA	1	.	.	.	37	.	field trials in 1 zone	excluded
H	B-5-WHEAT-GRAIN	1	.	.	.	42	.	field trials in 1 zone	excluded
H	B-5-WHEAT-GRAIN	2	.	.	.	9	.	field trials in 1 zone	excluded
H	B-6-CUCUMBER	2	5	.	.	.	.	field trials in 1 zone	excluded
H	B-6-MELON	2	7	.	.	.	.	field trials in 1 zone	excluded
H	B-6-ZUCCHINI	2	4	.	.	.	.	field trials in 1 zone	excluded
H	C-3-LEAFLETTUCE	2	.	.	.	13	.	field trials in 1 zone	excluded
H	C-3-LETTUCE,HEAD	2	.	.	.	13	.	field trials in 1 zone	excluded
H	E-1-CANOLA	3				22		field trials in 1 zone	excluded
H	E-1-LENTILS					11		field trials in 1 zone	excluded
I	B-8-APPLE	1	2	.	.	.	.	field trials in 1 zone	excluded
I	B-8-APPLE	5	6	.	.	.	.	field trials in 1 zone	excluded

PestType	CropPest	No_Appli	Number of field trials					Reason	Excluded
			EU	ASIA	SA	NA	AU_NZ		
I	B-8-BARLEY	1	11	.	.	.	.	field trials in 1 zone	excluded
I	B-8-BARLEY	2	8	.	.	.	.	field trials in 1 zone	excluded
I	B-8-BROCCOLI	1	12	.	.	.	.	field trials in 1 zone	excluded
I	B-8-CABBAGE	1	5	.	.	.	.	field trials in 1 zone	excluded
I	B-8-COMMONBEANS	1	14	.	.	.	.	field trials in 1 zone	excluded
I	B-8-KALE	1	3	.	.	.	.	field trials in 1 zone	excluded
I	B-8-LEAFYCABBAGE	1	4	.	.	.	.	field trials in 1 zone	excluded
I	B-8-LEEK	1	16	.	.	.	.	field trials in 1 zone	excluded
I	B-8-LETTUCE	1	38	.	.	.	.	field trials in 1 zone	excluded
I	B-8-PEAR	1	.	.	.	3	.	field trials in 1 zone	excluded
I	B-8-RAPE-PODS,WITHSEED	2	2	.	.	.	.	field trials in 1 zone	excluded
I	B-8-RAPE-SEED	2	8	.	.	.	.	field trials in 1 zone	excluded
I	B-8-SUGARBEET	1	10	.	.	.	.	field trials in 1 zone	excluded
I	B-8-WHEAT-EARS	2	13	.	.	.	.	field trials in 1 zone	excluded
I	B-8-WHEAT-EARS	3	7	.	.	.	.	field trials in 1 zone	excluded
I	B-8-WHEAT-GRAIN	3	10	.	.	.	.	field trials in 1 zone	excluded
I	D-1-COFFEE	4	.	.	11	.	.	field trials in 1 zone	excluded
I	F-1-LEAFLETTUCE	1	.	.	.	1	.	field trials in 1 zone	excluded
I	F-1-LETTUCE,HEAD	1	.	.	.	1	.	field trials in 1 zone	excluded
I	F-1-MANDARIN	1	6	.	.	.	.	field trials in 1 zone	excluded
I	F-1-MANDARIN	2	8	.	.	.	.	field trials in 1 zone	excluded
I	F-1-MANDARIN	3	1	.	.	.	.	field trials in 1 zone	excluded
I	F-1-ORANGE	1	4	.	.	.	.	field trials in 1 zone	excluded
I	F-1-ORANGE	2	8	.	.	.	.	field trials in 1 zone	excluded
PGR	C-2-STRAWBERRY	3	.	.	.	9	.	field trials in 1 zone	excluded

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Table 10: Number of field trials and combinations in CLA database that have field trials in more than 1 zone.
    Data included in the analysis based on similar PHI, larger number of field trials, and lowest proportion data < LOD or LOQ

Pest Type	CropPest	No Appli	Commodity	PHI	Number of field trials					Reason	Excluded
					EU	ASIA	SA	NA	AU_NZ		
F	B-1-APPLE	6	FRUIT	27	3	.	.	.	.	uncommon PHI	excluded
F	B-1-APPLE	6	FRUIT	28	3	.	.	.	.	uncommon PHI	excluded
F	B-1-APPLE	6	FRUIT	29	2	.	.	.	.	uncommon PHI	excluded
F	B-1-APPLE	6	FRUIT	34	3	.	.	.	.	uncommon PHI	excluded
F	B-1-APPLE	6	FRUIT	35	22	.	.	.	.	uncommon PHI	excluded
F	B-1-APPLE	6	FRUIT	36	7	.	.	.	.	uncommon PHI	excluded
F	B-1-APPLE	6	FRUIT	41	4	.	.	.	.	uncommon PHI	excluded
F	B-1-APPLE	6	FRUIT	42	24	.	.	.	.	uncommon PHI	excluded
F	B-1-APPLE	6	FRUIT	43	4	.	.	.	.	uncommon PHI	excluded
F	B-1-APPLE	6	FRUIT	48	6	.	.	.	.		
F	B-1-APPLE	6	FRUIT	49	17	.	.	.	.		
F	B-1-APPLE	6	FRUIT	50	1	1	.	.	.		
F	B-1-APPLE	7	FRUIT	20	.	1	.	.	.	No_Appli = 6 were used	excluded
F	B-1-APPLE	7	FRUIT	21	10	.	.	.	.	No_Appli = 6 were used	excluded
F	B-1-APPLE	7	FRUIT	22	2	.	.	.	.	No_Appli = 6 were used	excluded
F	B-1-PEACH	2	FRUIT	3	2	.	1	.	.	most data <LOD or <LOD	excluded
F	B-3-APPLE	4	FRUIT	6	1	.	.	.	.	common use pattern PHIs=13,14,15 were selected	excluded
F	B-3-APPLE	4	FRUIT	7	9	.	3	.	.	common use pattern PHIs=13,14,15 were selected	excluded
F	B-3-APPLE	4	FRUIT	8	3	.	.	.	.	common use pattern PHIs=13,14,15 were selected	excluded
F	B-3-APPLE	4	FRUIT	13	3	.	.	.	.		
F	B-3-APPLE	4	FRUIT	14	6	.	12	.	.		
F	B-3-APPLE	4	FRUIT	15	5	.	.	.	.		
F	B-3-APPLE	4	FRUIT	20	3	.	.	.	.	common use pattern PHIs=13,14,15 were selected	excluded
F	B-3-APPLE	4	FRUIT	21	9	.	3	.	.	common use pattern PHIs=13,14,15 were selected	excluded
F	B-3-APPLE	4	FRUIT	22	3	.	.	.	.	common use pattern PHIs=13,14,15 were selected	excluded
F	B-3-APPLE	4	FRUIT	27	2	.	.	.	.	common use pattern PHIs=13,14,15 were selected	excluded
F	B-3-APPLE	4	FRUIT	28	20	.	3	.	.	common use pattern PHIs=13,14,15 were selected	excluded
F	B-3-APPLE	4	FRUIT	29	4	.	.	.	.	common use pattern PHIs=13,14,15 were selected	excluded
F	B-3-APPLE	4	FRUIT	34	1	.	.	.	.	common use pattern PHIs=13,14,15 were selected	excluded
F	B-3-APPLE	4	FRUIT	35	11	.	3	.	.	common use pattern PHIs=13,14,15 were selected	excluded
F	B-3-APPLE	4	FRUIT	36	4	.	.	.	.	common use pattern PHIs=13,14,15 were selected	excluded
F	B-3-WHEAT-GRAIN	2	GRAIN	28	1	.	.	1	.	uncommon PHI	excluded

Pest Type	CropPest	No Appli	Commodity	PHI	Number of field trials					Reason	Excluded
					EU	ASIA	SA	NA	AU_NZ		
F	B-3-WHEAT-GRAIN	2	GRAIN	29	.	.	.	1	.	uncommon PHI	excluded
F	B-3-WHEAT-GRAIN	2	GRAIN	33	1	.	.	1	.		
F	B-3-WHEAT-GRAIN	2	GRAIN	34	.	.	.	1	.		
F	B-3-WHEAT-GRAIN	2	GRAIN	35	3	.	.	4	.		
F	B-3-WHEAT-GRAIN	2	GRAIN	36	4	.	.	3	.		
F	B-3-WHEAT-GRAIN	2	GRAIN	37	.	.	.	1	.		
F	B-3-WHEAT-GRAIN	2	GRAIN	38	.	.	.	2	.		
F	B-6-HOPS	2	DRIED CONES	2	1	.	.	1	.		
F	B-6-HOPS	2	DRIED CONES	3	4	.	.	2	.		
F	B-6-HOPS	2	DRIED CONES	4	1	.	.	1	.		
F	B-6-HOPS	2	GREEN CONES	2	1	.	.	1	.	commodity with same field trials	excluded
F	B-6-HOPS	2	GREEN CONES	3	4	.	.	2	.	commodity with same field trials	excluded
F	B-6-HOPS	2	GREEN CONES	4	1	.	.	1	.	commodity with same field trials	excluded
F	D-3-GRAPE	2		3	17	.	.	17	.		
F	D-3-STRAWBERRY	2	FRUIT	0	18	.	.	10	.		
F	D-3-TOMATO	2	FRUIT	0	10	.	.	12	.		
H	A-1-SORGHUM	1	GRAIN	95	.	.	.	1	.	most data <LOD or <LOD	excluded
H	A-1-SORGHUM	1	GRAIN	98	1	.	.	.	.	most data <LOD or <LOD	excluded
H	A-1-SORGHUM	1	GRAIN	99	.	.	.	1	.	most data <LOD or <LOD	excluded
H	A-1-SORGHUM	1	GRAIN	102	.	.	.	2	.	most data <LOD or <LOD	excluded
H	A-1-SORGHUM	1	GRAIN	107	1	.	.	1	.	most data <LOD or <LOD	excluded
H	A-1-SORGHUM	1	GRAIN	111	.	.	.	1	.	most data <LOD or <LOD	excluded
H	A-1-SORGHUM	1	GRAIN	112	.	.	.	1	.	most data <LOD or <LOD	excluded
H	A-1-SORGHUM	1	GRAIN	115	.	.	.	1	.	most data <LOD or <LOD	excluded
H	A-1-SORGHUM	1	GRAIN	117	.	.	.	1	.	most data <LOD or <LOD	excluded
H	A-1-SORGHUM	1	GRAIN	121	.	.	.	1	.	most data <LOD or <LOD	excluded
H	A-1-SORGHUM	1	GRAIN	123	1	.	.	.	.	most data <LOD or <LOD	excluded
H	A-1-SORGHUM	1	GRAIN	125	1	.	.	.	.	most data <LOD or <LOD	excluded
H	A-1-SORGHUM	1	GRAIN	128	.	.	.	1	.	most data <LOD or <LOD	excluded
H	A-1-SORGHUM	1	GRAIN	133	.	.	.	1	.	most data <LOD or <LOD	excluded
H	A-1-STRAWBERRY	2	FRUIT	24	.	.	.	1	.	most data <LOD or <LOD	excluded
H	A-1-STRAWBERRY	2	FRUIT	28	.	.	.	1	.	most data <LOD or <LOD	excluded
H	A-1-STRAWBERRY	2	FRUIT	29	.	.	.	2	.	most data <LOD or <LOD	excluded
H	A-1-STRAWBERRY	2	FRUIT	31	.	.	.	2	.	most data <LOD or <LOD	excluded
H	A-1-STRAWBERRY	2	FRUIT	32	.	.	.	1	.	most data <LOD or <LOD	excluded

Pest Type	CropPest	No Appli	Commodity	PHI	Number of field trials					Reason	Excluded
					EU	ASIA	SA	NA	AU_NZ		
H	A-1-STRAWBERRY	2	FRUIT	33	1	.	.	1	.	most data <LOD or <LOD	excluded
H	B-4-SOYBEAN	1	DRIED SEED	2	1	.	.	5	.		
H	B-4-SOYBEAN	1	DRIED SEED	3	.	.	.	15	.	uncommon PHI and most data < LOD	excluded
H	B-4-SOYBEAN	1	DRIED SEED	4	.	.	.	1	.	uncommon PHI and most data < LOD	excluded
H	B-7-CARROT	1	ROOTS	41	3	.	.	.	.	uncommon PHI	excluded
H	B-7-CARROT	1	ROOTS	42	5	.	.	.	.	uncommon PHI	excluded
H	B-7-CARROT	1	ROOTS	58	1	.	.	.	.	most data <LOD or <LOD	excluded
H	B-7-CARROT	1	ROOTS	59	.	.	.	1	.	most data <LOD or <LOD	excluded
I	B-8-CABBAGE	2	CABBAGE	3	1	.	.	.	.	label PHI = 7 was selected	excluded
I	B-8-CABBAGE	2	CABBAGE	4	1	.	1	.	.	label PHI = 7 was selected	excluded
I	B-8-CABBAGE	3	CABBAGE	7	2	.	.	2	.		
I	B-8-WHEAT-GRAIN	2	GRAIN	19	.	.	1	.	.	most data <LOD or <LOD	excluded
I	B-8-WHEAT-GRAIN	2	GRAIN	20	.	.	1	.	.	most data <LOD or <LOD	excluded
I	B-8-WHEAT-GRAIN	2	GRAIN	21	3	.	.	.	.	most data <LOD or <LOD	excluded
I	B-8-WHEAT-GRAIN	2	GRAIN	27	3	.	.	.	.	uncommon PHI	excluded
I	B-8-WHEAT-GRAIN	2	GRAIN	28	3	.	.	.	.	uncommon PHI	excluded
I	D-1-BLUEBERRY	2	FRUIT	3	5	.	3	13	5		
I	D-1-HOPS	1	DRIED CONES	20	2	.	.	.	.		
I	D-1-HOPS	1	DRIED CONES	21	5	.	.	3	.		
I	D-1-HOPS	1	DRIED CONES	22	1	.	.	.	.		
I	D-2-AVOCADO	3	FRUIT	1	.	.	3	2	.		
I	F-1-LEAFLETTUCE	2	LEAVES	0	.	.	.	1	.	uncommon PHI	excluded
I	F-1-LEAFLETTUCE	2	LEAVES	1	.	.	.	6	.	uncommon PHI	excluded
I	F-1-LEAFLETTUCE	2	LEAVES	3	.	.	.	1	.	uncommon PHI	excluded
I	F-1-LEAFLETTUCE	2	LEAVES	5	.	.	.	1	.	uncommon PHI	excluded
I	F-1-LEAFLETTUCE	2	LEAVES	6	2	.	.	.	.	uncommon PHI	excluded
I	F-1-LEAFLETTUCE	2	LEAVES	7	4	.	.	.	.	uncommon PHI	excluded
I	F-1-LEAFLETTUCE	2	LEAVES	8	1	.	.	.	.	uncommon PHI	excluded
I	F-1-LEAFLETTUCE	3	LEAVES	0	7	.	.	.	.	uncommon PHI	excluded
I	F-1-LEAFLETTUCE	3	LEAVES	1	7	.	.	12	.		
I	F-1-LEAFLETTUCE	3	LEAVES	3	7	.	.	.	.	uncommon PHI	excluded
I	F-1-LETTUCE,HEAD	2	HEAD	1	.	.	.	6	.	uncommon PHI and No_Appli = 3 were used	excluded
I	F-1-LETTUCE,HEAD	2	HEAD	7	2	.	.	.	.	uncommon PHI and No_Appli = 3 were used	excluded
I	F-1-LETTUCE,HEAD	2	HEAD	8	1	.	.	.	.	uncommon PHI and No_Appli = 3 were used	excluded
I	F-1-LETTUCE,HEAD	3	HEAD	0	3	.	.	.	.	same field trials as PHI = 1	excluded

Pest Type	CropPest	No Appli	Commodity	PHI	Number of field trials					Reason	Excluded
					EU	ASIA	SA	NA	AU_NZ		
I	F-1-LETTUCE,HEAD	3	HEAD	1	3	.	.	12	.		
I	F-1-LETTUCE,HEAD	3	HEAD	3	3	.	.	.	.	uncommon PHI	excluded
I	F-1-ORANGE	3	FRUIT	1	2	.	.	13	.		
I	F-2-APPLE	4	FRUIT	7	22	.	.	5	.		
I	F-2-GRAPE	3		1	11	.	.	.	2		
I	F-2-LEAFLETTUCE	4	LEAVES	3	15	.	.	11	.		

Table 11: Distribution of number of field trials of IR-4 Tomato

Chemical	Pest Type	Crop-Pest	PHI	Number of field trials						Reason	Excluded
				AF	ASIA	AU_NZ	EU	NA	SA		
1	I	IR4-1-TOMATO	0	5	7	2	5	6	2	Use data of chemical #4	excluded
			24	5	7	2	5	6	2	Use data of chemical #4	excluded
			72	5	7	2	5	6	2	Use data of chemical #4	excluded
2	F	IR4-2-TOMATO	0	5	7	2	5	6	2	Use data of chemical #4	excluded
			24	5	7	2	5	6	2	Use data of chemical #4	excluded
			72	5	7	2	5	6	2	Use data of chemical #4	excluded
3	F	IR4-3-TOMATO	0	5	7	2	5	6	2	Use data of chemical #4	excluded
			24	5	7	2	5	6	2	Use data of chemical #4	excluded
			72	5	7	2	5	6	2	Use data of chemical #4	excluded
4	I	IR4-4-TOMATO	0	5	7	2	5	6	2	Use data of PHI = 72 hrs	excluded
			24	5	7	2	5	6	2	Use data of PHI = 72 hrs	excluded
			72	5	7	2	5	6	2		
Note: There were 4 chemicals applied to each field trial and each field trial had 3 PHIs (0, 24, and 72 hours)											
Data of chemical 4 on PHI = 72 were selected for analysis because greatest PHI and lowest proportion of residues < LOD or LOQ.											

Table 12: Distribution of numbers of field trials and crop-pesticide combinations in FMC database

Pest Type	Crop-Pest	No Appli	Number of field trials					Reason	Excluded
			EU	ASIA	NA	SA	AF		
I	FMC-1-ALFALFA	2	4	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-1-ARTICHOKE	2	4	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-1-ASPARAGUS	4	.	1	.	.	.	Field trials in 1 zone	excluded
I	FMC-1-BARLEY	1	14	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-1-BEANS	2	13	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-1-BROCCOLI	2	7	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-1-BROCCOLI	6	.	.	6	.	.	Field trials in 1 zone	excluded
I	FMC-1-BRUSSELSPROUTS	2	7	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-1-CABBAGE,HEAD	2	13	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-1-CARAMBOLA	3	.	1	.	.	.	Field trials in 1 zone	excluded
I	FMC-1-CARAMBOLA	4	.	1	.	.	.	Field trials in 1 zone	excluded
I	FMC-1-CARROT	2	13	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-1-CAULIFLOWER	2	9	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-1-CHILLIPEPPER	3	.	1	.	.	.	Field trials in 1 zone	excluded
I	FMC-1-CHILLIPEPPER	4	.	1	.	.	.	Field trials in 1 zone	excluded
I	FMC-1-COFFEE	3	.	.	.	2	.	Field trials in 1 zone	excluded
I	FMC-1-CORN	2	7	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-1-COTTON	2	5	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-1-DURIAN	3	.	1	.	.	.	Field trials in 1 zone	excluded
I	FMC-1-GRAPE	1	13	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-1-GRAPE	2	1	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-1-LEEK	2	7	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-1-LETTUCE	2	14	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-1-LETTUCE	6	.	.	6	.	.	Field trials in 1 zone	excluded
I	FMC-1-LETTUCE	15	.	.	13	.	.	Field trials in 1 zone	excluded
I	FMC-1-LITCHI	3	.	1	.	.	.	Field trials in 1 zone	excluded
I	FMC-1-LONGAN	3	.	1	.	.	.	Field trials in 1 zone	excluded
I	FMC-1-LONGAN	4	.	1	.	.	.	Field trials in 1 zone	excluded
I	FMC-1-MANGO	4	.	1	.	.	.	Field trials in 1 zone	excluded
I	FMC-1-MANGO	7	.	1	.	.	.	Field trials in 1 zone	excluded
I	FMC-1-MANGO	8	.	1	.	.	.	Field trials in 1 zone	excluded
I	FMC-1-MELON	2	7	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-1-MUSTARDGREENS	4	.	.	7	.	.	Field trials in 1 zone	excluded

Pest Type	Crop-Pest	No Appli	Number of field trials					Reason	Excluded
			EU	ASIA	NA	SA	AF		
I	FMC-1-OKRA	4	.	1	.	.	.	Field trials in 1 zone	excluded
I	FMC-1-OKRA	5	.	1	.	.	.	Field trials in 1 zone	excluded
I	FMC-1-OLIVE	2	6	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-1-ONION	2	18	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-1-PAPAYA	2	.	1	.	.	.	Field trials in 1 zone	excluded
I	FMC-1-PEAS	2	5	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-1-POTATO	2	9	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-1-RAPESEED	2	4	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-1-SOYBEANS	1	.	.	.	2	.	Field trials in 1 zone	excluded
I	FMC-1-SPINACH	2	9	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-1-SUGARBEET	2	7	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-1-TOMATO	1	.	.	.	2	.	Field trials in 1 zone	excluded
I	FMC-1-TOMATO	2	6	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-1-WHEAT	1	16	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-2-APPLE	1	4		3			Different PHIs between zones, <LOQ	excluded
I	FMC-2-APPLE	5	6	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-2-APPLE	7	3	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-2-CHERRY	2	2	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-2-GRAPE	1	8	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-2-GRAPE	2	1	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-2-PEACH	1	3	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-2-PEACH	3	.	.	.	.	6	Field trials in 1 zone	excluded
I	FMC-2-PEAR	1	.	.	2	.	.	Field trials in 1 zone	excluded
I	FMC-3-ALFALFA	1	.	.	6	.	.	Field trials in 1 zone	excluded
I	FMC-3-APPLE	6	.	.	11	.	.	Field trials in 1 zone	excluded
I	FMC-3-BARLEY	1	1	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-3-BARLEY	2	16	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-3-BEANS	2	13	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-3-BEANS	6	.	.	21	.	.	Field trials in 1 zone	excluded
I	FMC-3-BROCCOLI	6	.	.	2	.	.	Field trials in 1 zone	excluded
I	FMC-3-CANTALOUPE	6	.	.	6	.	.	Field trials in 1 zone	excluded
I	FMC-3-CHERRY	6	.	.	6	.	.	Field trials in 1 zone	excluded
I	FMC-3-CHILLIPEPPER	6	.	.	3	.	.	Field trials in 1 zone	excluded
I	FMC-3-COFFEE	1	.	.	.	2	.	Field trials in 1 zone	excluded
I	FMC-3-CORN	1	8			6		Different commodities or PHIs between zones	excluded

Pest Type	Crop-Pest	No Appli	Number of field trials					Reason	Excluded
			EU	ASIA	NA	SA	AF		
I	FMC-3-CORN	2	.	.	6	.	.	Field trials in 1 zone	excluded
I	FMC-3-CORN	3	.	.	2	.	.	Field trials in 1 zone	excluded
I	FMC-3-CORN	4	.	.	9	.	.	Field trials in 1 zone	excluded
I	FMC-3-COTTON	1	.	.	.	3	.	Field trials in 1 zone	excluded
I	FMC-3-COTTON	2	4	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-3-CUCUMBER	1	2	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-3-CUCUMBER	6	.	.	6	.	.	Field trials in 1 zone	excluded
I	FMC-3-ENDIVE	1	4	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-3-LETTUCE	1	4	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-3-LETTUCE	6	.	.	6	.	.	Field trials in 1 zone	excluded
I	FMC-3-OAT	2	2	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-3-OILSEEDRAPE	1	3	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-3-OILSEEDRAPE	2	2	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-3-ONION	1	.	.	.	2	.	Field trials in 1 zone	excluded
I	FMC-3-ONION	5	.	.	4	.	.	Field trials in 1 zone	excluded
I	FMC-3-PEACH	6	.	.	8	.	.	Field trials in 1 zone	excluded
I	FMC-3-PEANUT	6	.	.	12	.	.	Field trials in 1 zone	excluded
I	FMC-3-PEAR	6	.	.	6	.	.	Field trials in 1 zone	excluded
I	FMC-3-PEAS	1	6	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-3-PEAS	2	28	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-3-PEAS	6	.	.	14	.	.	Field trials in 1 zone	excluded
I	FMC-3-PEPPER	1	2	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-3-PEPPER	6	.	.	6	.	.	Field trials in 1 zone	excluded
I	FMC-3-PLUM	6	.	.	6	.	.	Field trials in 1 zone	excluded
I	FMC-3-RICE	4	.	.	22	.	.	Field trials in 1 zone	excluded
I	FMC-3-SOYBEANS	1	.	.	.	2	.	Field trials in 1 zone	excluded
I	FMC-3-SOYBEANS	6	.	.	17	.	.	Field trials in 1 zone	excluded
I	FMC-3-SPINACH	6	.	.	5	.	.	Field trials in 1 zone	excluded
I	FMC-3-SUGARBEET	3	.	.	11	.	.	Field trials in 1 zone	excluded
I	FMC-3-SUGARCANE	4	.	.	8	.	.	Field trials in 1 zone	excluded
I	FMC-3-SWEETCORN	6	.	.	3	.	.	Field trials in 1 zone	excluded
I	FMC-3-TOMATO	1	.	.	.	4	.	Field trials in 1 zone	excluded
I	FMC-3-TOMATO	6	.	.	12	.	.	Field trials in 1 zone	excluded
I	FMC-3-TRITICALE	2	2	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-3-WHEAT	1	9	.	.	.	.	Field trials in 1 zone	excluded

Pest Type	Crop-Pest	No Appli	Number of field trials					Reason	Excluded
			EU	ASIA	NA	SA	AF		
I	FMC-3-WHEAT	2	13	.	.	.	.	Field trials in 1 zone	excluded
I	FMC-3-WHEAT	5	.	.	16	.	.	Field trials in 1 zone	excluded
I	FMC-3-YELLOWSQUASH	6	.	.	2	.	.	Field trials in 1 zone	excluded
I	FMC-3-ZUCCHINI	6	.	.	3	.	.	Field trials in 1 zone	excluded

VII. Appendix A: Exchangeability of Field Trial Residues between United States and Canada

Objective

The objective of this analysis was to evaluate the concept of exchangeability of field trial residues between the United States and Canada.

Database

The field trial residue database was obtained from PMRA. The database consists of the US and CAN field trial residue data of 219 different Crop-Pesticide combinations, 21 different crop groups, and 37 different pesticides. Each combination has at least one field trial for each country. Majority of the small number of field trials were from Canada (Table 1). Each field trial may have more than 1 residue value (replicates). We observed that some Crop-Pesticide combinations had more than one PHI; however, the difference was only 1 or 2 days apart. The Principle of Proportionality has been used to adjust the residues of field trials where different application rates were used.

The table below presents the number of field trials by each type of pesticide for each country

Pest Type	N field trials	
	Canada	United States
F	562	1331
I	297	622
H	27	56

Statistical Methods

Similar to the evaluation of global exchangeability of field trial residues, a rank-sum test for clustered data and a mixed-effects model were used to analyze and compare the field trial residues between the United States and Canada. The rank-sum test for clustered data, which is a non-parametric test, does not make any assumptions about the distribution of the field trial residues and directly use field trial residue data for the analysis without any transformation. The mixed-effects model analysis assumes the residue data follow lognormal distributions, so the residue data were log-transformed prior the analysis.

Results and Conclusions

Table A-1 below presents the results of analyses using mixed-effects model and rank-sum test for clustered data. Both rank-sum test for clustered data and mixed-effects model indicate that field trial residues between the United States and Canada are not significantly different (rank-sum test p-value = 0.268, mixed-effects model p-value = 0.281). The mixed-effects model shows that the residues of Canadian field trials are about 5% higher than the United States, but the difference is not statistically different (95% CI = (-4%, 15%)).

Table A-1: Results of rank-sum test and mixed-effects model analyses

Comparison	Mixed-effects model		Rank-Sum test for clustered data
	Ratio (95% CI)	p-value	p-value
Canada vs. United States	1.052 (0.959, 1.153)	0.281	0.268

Table A-2: The covariance matrix estimated from the mixed-effect model

Covariance Parameter Estimates		
Cov Parm	Subject	Estimate
Intercept	Crop_Chem	2.1426
Country	Crop_Chem	0.1150
Trial (Crop_Chem)		0.4754
Residual		0.0613

Regression Diagnostics

The histogram and Q-Q plot below show that the selected mixed-effects model appropriately fit the data.

Figure A- 1:   Histogram of estimated log (ratio) of field trial residues between Canada and the United States by crop-pesticide combination (log(ratio) = random effect + fixed effect)
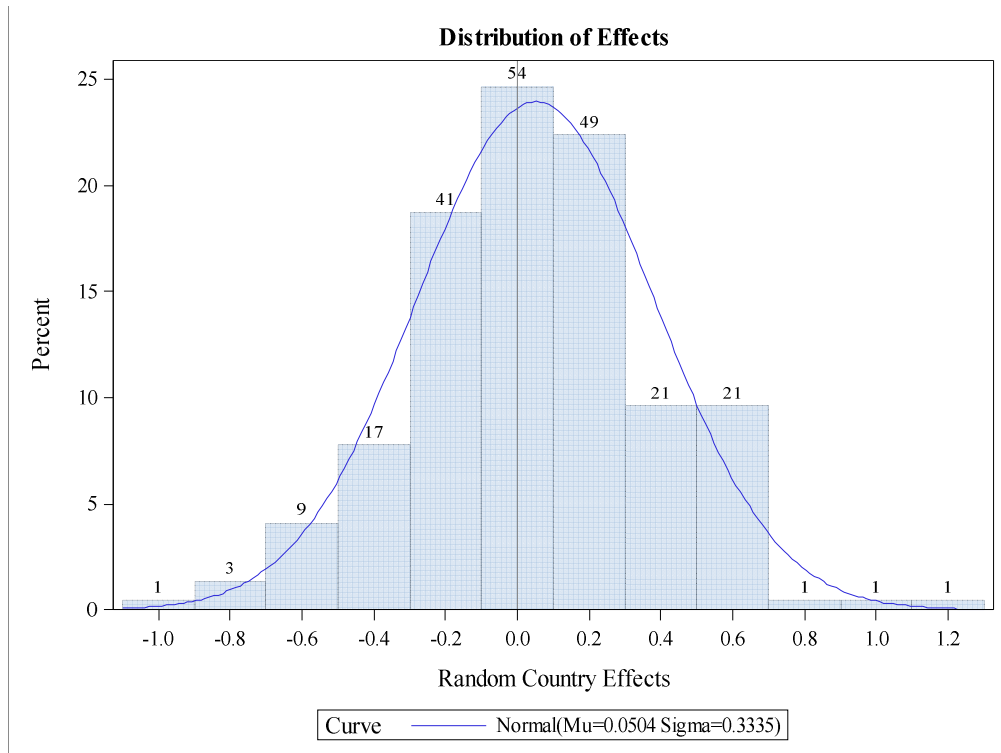
Figure A-2:   Normal Quantiles plot of estimated log (ratio) of field trial residues between Canada and the United States by crop-pesticide combination
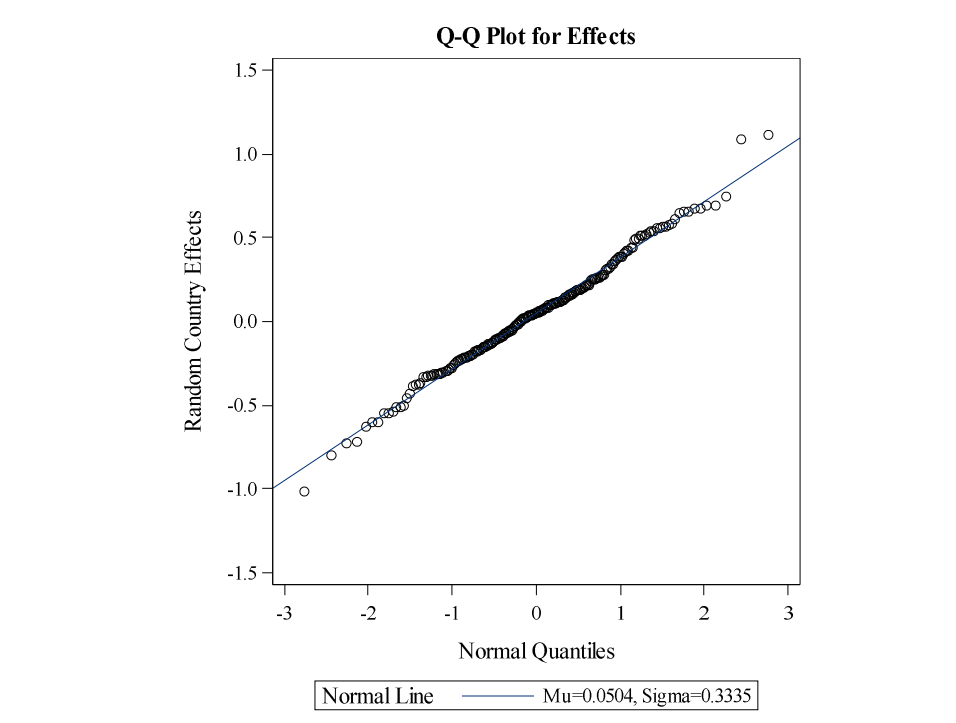
Figure A-3:   Histogram of estimated ratios of field trial residues between Canada and the United States by crop-pesticide combination
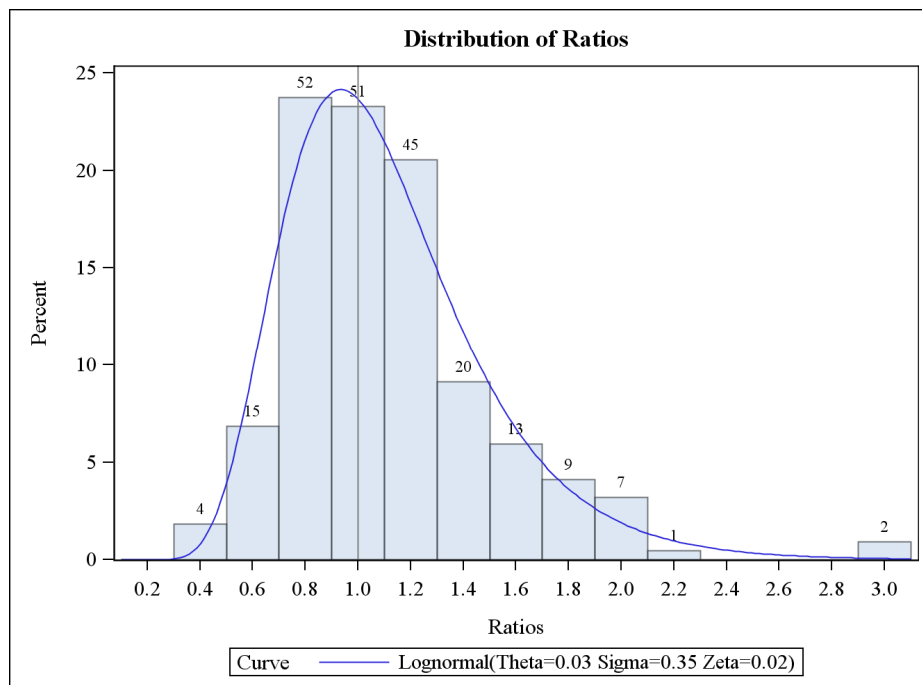
Table A-3: Estimated field trial residue ratio and associated number of field trial per crop-pesticide combination (sorted by estimated ratio)

Crop_Chem	Log(Ratio) Canada vs. US	Ratio Canada vs. US	Ratio US vs. Canada	# Trials in Canada	# Trials in US
Apples-F-21	-1.0142	0.36	2.76	11	13
HeadLettuce-I-2	-0.7948	0.45	2.21	2	8
Apples-M-1	-0.7299	0.48	2.07	11	14
Grapes-F-1	-0.7170	0.49	2.05	2	24
Apples-I-14	-0.6251	0.54	1.87	4	20
BellPeppers-I-3	-0.6027	0.55	1.83	4	7
Strawberries-I-4	-0.6008	0.55	1.82	4	6
Spinach-F-17	-0.5509	0.58	1.73	5	8
HeadLettuce-F-17	-0.5451	0.58	1.72	5	9
Cabbage-wwrapper-F-19	-0.5381	0.58	1.71	5	8
Cabbage-wwrapper-I-3	-0.5094	0.60	1.66	3	7
HeadLettuce-F-19	-0.5088	0.60	1.66	6	4
Cabbage-wwrapper-F-17	-0.5045	0.60	1.66	3	7
Ginseng-F-10	-0.4533	0.64	1.57	2	2
LeafLettuce-I-2	-0.4329	0.65	1.54	2	8
Sugarbeet-F-17	-0.3875	0.68	1.47	6	18
Peaches-I-4	-0.3806	0.68	1.46	5	10
Canola-F-2	-0.3771	0.69	1.46	18	2
Ginseng-F-9	-0.3700	0.69	1.45	1	2
Apples-F-9	-0.3294	0.72	1.39	5	17
Soybeans-I-6	-0.3273	0.72	1.39	3	18
Grapes-I-3	-0.3262	0.72	1.39	11	12
Cabbage-wwrapper-I-2	-0.3210	0.73	1.38	4	10
Strawberries-I-2	-0.3188	0.73	1.38	3	7
Peaches-I-2	-0.3130	0.73	1.37	5	13
Spinach-I-2	-0.3128	0.73	1.37	3	8
Strawberries-I-15	-0.3119	0.73	1.37	6	8
Peaches-F-13	-0.3101	0.73	1.36	2	22
LeafLettuce-F-1	-0.3068	0.74	1.36	1	8
BellPeppers-F-13	-0.3014	0.74	1.35	2	6
Cabbage-wwrapper-F-3	-0.2985	0.74	1.35	5	6
Grapes-F-21	-0.2977	0.74	1.35	5	12

Crop_Chem	Log(Ratio) Canada vs. US	Ratio Canada vs. US	Ratio US vs. Canada	# Trials in Canada	# Trials in US
Apples-F-13	-0.2828	0.75	1.33	4	24
Plums-I-2	-0.2791	0.76	1.32	5	8
BellPeppers-F-10	-0.2744	0.76	1.32	4	5
Peaches-I-3	-0.2626	0.77	1.30	11	12
BellPeppers-F-5	-0.2481	0.78	1.28	4	5
Cherries-F-13	-0.2428	0.78	1.27	2	10
MustardGreens-F-19	-0.2355	0.79	1.27	3	5
Cranberries-I-13	-0.2348	0.79	1.26	1	6
Apples-I-3	-0.2282	0.80	1.26	4	13
Non-bellPeppers-I-3	-0.2198	0.80	1.25	5	4
Pears-F-21	-0.2174	0.80	1.24	3	6
Edible-podded(Succulent)Beans-F-17	-0.2145	0.81	1.24	3	5
Cherries-I-2	-0.2129	0.81	1.24	5	10
LeafLettuce-F-17	-0.2099	0.81	1.23	5	10
Sugarbeet-F-13	-0.2084	0.81	1.23	3	9
SucculentPeas-I-3	-0.2043	0.82	1.23	5	1
Pears-I-14	-0.1963	0.82	1.22	4	10
Strawberries-F-17	-0.1946	0.82	1.21	3	6
Barley-grain-F-15	-0.1818	0.83	1.20	4	8
Plums-F-13	-0.1812	0.83	1.20	2	18
Raspberries-I-6	-0.1804	0.83	1.20	2	3
Barley-grain-F-12	-0.1732	0.84	1.19	10	2
MustardGreens-I-8	-0.1722	0.84	1.19	3	11
Raspberries-I-1	-0.1698	0.84	1.19	2	4
Pears-F-13	-0.1585	0.85	1.17	2	18
Apples-I-1	-0.1563	0.86	1.17	3	12
BellPeppers-F-1	-0.1561	0.86	1.17	2	5
Tomatoes-F-17	-0.1500	0.86	1.16	8	12
Spinach-F-1	-0.1403	0.87	1.15	1	7
Peaches-M-1	-0.1395	0.87	1.15	5	10
Greenonion-F-17	-0.1336	0.87	1.14	2	4
DryBeans-F-5	-0.1308	0.88	1.14	5	9
Celery-F-1	-0.1296	0.88	1.14	2	7
Pears-F-14	-0.1253	0.88	1.13	4	14
Carrots-F-9	-0.1221	0.89	1.13	10	16
Tomatoes-I-2	-0.1147	0.89	1.12	5	18

Crop_Chem	Log(Ratio) Canada vs. US	Ratio Canada vs. US	Ratio US vs. Canada	# Trials in Canada	# Trials in US
Raspberries-F-4	-0.1075	0.90	1.11	3	2
Strawberries-F-8	-0.1056	0.90	1.11	1	10
SucculentBeans-I-8	-0.1055	0.90	1.11	5	7
LeafLettuce-F-19	-0.0951	0.91	1.10	6	5
MustardGreens-I-3	-0.0951	0.91	1.10	2	6
Celery-I-2	-0.0941	0.91	1.10	2	8
Spinach-F-3	-0.0931	0.91	1.10	3	8
Tomatoes-F-1	-0.0920	0.91	1.10	4	14
Cantaloupe-F-1	-0.0814	0.92	1.08	1	7
Spinach-F-19	-0.0705	0.93	1.07	3	8
Raspberries-M-1	-0.0679	0.93	1.07	3	3
Peaches-I-8	-0.0675	0.93	1.07	5	10
Carrots-F-10	-0.0660	0.94	1.07	3	9
Peaches-F-17	-0.0593	0.94	1.06	4	9
Celery-F-3	-0.0566	0.94	1.06	9	8
RadishTops-F-3	-0.0514	0.95	1.05	2	5
Carrots-F-7	-0.0511	0.95	1.05	4	9
DryPeas-F-17	-0.0486	0.95	1.05	8	6
BellPeppers-I-8	-0.0317	0.97	1.03	3	6
SucculentShelledPeas-F-17	-0.0283	0.97	1.03	3	4
Broccoli-F-19	-0.0223	0.98	1.02	5	7
Cucumber,cucumbers-F-1	-0.0158	0.98	1.02	1	7
Tomatoes-F-13	-0.0130	0.99	1.01	4	14
Celery-F-19	-0.0080	0.99	1.01	9	8
Wheat-grain-F-15	-0.0020	1.00	1.00	4	11
Oat-grain-F-15	-0.0016	1.00	1.00	4	8
Peaches-I-12	0.0057	1.01	0.99	8	16
Celery-F-17	0.0160	1.02	0.98	6	8
Greenonion-F-3	0.0195	1.02	0.98	1	4
Wheat-grain-F-20	0.0198	1.02	0.98	9	9
Apples-I-8	0.0217	1.02	0.98	6	24
Sunflowers-F-13	0.0255	1.03	0.97	6	2
Radishes-F-17	0.0291	1.03	0.97	1	5
Barley-grain-F-18	0.0336	1.03	0.97	10	11
Apples-I-12	0.0380	1.04	0.96	12	18
Raspberries-I-3	0.0396	1.04	0.96	5	1

Crop_Chem	Log(Ratio) Canada vs. US	Ratio Canada vs. US	Ratio US vs. Canada	# Trials in Canada	# Trials in US
HeadLettuce-F-1	0.0402	1.04	0.96	1	7
SummerSquash-F-1	0.0410	1.04	0.96	1	4
Apples-F-3	0.0414	1.04	0.96	8	24
Cherries-F-17	0.0443	1.05	0.96	1	8
Raspberries-F-6	0.0453	1.05	0.96	3	2
Oat-grain-F-19	0.0551	1.06	0.95	4	8
Raspberries-F-19	0.0558	1.06	0.95	1	5
Apples-I-11	0.0559	1.06	0.95	5	32
Non-bellPeppers-F-17	0.0571	1.06	0.94	5	4
SucculentBeans-F-3	0.0618	1.06	0.94	3	7
EdiblePoddedPeas-I-3	0.0626	1.06	0.94	1	3
Grapes-I-12	0.0663	1.07	0.94	8	22
BellPeppers-F-9	0.0747	1.08	0.93	3	6
Greenonion-F-19	0.0754	1.08	0.93	1	4
Soybeans-F-17	0.0823	1.09	0.92	6	14
Strawberries-I-8	0.0825	1.09	0.92	2	8
Apples-F-19	0.0841	1.09	0.92	8	24
SummerSquash-F-3	0.0856	1.09	0.92	2	7
HighbushBlueberries-I-3	0.0956	1.10	0.91	1	6
BellPeppers-F-17	0.0974	1.10	0.91	5	6
DryBeans-F-17	0.0995	1.10	0.91	5	9
DryShelledPeas-F-19	0.1029	1.11	0.90	4	5
Apples-I-2	0.1042	1.11	0.90	3	17
Tomatoes-F-3	0.1042	1.11	0.90	3	16
Raspberries-I-15	0.1061	1.11	0.90	5	6
MustardGreens-F-17	0.1096	1.12	0.90	1	8
Melon(cantaloupe,muskmelon,mel-F-17	0.1098	1.12	0.90	2	6
Cantaloupe-F-3	0.1130	1.12	0.89	1	7
Peaches-F-3	0.1131	1.12	0.89	1	21
SummerSquash-F-19	0.1201	1.13	0.89	3	7
Wheat-grain-F-18	0.1210	1.13	0.89	12	14
SucculentShelledPeas-F-19	0.1246	1.13	0.88	1	7
Raspberries-F-3	0.1251	1.13	0.88	1	5
Broccoli-I-3	0.1254	1.13	0.88	2	7
DryBeans-F-3	0.1381	1.15	0.87	1	9

Crop_Chem	Log(Ratio) Canada vs. US	Ratio Canada vs. US	Ratio US vs. Canada	# Trials in Canada	# Trials in US
Rye-grain-F-15	0.1413	1.15	0.87	2	3
Spinach-F-10	0.1470	1.16	0.86	3	8
Cranberries-I-7	0.1511	1.16	0.86	1	5
Broccoli-F-1	0.1553	1.17	0.86	1	9
Pears-I-1	0.1594	1.17	0.85	4	6
Broccoli-F-2	0.1595	1.17	0.85	2	2
Canola-F-13	0.1619	1.18	0.85	13	3
Broccoli-F-17	0.1716	1.19	0.84	1	6
Grapes-F-8	0.1717	1.19	0.84	8	18
Broccoli-F-3	0.1794	1.20	0.84	5	6
SucculentBeans-I-3	0.1827	1.20	0.83	2	7
HighbushBlueberries-F-19	0.1852	1.20	0.83	3	3
Cabbage-wwrapper-F-1	0.1852	1.20	0.83	1	9
Cranberries-I-3	0.1881	1.21	0.83	2	4
SucculentBeans-F-19	0.1913	1.21	0.83	3	6
Cherries-I-9	0.1942	1.21	0.82	1	11
Cabbage-wwrapper-F-10	0.2020	1.22	0.82	2	6
HighbushBlueberries-I-12	0.2034	1.23	0.82	1	5
Cherries-I-8	0.2071	1.23	0.81	1	6
Pears-F-19	0.2164	1.24	0.81	4	16
Cauliflower-F-17	0.2176	1.24	0.80	1	2
Spinach-F-5	0.2179	1.24	0.80	3	8
SucculentPeas-F-3	0.2206	1.25	0.80	1	7
Pears-I-6	0.2408	1.27	0.79	4	7
Cucumber,cucumbers-F-17	0.2490	1.28	0.78	3	7
Ginseng-F-8	0.2519	1.29	0.78	3	2
Canola-F-17	0.2531	1.29	0.78	15	6
Cucumber,cucumbers-M-1	0.2541	1.29	0.78	2	6
Cucumber,cucumbers-F-19	0.2626	1.30	0.77	1	11
Pears-I-3	0.2644	1.30	0.77	4	7
Raspberries-F-8	0.2648	1.30	0.77	2	3
Peaches-F-19	0.2712	1.31	0.76	1	21
Broccoli-F-10	0.2748	1.32	0.76	2	5
Tomatoes-F-2	0.2775	1.32	0.76	6	22
Apples-I-10	0.2791	1.32	0.76	6	12
Squash-F-17	0.3082	1.36	0.73	3	6

Crop_Chem	Log(Ratio) Canada vs. US	Ratio Canada vs. US	Ratio US vs. Canada	# Trials in Canada	# Trials in US
Apples-F-17	0.3131	1.37	0.73	4	10
DryBulbOnion-F-10	0.3172	1.37	0.73	2	6
BulbOnion-F-17	0.3225	1.38	0.72	5	5
RadishRoots-F-3	0.3394	1.40	0.71	2	5
Grapes-F-16	0.3425	1.41	0.71	4	24
Cantaloupe-F-19	0.3638	1.44	0.70	1	7
Grapes-F-3	0.3684	1.45	0.69	1	15
Pears-I-2	0.3746	1.45	0.69	3	9
Wheat-grain-F-13	0.3825	1.47	0.68	10	15
Cucumber,cucumbers-F-3	0.3841	1.47	0.68	1	9
LowbushBlueberries-I-3	0.3881	1.47	0.68	3	1
Cabbage-wwrapper-F-2	0.4048	1.50	0.67	2	2
Pears-F-3	0.4160	1.52	0.66	4	16
Grapes-F-11	0.4191	1.52	0.66	5	11
Grapes-F-19	0.4207	1.52	0.66	1	47
Carrots-F-17	0.4397	1.55	0.64	4	9
Tomatoes-I-3	0.4433	1.56	0.64	7	13
BulbOnion-F-1	0.4807	1.62	0.62	1	9
Tomatoes-M-1	0.4966	1.64	0.61	1	11
Plums-F-3	0.4983	1.65	0.61	2	14
Pears-I-8	0.5100	1.67	0.60	4	8
Pears-I-12	0.5153	1.67	0.60	8	10
Canola-I-5	0.5156	1.67	0.60	30	6
DryPeas-F-3	0.5173	1.68	0.60	4	5
LowbushBlueberries-I-12	0.5262	1.69	0.59	5	1
Sunflowers-F-17	0.5358	1.71	0.59	4	5
BellPeppers-F-3	0.5378	1.71	0.58	2	6
Carrots-F-5	0.5541	1.74	0.57	1	8
HighbushBlueberries-F-10	0.5601	1.75	0.57	2	8
Grapes-F-5	0.5645	1.76	0.57	5	12
Barley-grain-F-13	0.5686	1.77	0.57	9	4
Plums-F-17	0.5720	1.77	0.56	3	7
Grapes-I-2	0.5868	1.80	0.56	8	26
Broccoli-F-5	0.6077	1.84	0.54	2	5
Plums-I-8	0.6452	1.91	0.52	5	6
Grapes-F-2	0.6577	1.93	0.52	6	16

Crop_Chem	Log(Ratio) Canada vs. US	Ratio Canada vs. US	Ratio US vs. Canada	# Trials in Canada	# Trials in US
Broccoli-I-2	0.6584	1.93	0.52	4	9
Plums-I-3	0.6740	1.96	0.51	5	12
Sunflowers-F-3	0.6781	1.97	0.51	2	7
Pears-F-17	0.6874	1.99	0.50	4	6
Grapes-M-1	0.6957	2.01	0.50	5	12
Plums-F-19	0.7429	2.10	0.48	2	14
BulbOnion-F-19	1.0886	2.97	0.34	4	7
BulbOnion-F-3	1.1179	3.06	0.33	3	7
* Note: After the analysis, one registrant indicates that the data of these crop-pesticide combinations (BulbOnion-F-19 and BulbOnion-F-3) were from same field trials. Since the results of comparisons using rank-sum test and mixed-effects model are expected not substantially different, the analysis that excluding the data of one of the two crop-pesticide combinations was not done.					

VIII. Appendix B: Exchangeability of Field Trial Residues between Northern Europe and Southern Europe

Objective

The objective of this analysis is to evaluate the exchangeability of field trial residues between Northern Europe and Southern Europe.

Database

Eight different member companies of CropLife America and IR-4 have provided field trial residue data for this analysis. Note that some but not all field trials included in this analysis were also included in the analysis of global exchangeability of field trial residues. The analysis included 702 field trials of 64 different crop-pesticide combinations. Below is the table presenting the distribution of field trials included in the analysis by type of pesticides (fungicide, herbicide, insecticide).

Pest Type	N field trials	
	EU-N	EU-S
F	91	104
H	8	8
I	234	257

Statistical Methods

Similar to the analysis of global exchangeability of field trial residues, mixed-effects models and rank-sum test for clustered data were used to analyze and compare the field trial residues between Northern Europe and Southern Europe. The rank-sum test for clustered data, which is a non-parametric test, does not make any assumptions about the distribution of the field trial residues and directly use field trial residue data for the analysis without any transformation. The mixed-effects model analysis assumes the residue data follow lognormal distributions, so the residue data were log-transformed prior the analysis.

Results and conclusions

Table B-1 below presents the results of analyses using mixed-effects model and rank-sum test for clustered data. Both Rank-Sum test and mixed-effects model analyses indicate that there were no systematic difference between field trial residues in Northern Europe and Southern Europe (p-values = 0.876 and 0.403, respectively). On average, field trial residues in Northern Europe were estimated about 8% higher than FT residues in Southern Europe (95% CI = (-10%, 29%)) but the differences were not significantly different.

Table B-1: Results of rank-sum test and mixed-effects model analyses

Comparison	Mixed-effects model		Rank-Sum test for clustered data
	Ratio (95% CI)	p-value	p-value
EU-N vs.EU-S	1.078 (0.902, 1.290)	0.403	0.876

Table B-2: The covariance matrix estimated from mixed-effects model.

Covariance Parameter Estimates		
Cov Parm	Subject	Estimate
Intercept	CropPest	2.9975
Zone	CropPest	0.1210
Trials (CropPest)		0.5528
Residual		0.09677

Regression diagnostics

The histogram and Q-Q plot below show that the selected mixed-effects model appropriately fit the data.

Figure B-1:   Histogram of estimated log (ratio) of field trial residues between Northern Europe and Southern Europe by crop-pesticide combination (log(ratio) = random effect + fixed effect)
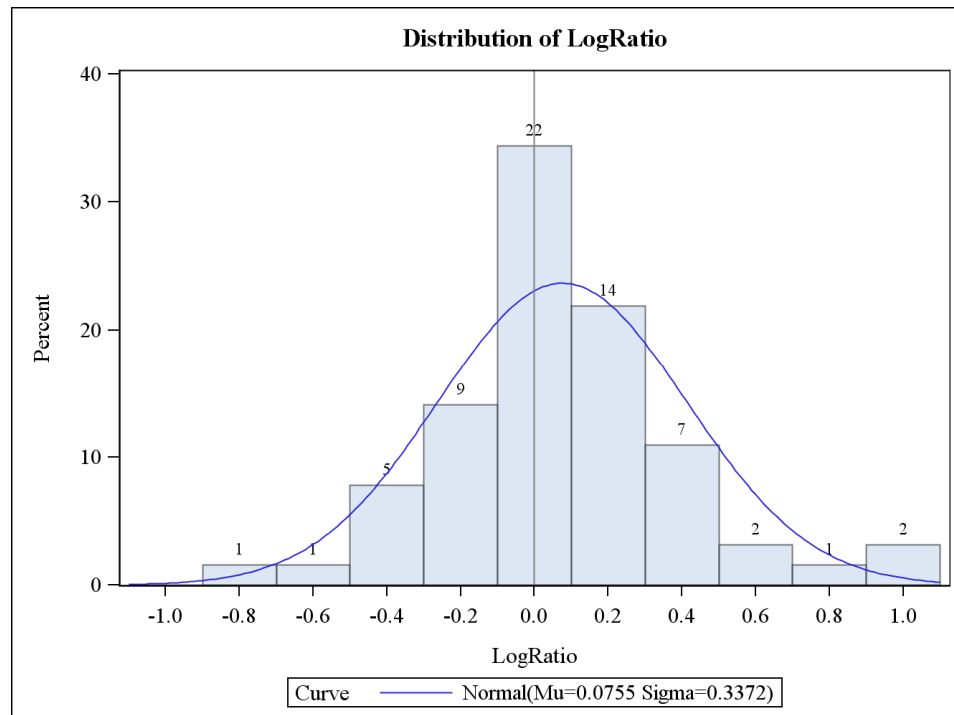
Figure B-2:   Normal Quantiles plot of estimated log (ratio) of field trial residues between Northern Europe and Southern Europe by crop-pesticide combination
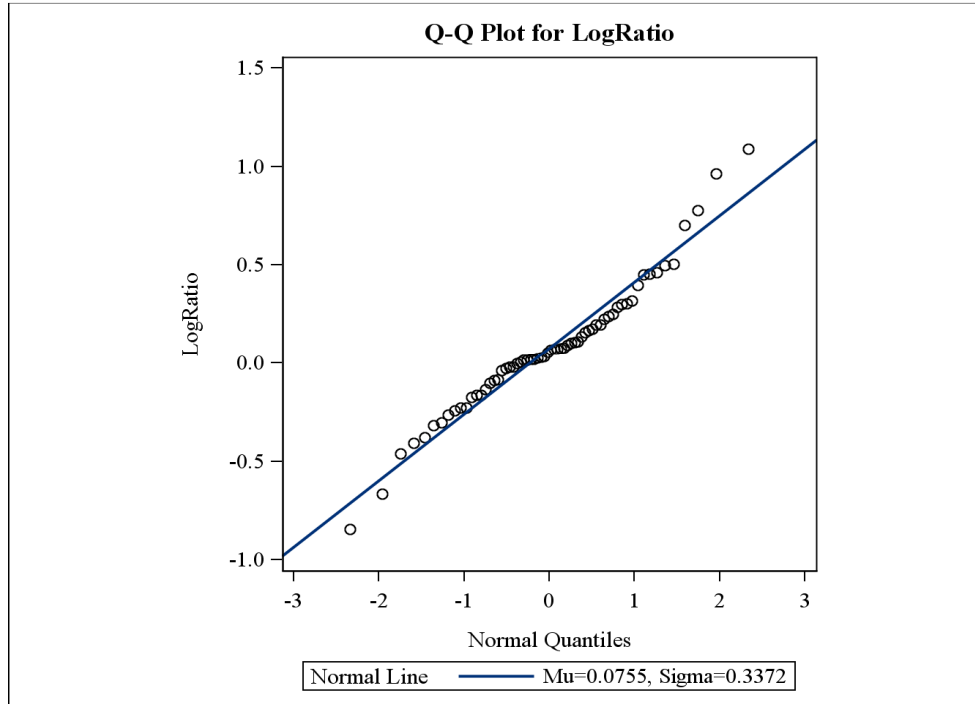
Figure B-3:   Histogram of estimated ratios of field trial residues between Northern Europe and Southern Europe by crop-pesticide combination
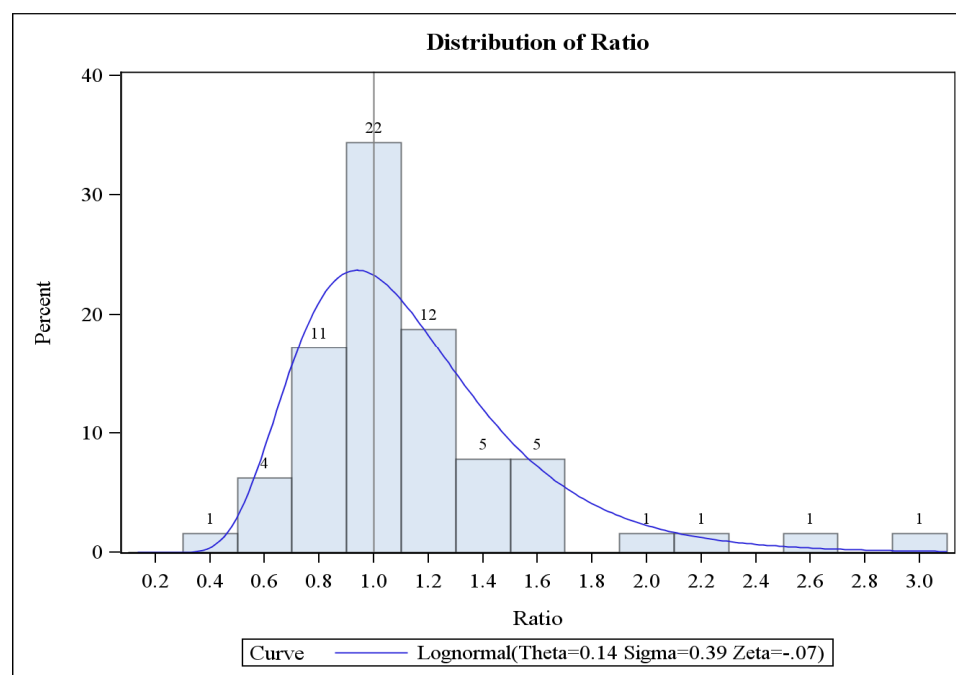
Table B-3:   Estimated field trial residue ratio and associated number of field trial per crop-pesticide combination (sorted by estimated ratio).

CropPest	Log(Ratio) EU-N vs. EU-S	Ratio EU-N vs. EU-S	Ratio EU-S vs. EU-N	# trials in EU-N	# trials in EU-S
FMC-1-CABBAGE,HEAD	-0.85	0.43	2.33	5	6
B-1-APPLE	-0.67	0.51	1.95	8	8
FMC-1-CARROT	-0.46	0.63	1.59	3	6
DAS-1-HEADLETTUCE	-0.41	0.67	1.50	3	3
B-8-RAPE-SEED	-0.38	0.68	1.46	3	5
DAS-1-TOMATO	-0.32	0.73	1.38	10	8
FMC-1-GRAPE	-0.30	0.74	1.36	4	4
IR44-TOMATO	-0.27	0.77	1.30	1	4
DAS-1-PEAR	-0.24	0.78	1.28	3	3
B-3-APPLE	-0.23	0.80	1.26	8	6
F-2-WINEGRAPE	-0.23	0.80	1.26	4	7
B-8-COMMONBEANS	-0.18	0.84	1.19	6	8
FMC-3-CORN	-0.16	0.85	1.18	7	4
F-1-LETTUCE,HEAD	-0.16	0.85	1.18	1	2
DAS-1-BARLEY-SEED	-0.14	0.87	1.15	7	6
FMC-1-ONION	-0.11	0.90	1.11	3	6
F-1-LEAFLETTUCE	-0.09	0.91	1.09	2	5

CropPest	Log(Ratio) EU-N vs. EU-S	Ratio EU-N vs. EU-S	Ratio EU-S vs. EU-N	# trials in EU-N	# trials in EU-S
B-1-CHERRY	-0.09	0.92	1.09	16	8
B-6-CUCUMBER	-0.04	0.96	1.04	3	2
B-8-WHEAT-EARS	-0.03	0.97	1.03	6	4
B-6-ZUCCHINI	-0.02	0.98	1.02	2	2
FMC-1-POTATO	-0.02	0.98	1.02	2	4
FMC-1-CORN	-0.01	0.99	1.01	4	1
FMC-1-CAULIFLOWER	0.00	1.00	1.00	3	3
DAS-1-APPLE	0.01	1.01	0.99	2	2
B-8-LETTUCE	0.02	1.02	0.98	18	20
D-3-GRAPES	0.02	1.02	0.98	9	8
FMC-1-WHEAT	0.02	1.02	0.98	8	8
D-3-STRAWBERRY	0.03	1.03	0.97	9	9
DAS-1-GRAPE	0.03	1.03	0.97	6	6
DAS-1-CANOLA-SEED	0.03	1.03	0.97	5	2
DAS-1-LEAFLETTUCE	0.05	1.06	0.95	3	3
B-6-MELON	0.07	1.07	0.93	3	4
FMC-1-SPINACH	0.07	1.07	0.93	2	5
F-2-LEAFLETTUCE	0.07	1.08	0.93	8	7
B-8-BARLEY	0.08	1.08	0.93	5	2
DAS-1-PEACH	0.08	1.08	0.92	2	4
DAS-1-WHEAT-GRAIN	0.09	1.10	0.91	6	6
B-8-LEEK	0.11	1.11	0.90	8	4
B-8-KALE	0.11	1.11	0.90	1	2
FMC-1-LETTUCE	0.11	1.12	0.90	3	11
B-1-PLUM	0.13	1.14	0.87	12	4
DAS-1-CHERRY	0.16	1.17	0.86	3	3
DAS-1-CUCUMBER	0.17	1.18	0.85	5	8
B-8-CABBAGE	0.17	1.19	0.84	1	4
B-8-SUGARBEET	0.20	1.22	0.82	1	8
FMC-1-BROCCOLI	0.20	1.22	0.82	2	4
D-1-BLUEBERRY	0.23	1.25	0.80	3	2
B-1-GRAPE	0.24	1.27	0.79	6	15
DAS-1-CABBAGE	0.25	1.28	0.78	4	2
DAS-1-BROCCOLI	0.29	1.33	0.75	3	4
F-2-APPLE	0.30	1.35	0.74	11	11
B-8-BROCCOLI	0.31	1.36	0.74	8	4
FMC-1-PEAS	0.32	1.37	0.73	3	1
FMC-1-BARLEY	0.40	1.49	0.67	7	8
B-1-PEACH	0.45	1.57	0.64	4	8
FMC-1-SUGARBEET	0.45	1.57	0.64	5	2
B-2-GRAPE	0.46	1.59	0.63	8	8
B-3-TOMATO	0.50	1.65	0.61	11	30

CropPest	Log(Ratio) EU-N vs. EU-S	Ratio EU-N vs. EU-S	Ratio EU-S vs. EU-N	# trials in EU-N	# trials in EU-S
FMC-3-WHEAT	0.51	1.66	0.60	6	5
FMC-3-BARLEY	0.70	2.01	0.50	6	6
B-8-LEAFYCABBAGE	0.78	2.17	0.46	2	2
FMC-3-PEAS	0.96	2.62	0.38	6	4
FMC-1-BEANS	1.09	2.97	0.34	4	8

Table B-4: Number of field trials and the range of PHIs included in the analysis per Crop-Pesticide combination

PestType	CropPest	No_Appli	PHI	EU_N	EU_S
F	B-1-APPLE	4	27	1	.
F	B-1-APPLE	4	28	6	6
F	B-1-APPLE	4	29	1	2
F	B-1-CHERRY	3	20	7	.
F	B-1-CHERRY	3	21	7	8
F	B-1-CHERRY	3	22	2	.
F	B-1-GRAPE	3	28	6	11
F	B-1-GRAPE	3	29	.	4
F	B-1-PEACH	3	20	1	1
F	B-1-PEACH	3	21	2	7
F	B-1-PEACH	3	22	1	.
F	B-1-PLUM	3	20	2	1
F	B-1-PLUM	3	21	7	3
F	B-1-PLUM	3	22	3	.
F	B-2-GRAPE	3	26	.	1
F	B-2-GRAPE	3	27	3	1
F	B-2-GRAPE	3	28	3	6
F	B-2-GRAPE	3	29	2	.
F	B-3-APPLE	4	13	2	1
F	B-3-APPLE	4	14	2	4
F	B-3-APPLE	4	15	4	1
F	B-3-TOMATO	3	6	.	1
F	B-3-TOMATO	3	7	9	25
F	B-3-TOMATO	3	8	2	3
F	B-3-TOMATO	3	9	.	1
F	D-3-GRAPES	2	3	9	8
F	D-3-STRAWBERRY	2	0	9	9
H	B-6-CUCUMBER	2	2	1	.
H	B-6-CUCUMBER	2	3	2	2
H	B-6-MELON	2	3	2	4
H	B-6-MELON	2	4	1	.
H	B-6-ZUCCHINI	2	3	2	2

PestType	CropPest	No_Appli	PHI	EU_N	EU_S
I	B-8-BARLEY	2	28	5	2
I	B-8-BROCCOLI	1	2	1	.
I	B-8-BROCCOLI	1	3	7	3
I	B-8-BROCCOLI	1	4	.	1
I	B-8-CABBAGE	1	7	.	3
I	B-8-CABBAGE	1	8	1	1
I	B-8-COMMONBEANS	1	3	5	8
I	B-8-COMMONBEANS	1	4	1	.
I	B-8-KALE	1	7	1	2
I	B-8-LEAFYCABBAGE	1	6	.	1
I	B-8-LEAFYCABBAGE	1	7	1	1
I	B-8-LEAFYCABBAGE	1	8	1	.
I	B-8-LEEK	1	2	1	.
I	B-8-LEEK	1	3	6	4
I	B-8-LEEK	1	4	1	.
I	B-8-LETTUCE	1	6	1	1
I	B-8-LETTUCE	1	7	16	17
I	B-8-LETTUCE	1	8	1	2
I	B-8-RAPE-SEED	2	13	1	1
I	B-8-RAPE-SEED	2	14	2	4
I	B-8-SUGARBEET	1	14	1	8
I	B-8-WHEAT-EARS	2	27	1	1
I	B-8-WHEAT-EARS	2	28	5	3
I	D-1-BLUEBERRY	2	3	3	2
I	DAS-1-APPLE	2	7	2	2
I	DAS-1-BARLEY-SEED	2	14	7	6
I	DAS-1-BROCCOLI	4	3	3	4
I	DAS-1-CABBAGE	4	3	4	2
I	DAS-1-CANOLA-SEED	2	14	5	2
I	DAS-1-CHERRY	2	7	3	3
I	DAS-1-CUCUMBER	4	1	5	8
I	DAS-1-GRAPE	4	7	6	6
I	DAS-1-HEADLETTUCE	4	3	3	3
I	DAS-1-LEAFLETTUCE	4	3	3	3
I	DAS-1-PEACH	2	7	2	4
I	DAS-1-PEAR	2	7	3	3
I	DAS-1-TOMATO	4	1	10	8
I	DAS-1-WHEAT-GRAIN	2	14	6	6
I	F-1-LEAFLETTUCE	2	6	.	2
I	F-1-LEAFLETTUCE	2	7	1	3
I	F-1-LEAFLETTUCE	2	8	1	.
I	F-1-LETTUCE,HEAD	2	7	.	2
I	F-1-LETTUCE,HEAD	2	8	1	.

PestType	CropPest	No_Appli	PHI	EU_N	EU_S
I	F-2-APPLE	4	7	11	11
I	F-2-LEAFLETTUCE	4	3	8	7
I	F-2-WINEGRAPE	3	1	4	7
I	FMC-1-BARLEY	1	28	6	8
I	FMC-1-BARLEY	1	29	1	.
I	FMC-1-BEANS	2	3	4	8
I	FMC-1-BROCCOLI	2	3	2	4
I	FMC-1-CABBAGE,HEAD	2	3	5	6
I	FMC-1-CARROT	2	3	3	6
I	FMC-1-CAULIFLOWER	2	3	3	3
I	FMC-1-CORN	2	62	.	1
I	FMC-1-CORN	2	68	1	.
I	FMC-1-CORN	2	75	1	.
I	FMC-1-CORN	2	76	1	.
I	FMC-1-CORN	2	77	1	.
I	FMC-1-GRAPE	1	14	4	4
I	FMC-1-LETTUCE	2	3	3	11
I	FMC-1-ONION	2	3	3	6
I	FMC-1-PEAS	2	3	3	1
I	FMC-1-POTATO	2	3	2	4
I	FMC-1-SPINACH	2	3	2	5
I	FMC-1-SUGARBEET	2	14	5	2
I	FMC-1-WHEAT	1	27	.	2
I	FMC-1-WHEAT	1	28	8	6
I	FMC-3-BARLEY	2	29	1	.
I	FMC-3-BARLEY	2	30	.	1
I	FMC-3-BARLEY	2	31	.	1
I	FMC-3-BARLEY	2	33	1	.
I	FMC-3-BARLEY	2	34	1	3
I	FMC-3-BARLEY	2	35	2	1
I	FMC-3-BARLEY	2	36	1	.
I	FMC-3-CORN	1	74	2	3
I	FMC-3-CORN	1	75	2	.
I	FMC-3-CORN	1	76	3	.
I	FMC-3-CORN	1	77	.	1
I	FMC-3-CORN	1	78	1	.
I	FMC-3-CORN	1	80	.	1
I	FMC-3-CORN	1	84	.	1
I	FMC-3-CORN	1	87	.	1
I	FMC-3-PEAS	2	7	6	4
I	FMC-3-WHEAT	2	31	.	1
I	FMC-3-WHEAT	2	32	1	.

PestType	CropPest	No_Appli	PHI	EU_N	EU_S
I	FMC-3-WHEAT	2	35	5	4
I	IR44-TOMATO	.	72	1	4

IX.   Appendix C: Simulation to Evaluate the Impact of Variation between Crop-Pesticide Combinations on the Significance of Zone Effects

Due to different chemicals and crops, there may be large differences between the residue distributions of different crop-pesticide combinations. Since the setting of an MRL is basically performed separately for each crop-pesticide combination, the variation between crop-pesticide combinations should not be a factor in the determination of significance of zone effect in the global zoning analysis that pools data of many crop-pesticide combinations into a single analysis. For this reason, the statistical method or model used to analyze the pooled residue database must be able to characterize the total random variation in the database into 3 different variance components: i) variation between crop-pesticide combinations, ii) variation of random zone effects among crop-pesticide combinations, and iii) the variation within crop-pesticide combination, and the significance of zone effect should not be impacted by the variation between crop-pesticide combinations.

For the global zoning analysis, the study design is viewed as an unbalanced incomplete block study design. The selected mixed-effect model used for the global zoning analysis can separate the total variation in the residue database into zone variation (i.e. systematic differences between zones, called fixed effects) and the three variance components (i.e., variation between crop-pesticide combinations, variation of random zone effects of crop-pesticide combinations, and variation within crop-pesticide combination; these three components are called random effects), and the model mainly uses the variation between zones, the variation of random zone effects among crop-pesticide combinations, and the variation within crop-pesticide combination to determine the significance of zone effect. To demonstrate that the variation in residues between what may be very different crop-pesticide combinations has no or negligible impact on the significance of zone effects, a simulation was conducted as described in the next paragraph.

There were six different synthetic residue databases randomly created from lognormal distributions with coefficient of variation (CV) = 1. Note that if a lognormal distribution has a CV = 1, the variance of log(residue) is 0.69315. The variation between crop-pesticide combinations in six databases range from between 0 to 10 times the variation of within crop-pesticide combination, and the variation between crop-pesticide combinations is established in the simulation as the only difference between the six databases. For the sake of simplicity, the simulation was set to have only 2 zones and 20 crop-pesticide combinations in each database. The residue distributions in zone 1 were systematically 25% greater than residue distributions in zone 2, and a random number generated from normal distribution mean = 0, SD = 0.5*0.69315 was added to all the logs of residues within a crop-pesticide combination in zone 1 to create a random zone effect for each crop-pesticide combination. Also, the number of field trials of any crop-pesticide combination could be different between zones since the number of field trials of a crop-pesticide combination in a zone was a random integer number between 3 and 8.

The same mixed-effects model used for the global zoning analysis was now used to analyze each of 6 different synthetic residue databases.

Results of simulation
The characteristics of residue databases and the results of analyses are presented in the Table C-1. The estimated variances within crop-pesticide combination from the analyses of 6 different

synthetic residue database range from 0.6072 to 0.6104. Despite the difference between the estimated variances between crop-pesticide combinations among the analyses of 6 different databases (ranging from 0.0 to 6.9116, or about 11 times the estimated variation within crop-pesticide combination), the estimated residue ratios (and 95% CIs) and their associated p-values are very consistent among analyses of these 6 different databases (estimated residue ratios range from 1.461 to 1.488, and p-values range from 0.012 to 0.016).

Table C-1: inputted parameters of simulation and the results of analysis using mixed-effects model

Databases	Inputted parameters of simulation			Estimated values from the analysis				
	Variance within crop-pest combination	Variance between Crop-Pest combinations	Residue Ratio (zone 1/zone2)	Variance of Zone Effect among Crop-Pest combinations	Variance within Crop-Pest combination	Variance between Crop-Pest combinations	Residue Ratio (95% CI) (zone 1/zone2)	p-value
1	0.69315	0.0 × 0.69315	1.25	0.07519	0.6104	0	1.461 (1.096, 1.947)	0.012
2	0.69315	0.5 × 0.69315	1.25	0.1059	0.6072	0.3278	1.478 (1.083, 2.018)	0.016
3	0.69315	1.0 × 0.69315	1.25	0.1057	0.6076	0.6710	1.482 (1.086, 2.023)	0.016
4	0.69315	2.0 × 0.69315	1.25	0.1056	0.6078	1.3607	1.485 (1.087, 2.027)	0.016
5	0.69315	4.0 × 0.69315	1.25	0.1055	0.6080	2.7450	1.486 (1.089, 2.029)	0.015
6	0.69315	10.0 × 0.69315	1.25	0.1054	0.6080	6.9116	1.488 (1.090, 2.031)	0.015

Conclusion of the simulation
The results of the simulation indicate that the variation between crop-pesticide combinations in a residue database does not have any impact or almost no impact on the significance of zone effects in the analysis. This results could have been expected from the nature of the block study design.

X.   Appendix D: Simulation to Evaluate Zone Impact on Global and Zone-Specific MRLs

Conclusions

From the scenarios that were evaluated in the simulation, the global MRLs calculated from pooling zonal residues are generally better than zone-specific MRLs that are calculated for each individual zone from zone-specific supervised field trial data, defined as having a lower proportion of estimated MRLs below the true 95th percentile.

Background and algorithm of simulation

The simulation was conducted to evaluate the zone effects on MRLs if residue data were pooled from different zones. The simulation was set for the more extreme case in which supervised field trial residues in Australia and New Zealand are 30% less than the corresponding supervised field trial residues in Europe, North America, and South America. For the simulation, field trial residues were randomly generated from lognormal distributions with CV = 1 (reasonable assumption for field trial residues). The simulations were set to evaluate the impact of zone effect on MRLs when geometric mean of residues in Europe was arbitrarily selected to be 0.5 ppm.

For each iteration in the simulation, the MRLs resulting from 9, 7, 5, 4, and (then) 3 field trials per zone (lowest number field trials required by OECD MRL calculator) were calculated for each zone. Also, the global MRLs (pooling residues from 4 zones) were computed.

Results of Simulation

Panel Figure D-1 presents the box-plots of distributions of global and zone-specific MRLs from the simulation with 1000 iterations.

Table D-1 presents the proportion of global and zone-specific MRLs that were below the 95th percentile values of the zone-specific residue distribution.

The global MRLs calculated from pooling 3 FT residues per zone vs. the zonal MRLs calculated from 3 FT per zone:
  - Lower proportion of Global MRLs below the zone-specific 95%-tiles (1% for AU-NZ and 9% for other zones) compared to zone-specific MRLs (26% -29% for all zones).
  - The distribution of Global MRLs is narrower compared to all zonal MRLs (desirable).
  - Global MRLs are much better than zone-specific MRLs in this case.

The global MRLs calculated from pooling 3 FT residues per zone vs. the zonal MRLs calculated from 5 FT per zone:
  - Lower proportion of Global MRLs below the zone-specific 95%-tiles (1% for AU-NZ and 9% for other zones) compared to zone-specific MRLs (16% -19% for all zones).
  - The distribution of Global MRLs is narrower compared to zonal MRLs in Europe, North America, and South America (desirable).
  - Zonal MRLs of Australia and New Zealand are about 30% lower than the Global MRLs. However, the Global MRLs are still in the range of the zonal MRLs in Australia and New Zealand.
  - Global MRLs are much better than zone-specific MRLs in this case.

The global MRLs calculated from pooling 3 FT residues per zone vs. the zonal MRLs calculated from 7 FT per zone:
- Lower proportion of Global MRLs below the zone-specific 95%-tiles (1% for AU-NZ and 9% for other zones) compared to zone-specific MRLs (11% -14% for all zones).
- The distribution of Global MRLs is comparable to zone-specific MRLs in Europe, North America, and South America (desirable).
- The distribution of Global MRLs is unsubstantially elevated compared to MRL distribution of Australia-New Zealand (undesirable). However, the Global MRLs are still in the range of the zonal MRLs in Australia and New Zealand.
- Global MRLs are much better than zone-specific MRLs in this case.

Note that the results of 4 FT and 9 FT per zone in the simulation were similar to that of 5 FT and 7 FT, respectively. Therefore, the above comments for 5 FT and 7 FT per zone can be applied for 4 FT and 9FT, respectively.

Table D-1: Proportion of MRLs below the 95th percentile value of zone-specific residue distributions

Number of Base FT	Scenario	P95AUNZ	P95EU-NA-SA
3	3 AUNZ	0.257	.
	3 EU	.	0.292
	3 NA	.	0.255
	3 SA	.	0.272
	3 AUNZ +3 NA +3 SA +3 EU	0.008	0.091
4	4 AUNZ	0.194	.
	4 EU	.	0.218
	4 NA	.	0.193
	4 SA	.	0.24
	4 AUNZ +4 NA +4 SA +4 EU	0.001	0.056
5	5 AUNZ	0.158	.
	5 EU	.	0.179
	5 NA	.	0.151
	5 SA	.	0.193
	5 AUNZ +5 NA +5 SA +5 EU	0	0.028
7	7 AUNZ	0.112	.
	7 EU	.	0.141
	7 NA	.	0.113
	7 SA	.	0.139
	7 AUNZ +7 NA +7 SA +7 EU	0	0.018
9	9 AUNZ	0.071	.
	9 EU	.	0.101
	9 NA	.	0.094
	9 SA	.	0.098
	9 AUNZ +9 NA +9 SA +9 EU	0	0.005

Panel Figure D-1: Distribution of MRLs when residues in Europe, North America, and South America follow a lognormal distribution GM = 0.1 and CV = 1, and residues in Australia and New Zealand are 30% less than Europe, North America, and South America.
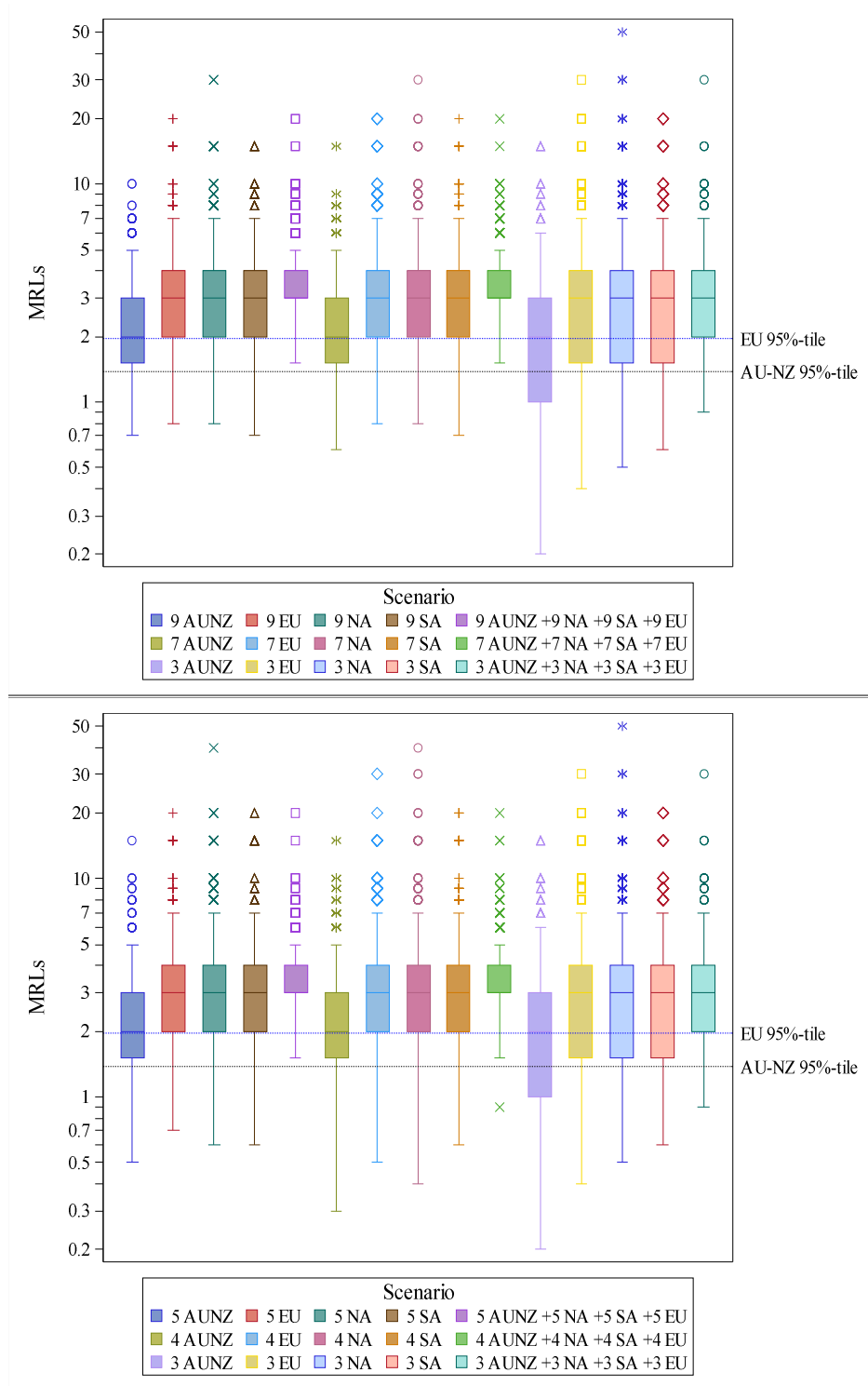
XI. Appendix E: SAS Code for the Analysis of Global Exchangeability of Field Trial Residues

E – 1. SAS code to clean CLA database

```
*====*====*====*====*====*====*====*====*====*====*====*====*=*
* Programmer: James Nguyen, US EPA                           *
*                                                            *
* Project:   Global Zoning/Exchangeability Analysis          *
*                                                            *
* Study:   CLA database                                      *
*                                                            *
* Purpose: Read and clean residue data from CLA              *
*                                                            *
* Data Sources:                                              *
*   – Zoning Data 20150112.xlsx                              *
*   – Zoning Data 20150106 Company B_corrected_April2015.xlsx *
*   – Company F data_Updated treatment rate for compound     *
*     F2_April 3 2014.xlsx                                   *
*                                                            *
* Last Modified Dates:                                       *
*                                                            *
* Notes:                                                     *
*====*====*====*====*====*====*====*====*====*====*====*====**;
options noxwait noxsync FormDlim = "=" nodate nonumber orientation= landscape mprint;
libname CLA "F:\Crop Residue\Crop Residue – Zoning\Global Zoning\CLA\data";

%let junk = C:\Documents and Settings\jnguyen\Desktop\SAS Junks;

%Macro insert;
       infile tmp dlm = '09'x dsd truncover lrecl=10000 firstobs=1 ;
             input
                        Company:           $3.                    /*    1       */
                        ReportNo:          $20.          /*    2       */
                        Type:              $20.          /*    3       */

                        Chemical:          $5.                    /*    4       */
                        Zone:              $20.          /*    5       */

                        Country:           $20.          /*    6       */
                        TrialID:           $40.          /*    7       */

                        No_Appli:          best12.       /*    8       */
                        Ap_rate:           $40.          /*    9       */

                        PHI:               best12.       /*    10      */
                        Crop:              $22.          /*    11      */
                        Commodity:         $20.          /*    12      */
                        Replicate:         $2.                    /*    13      */

                        Residue:           $10.          /*    14      */
                        Censored:          $12.          /*    15      */

                        Observation:   $20.           /*    16      */
%Mend;

x "'F:\Crop Residue\Crop Residue – Zoning\Global Zoning\CLA\data\Zoning Data
20150112.xlsx'";

filename tmp dde "Excel|Company A!r2c1:r47c16" notab;
data CompA;    %insert;;        run;

filename tmp dde "Excel|Company C!r2c1:r198c16" notab;
data CompC;    %insert;;        run;

filename tmp dde "Excel|Company D!r2c1:r238c16" notab;
```

```
data CompD;      %insert;;        run;

filename tmp dde "Excel|system";
data _null_;   file tmp;       put '[Error(False)]'; put '[quit()]';run;


*===> use the updated data of company B;

x "'F:\Crop Residue\Crop Residue – Zoning\Global Zoning\CLA\data\Zoning Data 20150106
Company B_corrected_April2015.xlsx'";
filename tmp dde "Excel|Company B!r2c1:r2285c16" notab;
data CompB;      %insert;;        run;
filename tmp dde "Excel|system";
data _null_;   file tmp;       put '[Error(False)]'; put '[quit()]';run;


*===> use the updated data of company F;

x "'F:\Crop Residue\Crop Residue – Zoning\Global Zoning\CLA\data\Company F data_Updated
treatment rate for compound F2_April 3 2014.xlsx'";
filename tmp dde "Excel|Company F!r2c1:r395c19" notab;
data CompF;
        infile tmp dlm = '09'x dsd truncover lrecl=10000 firstobs=1 ;
                input
                    Company:           $3.                    /*    1       */
                    ReportNo:          $20.           /*    2      */
                    Type:              $20.           /*    3      */

                    Chemical:          $5.                    /*    4       */
                    Zone:              $20.           /*    5      */

                    Country:           $20.           /*    6      */
                    TrialID:           $40.           /*    7      */

                    No_Appli:          best12.        /*    8      */
                    Ap_rate:           $40.           /*    9      */

                    PHI:               best12.        /*    10     */
                    Crop:              $22.           /*    11     */
                    Commodity:         $20.           /*    12     */
                    Replicate:         $2.                    /*    13      */

                    Residue:           $10.           /*    14     */
                    Censored:          $12.           /*    15     */

                    Observation:   $20.          /*    16     */
                    formulation:   $2.           /*    17     */
                    AppMethod:         $20.           /*    18     */
                    Comment:           $20.           /*    19     */
        ;
run;
filename tmp dde "Excel|system";
data _null_;   file tmp;       put '[Error(False)]'; put '[quit()]';run;

Data CompF;
        set CompF;
        if AppMethod = "drip irrigation" then delete;
run;


Data CLA;
        set CompA CompB CompC CompD CompF;
run;


/*
Proc datasets nolist; delete CompA CompB CompC CompD CompF; quit;

Proc freq data=CLA;   table Zone/nopercent nocol norow nocum out=freq; run;
Proc freq data = CLA;  table Country*Zone/nocum nopercent nocol norow out=freq; run;
```

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```
Proc freq data=CLA;     table  Crop/ out=freq; run;
Proc freq data=CLA;     table  Type/ out=freq; run;
Proc freq data=CLA;     table  Chemical/ out=freq; run;
Proc freq data=CLA;     table  Ap_rate/ out=freq; run;
Proc freq data=CLA;     table  PHI/ out=freq; run;

*/

Data CLA;
        set CLA;
        if zone = "Greenhouse" then delete;

        if Zone in ("ANZ", "South Australia") then Zone = "AU-NZ";
        if upcase(Zone) in ("EU-N","EU-S","NEU","SEU") then Zone = "EU";
        if Zone in ("N. America","N.America") or index(upcase(Zone),"NAFTA") > 0 then Zone
= "NA";
        if Zone in ("S. America","") then Zone = "SA";
        if Zone in ("Asia") then Zone = "ASIA";

        if PHI = 2.5 then PHI = 3;
        length PestType $3.;
        if Type in ("I", "Insecticide","insecticide") then PestType="I";
        else PestType = compress(Type);

        Crop = upcase(Crop);
        Commodity = upcase(Commodity);

        if index(Crop, "BLUEBERRY") > 0 then Crop = "BLUEBERRY";
        if index(Crop, "WHEAT") > 0 then Crop = "WHEAT";
        if index(Crop, "BARLEY") > 0 then Crop = "BARLEY";
        if index(Crop, "GRAPE") > 0 then Crop = "GRAPE";
        if index(Crop, "LEAF LETTUCE") > 0 or Crop = "LETTUCE, LEAF" then Crop = "LEAF
LETTUCE";

        if index(Ap_rate, "g/tree") > 0 then delete;

        length CropPest $60.;
        CropPest = compress(Chemical||'-'||Crop);
        Country_Trial = compress(upcase(Country)||"-"||upcase(TrialID)||"---"||ReportNo);
run;quit;
Proc sort data = CLA; by CropPest; run;


/*
Proc freq data=CLA; table  CropPest*PestType/nocol norow nocum nopercent; run;
Proc freq data=CLA; table  Commodity/nocol norow nocum nopercent out=freq;
        by CropPest;
run;
*/

Data CLA;
        set CLA;
        if Crop = "HOPS" and Commodity in ("DRIED CONES","DRY CONES") then Commodity =
"DRIED CONES";
        if Crop = "CABBAGE" and Commodity in ("CABBAGE","CABBAGE, HEAD") then Commodity
="CABBAGE";
        if Crop = "GRAPE" and Commodity in ("BUNCHES","FRESH FRUIT","FRUIT") then
Commodity = "FRUIT";
        if Crop = "LEAF LETTUCE" and Commodity in ("LEAVES","LEAVES (SCAROLE)","PLANT")
then Commodity = "LEAVES";
        if Crop = "LEEK" and Commodity in ("LEEK","PLANT W/O ROOTS") then Commodity =
"LEEK";
        if Crop = "LETTUCE, HEAD" and Commodity in ("HEAD","LEAVES","PLANT") then
Commodity = "HEAD";
        if Crop = "STRAWBERRY" and Commodity in ("FRESH FRUIT","FRUIT","WHOLE FRUIT") then
Commodity = "FRUIT";
        if Crop = "SUGAR BEET" and Commodity in ("LEAVES W/TOPS","TOPS") then Commodity =
"TOPS";
        if Crop = "TOMATO" and Commodity in ("FRESH FRUIT","FRUIT") then Commodity =
"FRUIT";
```

```
        if Crop = "WHEAT" and Commodity in ("EAR","EARS") then Commodity = "EARS";

        if Crop in ("HOPS", "WHEAT", "RAPE") then CropPest=compress(CropPest||"-
"||Commodity);
run;
quit;

*===> select data: have trials more than 1 zone, and same number of applications;title;

%Macro clean;
        *===> Identify CropPest have trials more than 1 ZONE;

        Proc SQL;
                create table CropPest_Zone_App_Trial as
                        select PestType, CropPest, ZONE, No_Appli, count(*) as NTrial
                        from (select distinct PestType, CropPest, ZONE, No_Appli,
Country_Trial
                                from CLA)
                        group by PestType, CropPest, ZONE, No_Appli
                        order by PestType, CropPest, No_Appli, ZONE;

                create table CropPest_Zone_App as
                        select PestType, CropPest, No_Appli, count(*) as NZONE
                        from (select distinct PestType, CropPest, ZONE, No_Appli
                                from CropPest_Zone_App_Trial)
                        group by PestType, CropPest, No_Appli
                        order by PestType, CropPest, No_Appli;
        quit;


        Proc transpose data = CropPest_Zone_App_Trial out =
CropPest_Zone_App_Trial(drop=_NAME_);
                by PestType CropPest No_Appli;
                ID ZONE;
                var NTrial;
        run;

        *==> exclude CropPest-No_Appli that have trials in 1 zone;
        Proc sort data = CropPest_Zone_App_Trial;    by PestType CropPest No_Appli; run;
        Proc sort data = CLA;                                       by PestType CropPest
No_Appli; run;
        Data CLA;
                merge CLA CropPest_Zone_App;
                by PestType CropPest No_Appli;
                if NZONE > 1;
        run;

        *==> Exclude by Zone and No_Appli;
        Data Exclude1;
                merge CropPest_Zone_App_Trial CropPest_Zone_App;
                by PestType CropPest No_Appli;
                if NZONE < 2;
                Reason = "field trials in 1 zone";
                Excluded = "excluded";
        run;

        Proc datasets nolist; delete CropPest_Zone_App_Trial CropPest_Zone_App; run;quit;


        *===> Identify trials have similar PHI between zones;

        Proc SQL;
                create table CropPest_Zone_App_PHI as
                        select PestType, CropPest, Zone, No_Appli, PHI, Commodity, count(*)
as NTrial
                        from (select distinct PestType, CropPest, No_Appli, Zone, PHI,
Commodity, Country_Trial
                                from CLA)
                        group by PestType, CropPest, No_Appli, Commodity, Zone, PHI
```

```
                              order by PestType, CropPest, No_Appli, Commodity, PHI, Zone;
        quit;
%Mend;

%clean;



*===> select trials based on: 1) similar PHI between zones, 2) larger PHI;
Data CLA;
        set CLA;
        if CropPest = "A-1-SORGHUM" then delete;

        if CropPest = "A-1-STRAWBERRY" then delete;

        if CropPest = "B-1-APPLE" and PHI < 48 then delete;

        if CropPest = "B-3-APPLE" and PHI < 13 then delete;
        if CropPest = "B-3-APPLE" and PHI > 15 then delete;

        if CropPest = "B-3-WHEAT-GRAIN" and PHI < 33 then delete ;

        if CropPest = "B-4-SOYBEAN" and PHI > 2 then delete;

        if CropPest = "B-6-HOPS-GREENCONES" then delete;

        if CropPest = "B-7-CARROT" and PHI < 58 then delete ;

        if CropPest = "B-8-CABBAGE" and PHI ^= 7 then delete ;

        if CropPest = "B-8-WHEAT-GRAIN" and PHI > 21 then delete;

        if CropPest = "F-1-LETTUCE,HEAD" and PHI > 1 then delete;
        if CropPest = "F-1-LETTUCE,HEAD" and No_Appli = 2 then delete;

        if CropPest = "F-1-LEAFLETTUCE" and PHI ^=1 then delete;
        if CropPest = "F-1-LEAFLETTUCE" and No_Appli = 2 then delete;
run;


Proc transpose data = CropPest_Zone_App_PHI out = Tabulate1;
        by PestType CropPest No_Appli Commodity PHI;
        ID ZONE;
        var NTrial;
run;

Data Tabulate1;
        set Tabulate1;

        length Reason $60.;
        if CropPest = "A-1-SORGHUM" then do; Excluded= "excluded"; Reason = "most data
<LOD or <LOD"; end;

        if CropPest = "A-1-STRAWBERRY" then do; Excluded= "excluded"; Reason = "most data
<LOD or <LOD"; end;

        if CropPest = "B-1-APPLE" and No_Appli = 6 and PHI < 48 then do; Excluded=
"excluded"; Reason = "uncommon PHI"; end;
        if CropPest = "B-1-APPLE" and No_Appli = 7 then do; Excluded= "excluded"; Reason =
"No_Appli = 6 were used"; end;

        if CropPest = "B-3-APPLE" and PHI < 13 then do; Excluded= "excluded"; Reason =
"common use pattern PHIs=13,14,15 were selected"; end;
        if CropPest = "B-3-APPLE" and PHI > 15 then do; Excluded= "excluded"; Reason =
"common use pattern PHIs=13,14,15 were selected"; end;

        if CropPest = "B-3-WHEAT-GRAIN" and PHI < 33 then do; Excluded= "excluded" ;
Reason = "uncommon PHI"; end;
```

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```
        if CropPest = "B-4-SOYBEAN" and PHI > 2 then do; Excluded= "excluded"; Reason =
"uncommon PHI and most data < LOD"; end;

        if CropPest = "B-6-HOPS-GREENCONES" then do; Excluded= "excluded"; Reason =
"commodity with same field trials"; end;

        if CropPest = "B-7-CARROT" and PHI < 58 then do; Excluded= "excluded" ; Reason =
"uncommon PHI"; end;

        if CropPest = "B-8-CABBAGE" and PHI ^= 7 then do; Excluded= "excluded" ; Reason =
"label PHI = 7 was selected"; end;

        if CropPest = "B-8-WHEAT-GRAIN" and PHI > 21 then do; Excluded= "excluded"; Reason
= "uncommon PHI"; end;

        if CropPest = "F-1-LETTUCE,HEAD" and PHI = 0 then do; Excluded= "excluded"; Reason
= "same field trials as PHI = 1"; end;
        if CropPest = "F-1-LETTUCE,HEAD" and PHI > 1 then do; Excluded= "excluded"; Reason
= "uncommon PHI"; end;
        if CropPest = "F-1-LETTUCE,HEAD" and No_Appli = 2 then do; Excluded= "excluded";
Reason = "uncommon PHI and No_Appli = 3 were used"; end;

        if CropPest = "F-1-LEAFLETTUCE" and PHI ^=1 then do; Excluded= "excluded"; Reason
= "uncommon PHI"; end;
        if CropPest = "F-1-LEAFLETTUCE" and No_Appli = 2 then do; Excluded= "excluded";
Reason = "uncommon PHI"; end;
run;

Proc freq data=CLA; table  CropPest/nocol norow nocum nopercent;run;

/*
Proc SQL;
        create table Crop_Commodity as
        select Crop, Chemical, Country_Trial, count(*) as NCOMMOD
        from    (select distinct Crop, Chemical, Commodity, Country_Trial
                        from CLA)
        group by Crop, Chemical, Country_Trial
        having NCOMMOD > 1;

        create table Crop_Commod as
        select Crop, Chemical, count(*) as NCOMMOD
        from (select distinct Crop, Chemical, Commodity
                from CLA)
        group by Crop, Chemical
        having NCOMMOD > 1;
quit;
*/

*===> normalize application rate;

/*
Proc freq data = CLA; table Censored/out=freq; run;
*/

Data CLA;
        set CLA;
        Rate = input(compress(Ap_rate,","), best12.);
run;


*===> the data now has only 1 number of applications per CropPest,
        no need to include No_Appli in the algorithm;

Proc SQL;
        Create table CLA1 as
                select *, min(Rate) as MinRate
                from CLA
                group by CropPest;
quit;
```

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```
Data CLA1;
        set CLA1;
        if Censored not in ("<LOD", "<LOQ", "LOD<x<LOQ") then Res=input(Residue,
best12.)*MinRate/Rate;
run;
/*
Data LODLOQ check;
        set CLA1;
        if Censored in ("<LOD","<LOQ","LOD<x<LOQ") then output LODLOQ;
        if index (Residue, "<") > 0 and Censored not in ("<LOD","<LOQ","LOD<x<LOQ") then
output check;
run;

Data check;
        set CLA1;
        if CropPest ="B-8-WHEAT-GRAIN";
        keep Zone Residue Res Censored Country_Trial;
run;

*/
*===> exclude CropPest that have most of data below LOD or LOQ;
Data CLA1;
        set CLA1;
        if CropPest in ("B-1-PEACH", "B-7-CARROT","B-8-WHEAT-GRAIN") then delete;
        if Censored in ("LOD<x<LOQ") and index(Residue,"<") = 0 then Res = input(Residue,
best12.)*MinRate/Rate;
        else if Censored in ("<LOD", "<LOQ", "LOD<x<LOQ") then Res =
(input(compress(Residue,"<"), best12.)/2)*MinRate/Rate;
run;

Data Tabulate1;
        set Tabulate1;
        if CropPest = "B-1-PEACH" then do; Reason = "most data <LOD or <LOD"; Excluded =
"excluded"; end;
        if CropPest = "B-7-CARROT" and PHI >= 58 then do; Reason = "most data <LOD or
<LOD"; Excluded = "excluded"; end;
        if CropPest = "B-8-WHEAT-GRAIN" and PHI <= 21 then do; Reason = "most data <LOD or
<LOD"; Excluded = "excluded"; end;
run;

Data CLA.CLA_May2015;
        set CLA1;
        keep Company Zone Crop PestType replicate Res Censored CropPest Chemical
Country_Trial Commodity Observation;
run;


/*
Proc SQL;
        create table CropPest as
        select distinct CropPest
        from CLA1;
quit;
*/


ods rtf file="&junk\CLA Tabulate.rtf";
Proc print data = Exclude1 noobs; run;
Proc print data = Tabulate1 noobs; run;
ods rtf close;
```

E – 2.   SAS code to clean DAS database

```
*====*====*====*====*====*====*====*====*====*====*====*
* Programmer: James Nguyen, US EPA                      *
*                                                       *
* Project:   Global Zoning/Exchangeability Analysis     *
*                                                       *
* Study:   DAS database                                 *
*                                                       *
* Purpose:  Read and clean residue data from DAS        *
*                                                       *
* Data Sources:                                         *
*  – "Global Zoning_JMP New DAS Data sets by            *
*      rateXDE-208_Sept 6 2013.xlsx"                    *
*                                                       *
* Notes:                                                *
*====*====*====*====*====*====*====*====*====*====*====*;
options noxwait noxsync FormDlim = "=" nodate nonumber;
libname DAS "F:\Crop Residue\Crop Residue – Zoning\Global Zoning\DAS\Data";

%let junk = C:\Users\JNguyen\Desktop\Junks;

x "'F:\Crop Residue\Crop Residue – Zoning\Global Zoning\DAS\Data\Global Zoning_JMP New
DAS Data sets by rateXDE-208_Sept 6 2013.xlsx'";
filename tmp dde "Excel|New Data!r2c1:r1020c12" notab;

Data DAS;
        infile tmp dlm='09'x dsd truncover lrecl=10000 firstobs=1;
        input
                Crop:           $22.    /*      1       */
                Zone:           $20.    /*      2       */
                TrialID:        $40.    /*      3       */
                Trial:          $20.    /*      4       */
                Replicate:      $2.             /*      5       */
                Residue:        $10.    /*      6       */
                Censored:       $12.    /*      7       */
                Molecule:       $12.    /*      8       */
                GAP:            $40.    /*      9       */
                Commod_Cat:     $40.    /*      10      */
                Commod_Siz:     $40.    /*      11      */
                Surface:        $30.    /*      12      */
                ;
run;

filename tmp dde "Excel|system";

data _null_;
        file tmp;
        put '[Error(False)]';
        put '[quit()]';
run;
/*
Proc Freq data = DAS; table ZONE; run;
Proc Freq data = DAS; table Crop; run;
Proc Freq data = DAS; table Crop*GAP/nocol norow nocum nopercent out=freq; run;
Proc freq data = DAS;  where index(upcase(Crop),"WHEAT")>0;
        table TrialID*Crop/ nocol norow nocum nopercent;
run;
Proc freq data = DAS;  where index(upcase(Crop),"BARLEY")>0;
        table TrialID*Crop/ nocol norow nocum nopercent;
run;
Proc freq data = DAS;  where index(upcase(Crop),"COTTON")>0;
        table TrialID*Crop/ nocol norow nocum nopercent;
run;
Proc Freq data = DAS; table Censored/out=freq; run;
Proc Freq data = DAS; table Crop*Commod_Cat/nocol norow nocum nopercent out=freq; run;
Proc Freq data = DAS; table GAP/nocol norow nocum nopercent; run;
*/
```

```
*===> Each Cotton trial has 2 commodities: Seed and Gin-by-Product,
             Seed is selected for analysis;
*===> Each Wheat trial has 4 commodities: Grain and Straw (PHI 14) and Hay and Forage
(PHI 7),
             Grain and Hay are selected for analysis and assumed to be independent
crops;
*===> Each Barley trial has 2 commodities: Seed and Straw,
             Seed is selected for analysis;

Data DAS;
      set DAS;
      if Zone = "US" then Zone = "NA";
      if Zone = "ANZ" then Zone = "AU-NZ";
      if Zone = "BRZ" then Zone = "SA";

      Company="DAS";
      Chemical = "DAS-1";

      length PestType $2.;
      PestType = "I";

      length CropPest $40.;
      CropPest = compress(Chemical||'-'||upcase(Crop));

      if GAP="4X100 PHI 1" then GAP = "4x100 PHI 1";

      PHI = input(compress(substr(GAP, index(GAP, "PHI") + 3, index(GAP, "PHI") + 3 +
3)),best12.);

      *==> create below variable to match with other database,
             Crop is used instead of country to separate the commodities of same field
trial;
      Country_Trial = compress(upcase(Crop)||"-"||upcase(TrialID));

      Res = input(compress(Residue, "<"), best12.);
      if Censored in ("<LOD") then Res=Res/2;

      if Crop = "Barley - Straw" then delete;
      if Crop = "Cotton - Gin Byproduct" then delete;
      if Crop in ("Wheat - Hay","Wheat - Straw", "Wheat - Forage") then delete;

      keep Company Zone Crop PestType CropPest Country_Trial GAP Censored Chemical
Replicate Res;

run;

Data DAS.DAS_May2015;
      set DAS;
run;


Proc SQL;
      create table CropPest_Zone_Trial as
             select PestType, CropPest, ZONE, GAP, count(*) as NTrial
             from (select distinct PestType, CropPest, ZONE, Country_Trial, GAP
                     from DAS)
             group by PestType,CropPest, GAP, ZONE
             order by PestType,CropPest, GAP, ZONE;
quit;

Proc transpose data = CropPest_Zone_Trial out = CropPest_Zone_Trial(drop=_NAME_);
      by PestType CropPest GAP;
      ID ZONE;
      var NTrial;
run;

ods rtf file="&junk\DAS Number of Trials per Crop-Pest x Zone.rtf";
Proc print data = CropPest_Zone_Trial noobs; run;quit;
ods rtf close;
```

```
Proc datasets nolist; delete CropPest_Zone_Trial; run;quit;
```

E – 3.   SAS code to clean IR-4 database

```
*====*====*====*====*====*====*====*====*====*====*====*
* Programmer: James Nguyen, US EPA                      *
*                                                       *
* Project:   Global Zoning/Exchangeability Analysis     *
*                                                       *
* Study:   IR-4  database                               *
*                                                       *
* Purpose: Read and clean IR-4 database                 *
*                                                       *
* Data Sources:                                         *
*     - "Zoning Data 20150112.xlsx"                     *
*                                                       *
* Last Modified Dates:                                  *
*                                                       *
* Notes:                                                *
*====*====*====*====*====*====*====*====*====*====*====*;
options noxwait noxsync FormDlim = "=" nodate nonumber orientation= landscape mprint;
libname CLA "F:\Crop Residue\Crop Residue - Zoning\Global Zoning\CLA\data";

%let junk = C:\Documents and Settings\jnguyen\Desktop\SAS Junks;




*===> IR-4 Tomato data;

x "'F:\Crop Residue\Crop Residue - Zoning\Global Zoning\CLA\data\Zoning Data
20150112.xlsx'";
filename tmp dde "Excel|IR-4 Tomato data!r2c1:r649c23" notab;
data IR4Toma;
      infile tmp dlm='09'x dsd truncover lrecl=10000 firstobs=1;
      input
                  TrialID:          $40.          /*    1     */

                  Location:         $3.                /*    2     */
                  Country:          $20.          /*    3     */
                  TrialNo:          $40.          /*    4     */

                  Zone:             $20.          /*    5     */

                  Climate:          $40.          /*    6     */

                  PHI:              best12.       /*    7     */
                  Replicate:        $2.                /*    8     */

                  Chemical:         $5.                /*    9     */
                  Residue:          $10.          /*    10    */
                  Censored:         $12.          /*    11    */

                  LOD:              $10.          /*    12    */
                  LOQ:              $10.          /*    13    */
                  CensoredCal:  $12.        /*    14    */
                  ConsoredErr:  $40.        /*    15    */
                  Rainfall:         $40.          /*    16    */

                  Surface:          $40.          /*    17    */

                  FruitWeight:  $40.        /*    18    */
                  RainNoRain:       $40.          /*    19    */

                  CumRain:          $40.          /*    20    */

                  MetaResidue:  $10.        /*    21    */
                  MetaLOD           $10.          /*    22    */
                  MetaLOQ           $10.          /*    23    */
                  ;
run;
```

```
filename tmp dde "Excel|system";

data _null_;
      file tmp;
      put '[Error(False)]';
      put '[quit()]';
run;
/*
Proc freq data = IR4Toma; table TrialID; run;
Proc freq data = IR4Toma; table Residue/nopercent nocum; run;
Proc freq data = IR4Toma; table Chemical*PHI*Censored/nopercent nocum; run;
Proc freq data = IR4Toma; table Zone*Country/nopercent nocum; run;
Proc freq data = IR4Toma; table Zone/nopercent nocum; run;
*/
Data IR4Toma;
      set IR4Toma;

      Company = "IR4";

      Censored=CensoredCal;

      if TrialID = "KE1" then TrialID="KE2"; *==> fix typo in TrialID;

      if Censored ^= "<LOD" then Res = input(Residue,best12.);
      else if Censored = "<LOD" then Res = input(LOD,best12.)/2;

      length Crop      $22.;

      Crop = "TOMATO";

      length CropPest $40.;
      CropPest = compress("IR4"||Chemical||'-'||Crop);
      Country_Trial = compress(upcase(Country)||"-"||upcase(TrialID));

      if Zone = "S America" then Zone = "SA";
      if Zone = "N America" then Zone = "NA";
      if Zone = "Europe" then Zone = "EU";
      if Zone = "Africa" then Zone = "AF";
      if Zone = "Australia" then Zone = "AU-NZ";
      if Zone = "Asia" then Zone = "ASIA";

      length PestType $3.;
      if Chemical=1 then PestType = "I";
      if Chemical=2 then PestType = "F";
      if Chemical=3 then PestType = "F";
      if Chemical=4 then PestType = "I";

      keep Company PestType Zone Crop Chemical CropPest PHI Country_Trial Censored
Replicate Res;
run;

Data CLA.IR4Toma CLA.IR4Toma1 CLA.IR4Toma2 CLA.IR4Toma3 CLA.IR4Toma4;
      set IR4Toma;

      if PHI = 72;

      if Chemical=1 then output CLA.IR4Toma1;
      if Chemical=2 then output CLA.IR4Toma2;
      if Chemical=3 then output CLA.IR4Toma3;
      if Chemical=4 then output CLA.IR4Toma4;
run;

Proc SQL;
      create table IR4 as
      select PestType, CropPest, Chemical, Zone, PHI, count(*) as NTRial
      from (select distinct PestType, CropPest, Chemical, Zone, PHI, Country_Trial
              from IR4Toma)
      group by Chemical, PestType, CropPest, PHI, Zone
      order by Chemical, PestType, CropPest, PHI, Zone;
```

```
        create table IR4_LOD as
        select PestType, CropPest, Chemical, Zone, PHI, Censored, count(*) as NTRial
        from IR4Toma
        group by Chemical, PestType, CropPest, PHI, Censored, Zone
        order by Chemical, PestType, CropPest, PHI, Censored, Zone;
quit;

Proc transpose data = IR4 out=IR4;
        by Chemical PestType CropPest  PHI;
        ID Zone;
        var NTRial;
run;

Proc transpose data = IR4_LOD out=IR4_LOD;
        by Chemical PestType CropPest PHI Censored;
        ID Zone;
        var NTRial;
run;

ods rtf file="&junk\IR4 Tabulate.rtf";
Proc print data = IR4 noobs; run;
Proc print data = IR4_LOD noobs; run;
ods rtf close;
```

E – 4.   SAS code to analyze the data using mixed-effect model and Rank-Sum test for clustered data

```
*=============================================================*
* Programmer: James Nguyen, US EPA                           *
*                                                            *
* Project: Global Zoning/Exchangeability Analysis            *
*                                                            *
* Purpose: Perform data analysis using                       *
*            – Mixed-effect model                            *
*            – Rank-Sum test for clustered data              *
*                                                            *
* Data Sources: CLA + DAS + IR4                              *
*                                                            *
* Date: 5/2015                                               *
*=============================================================*;
option formdlim="=" nodate nonumber;

libname CLA "F:\Crop Residue\Crop Residue – Zoning\Global Zoning\CLA\data";
libname DAS "F:\Crop Residue\Crop Residue – Zoning\Global Zoning\DAS\Data";

Data Combine;
        set CLA.CLA_May2015 DAS.DAS_May2015 CLA.IR4Toma4;
        logRes = log(Res);
        Crop = upcase(crop);
run;

Proc SQL;
        create table Type as
                select PestType, Zone, count(*) as NTrial
                from (select distinct PestType, CropPest, Zone, Country_Trial
                        from combine)
                group by PestType, Zone;
quit;

Proc transpose data = Type out=Type;
        by PestType;
        ID Zone;
        var NTrial;
run;

ods rtf file = "C:\Users\JNguyen\Desktop\Junks\PestType.rtf";
Proc print data = Type noobs; run;
ods rtf close;


*===> generate table of number field trials included in the analysis by zone;

Proc SQL;
        create table NTrial as
        select PestType, CropPest, Zone, count(*) as NTrial
        from (select distinct PestType, CropPest, Zone, Country_Trial
                from Combine)
        group by PestType, CropPest, Zone
        order by PestType, CropPest, Zone;
quit;

Proc transpose data = NTrial out = NTrial(drop=_NAME_);
        by PestType CropPest;
        ID Zone;
        var NTrial;
run;

ods rtf file = "C:\Users\JNguyen\Desktop\Junks\NTrial.rtf";
Proc print data = NTrial noobs; run;
ods rtf close;
```

```
*===> delete field trials in Asia or Africa due to small number
       of crop-pesticide combinations in Asia and Africa;

Data Combine;
       set Combine;
       if CropPest = "B-1-APPLE" or Zone in ("ASIA","AF") then delete;
run;


Proc SQL;
       create table Crop as
             select distinct Crop
             from combine;

       create table Chemical as
             select distinct Chemical
             from combine;

       create table CropPest as
             select distinct CropPest
             from combine;
quit;


*===> distribution of PHI;
Proc SQL;
       create table PHI as
       select CropPest, round(avg(PHI),1.0) as PHI
       from combine
       group by CropPest
       order by PHI;
quit;
ods rtf file = "C:\Users\JNguyen\Desktop\Junks\PHI.rtf" startpage=no;
Proc freq data = PHI; table PHI/nopercent norow; run;
ods rtf close;


*===> Number of Chemicals and Crop;
Proc SQL;
       create table ListCrop as
             select distinct Crop
             from combine;
       create table ListChemical as
             select distinct PestType, Chemical
             from combine;
quit;




*====> Analysis;



Proc sort data = combine; by Zone CropPest Country_Trial Replicate; run;

Proc SQL;
       create table CropPestZone as
       select distinct CropPest, Zone
       from combine
       order by CropPest, Zone;
quit;
Proc freq data = CropPestZone; table Zone/nocum nopercent; run;

ods listing;
ods select default;

*===> common zone effects;
```

```
ods select CovParms Tests3 FitStatistics;
Proc mixed data = combine;
      class Zone CropPest Country_Trial;
      model logRes = Zone/solution;
      random CropPest Country_Trial(CropPest);
run;

/*
ods select CovParms Tests3 FitStatistics ;
Proc mixed data = combine;
      class Zone CropPest Country_Trial;
      model logRes = Zone/solution;
      random intercept zone/subject=CropPest solution;
      random Country_Trial(CropPest)/group=zone;
run;
*/

*===> random zone effects;
ods rtf file = "C:\Users\JNguyen\Desktop\Junks\mixed model output.rtf" startpage=no;
ods select CovParms Tests3 FitStatistics solutionf;
*ods exclude ClassLevels SolutionR ;
Proc mixed data = combine;
      class Zone CropPest Country_Trial;
      model logRes = Zone/solution outp=pred;
      random intercept zone/subject=CropPest solution;
      random Country_Trial(CropPest);
      lsmeans Zone/pdiff cl;
      ods output solutionf=solutionf SolutionR  = SolutionR Diffs=Diffs;
run;

ods rtf close;


data solutionf;
      retain int;
      set solutionf;
      if effect = "Intercept" then int = estimate;
      if effect = "Intercept" then delete;
run;
Data solutionf;
      set solutionf;
      fix_effect = sum(int,estimate);
      keep zone fix_effect;
run;


Data Diffs;
      set Diffs;
      Comparison = compbl(Zone||" vs."||_Zone);
      Ratio_CI = trim(left(compress(left(put(exp(Estimate), 10.3)))))||
              "  "||trim(left(compbl("("||compress(left(put(exp(Lower),10.3)))||
              ", "||compress(left(put(exp(Upper),10.3)))||")")));
      p_value = probt;
run;

ods rtf file = "C:\Users\JNguyen\Desktop\Junks\Fixed effects.rtf" startpage=no;
Proc print data = Diffs noobs;
      var Comparison Ratio_CI p_value;
      format p_value pvalue5.;
run;
ods rtf close;


Proc sort data = Solutionr;
      where Zone ^= "";
      by CropPest Zone;
run;

Data Solutionr;
      merge Solutionr CropPestZone(in=mustin);
```

```
                    by CropPest Zone;
                    if mustin=1;
        run;

        Proc sort data = Solutionr; by Zone; run;
        Proc sort data = Solutionf; by zone; run;

        Data Solutionr;
                merge Solutionr Solutionf;
                by Zone;
                LogRatio=estimate+fix_effect;
                label estimate = "Random effect of Zone by Crop-Pesticide";
        run;

        ods rtf file = "C:\Users\JNguyen\Desktop\Junks\Global Zoning residuals.rtf" startpage=no;
                Proc sort data = pred; by Zone; run;
                ods graphics/reset=all height = 5in width=7in;
                Proc SGPLOT data = pred;
                        scatter x = Pred y = resid;
                        refline 0/axis=y;
                run;

                ods graphics/reset=all height = 9in width=7in;
                Proc SGPANEL data = pred;
                        panelby Zone/columns=1 rows=4;
                        scatter x = Pred y = resid;
                        refline 0/axis=y;
                run;
        ods rtf close;

        ods graphics/reset=all;
        ods rtf file = "C:\Users\JNguyen\Desktop\Junks\Global Zoning random effects.rtf"
        startpage=no;
        ods select Histogram QQPlot;
        Proc univariate data =Solutionr;
                var estimate;
                histogram estimate/normal (color=(red blue) mu=est sigma=est) href = 0
        BARLABEL=COUNT
                                        midpoints = -0.1 0.0 0.1;
                qqplot estimate / normal(mu=est sigma=est) square ctext=blue;
        run;
        ods select Histogram QQPlot;
        Proc univariate data =Solutionr;
                var LogRatio;
                histogram LogRatio/normal (color=(red blue) mu=est sigma=est) href = 0
        BARLABEL=COUNT
                                        midpoints = -2.1 -2.0 -1.9;
                qqplot LogRatio / normal(mu=est sigma=est) square ctext=blue;
        run;
        ods rtf close;

        Proc sort data = Solutionr; by estimate; run;
        data outlierRand; set Solutionr; if _N_ in (1,2,94,95,96,97); run;

        ods rtf file = "C:\Users\JNguyen\Desktop\Junks\outliers random effects.rtf" startpage=no;
        Proc print data = outlierRand noobs;
                var CropPest Zone Estimate;
                format Estimate 6.4;
        run;
        ods rtf close;


        Proc sort data = Solutionr; by CropPest Zone; run;

        Proc transpose data = Solutionr out = Random(drop=_NAME_);
                by CropPest;
                id Zone;
                var LogRatio ;
        run;
```

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```
Data Random;
      set Random;
      AU_NZ_EU=AU_NZ-EU;
      AU_NZ_NA=AU_NZ-NA;
      AU_NZ_SA=AU_NZ-SA;
      EU_NA=EU-NA;
      EU_SA=EU-SA;
      NA_SA=NA-SA;
      drop AU_NZ EU NA SA;
run;

Proc transpose data = Random out=Random;
      by CropPest;
run;

Data Random;
      set Random;
      if COL1=. then delete;
      LogRatio= COL1;
      Ratio = exp(COL1);
run;

Proc sort data = Random; by _NAME_; run;


ods rtf file = "C:\Users\JNguyen\Desktop\Junks\Figures Global Zoning random effects.rtf"
startpage=no;
ods select Histogram QQPlot;
Proc univariate data =Random;
      by _NAME_;
      var LogRatio;
      histogram LogRatio/normal (color=(red blue) mu=est sigma=est) href = 0
BARLABEL=COUNT
                                      midpoints = -1.0 -.8 -.6 -.4 -.2 0 .2 .4 .6 .8 1;
      qqplot LogRatio / normal(mu=est sigma=est) square ctext=blue;
run;
ods select Histogram;
Proc univariate data =Random;
      by _NAME_;
      var Ratio;
      histogram Ratio/lognormal (color=(red blue) theta=est) href = 1 BARLABEL=COUNT
                                      midpoints = .2 .4 .6 .8 1.0 1.2 1.4 1.6 1.8 2.0;
run;
ods rtf close;

Proc SQL;
      create table NTRial as
      select ZONE, CropPest, count(*) as NTRIAL
      from (select distinct ZONE, CropPest, Country_Trial
                 from combine)
      group by ZONE, CropPest
      order by CropPest, ZONE;
quit;
Proc transpose data = NTRial out = NTRial;
      by CropPest;
      id ZONE;
      var NTRIAL;
run;

Data AU_NZ_EU;
      set NTRIAL;
      if AU_NZ+EU ^=.;
      _NAME_ = "AU_NZ_EU";
      N1 = AU_NZ;
      N2 = EU;
      keep CROPPEST _NAME_ N1 N2;
run;
Data AU_NZ_NA;
```

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```
            set NTRIAL;
            if AU_NZ+NA ^=.;
            _NAME_ = "AU_NZ_NA";
            N1 = AU_NZ;
            N2 = NA;
            keep CROPPEST _NAME_ N1 N2;
        run;
Data AU_NZ_SA;
            set NTRIAL;
            if AU_NZ+SA ^=.;
            _NAME_ = "AU_NZ_SA";
            N1 = AU_NZ;
            N2 = SA;
            keep CROPPEST _NAME_ N1 N2;
        run;
Data EU_NA;
            set NTRIAL;
            if EU+NA ^=.;
            _NAME_ = "EU_NA";
            N1 = EU;
            N2 = NA;
            keep CROPPEST _NAME_ N1 N2;
        run;
Data EU_SA;
            set NTRIAL;
            if EU+SA ^=.;
            _NAME_ = "EU_SA";
            N1 = EU;
            N2 = SA;
            keep CROPPEST _NAME_ N1 N2;
        run;
Data NA_SA;
            set NTRIAL;
            if NA+SA ^=.;
            _NAME_ = "NA_SA";
            N1 = NA;
            N2 = SA;
            keep CROPPEST _NAME_ N1 N2;
        run;

    Proc sort data = Random; by _NAME_ CropPest; run;
    Proc sort data = AU_NZ_EU; by _NAME_ CropPest; run;
    Proc sort data = AU_NZ_NA; by _NAME_ CropPest; run;
    Proc sort data = AU_NZ_SA; by _NAME_ CropPest; run;
    Proc sort data = EU_NA; by _NAME_ CropPest; run;
    Proc sort data = EU_SA; by _NAME_ CropPest; run;
    Proc sort data = NA_SA; by _NAME_ CropPest; run;

    Data Random1;
            merge Random AU_NZ_EU AU_NZ_NA AU_NZ_SA EU_NA EU_SA NA_SA;
            by _NAME_ CropPest;
            InverseRatio = 1/Ratio;
        run;

    Proc sort data = Random1; by _NAME_ Ratio; run;

    ods rtf file = "C:\Users\JNguyen\Desktop\Junks\Global Zoning random effects.rtf"
    startpage=no;
    Proc report data = Random1  nowd;
            column _NAME_ CropPest LogRatio Ratio InverseRatio N1 N2;
            define _NAME_/order;
            format LogRatio Ratio InverseRatio 6.2;
        run;
    ods rtf close;




    Proc freq data = combine; table Country_Trial/out=freq; run;
```

```
*===> Non-parametric analysis;

Proc SQL;
      create table Kruskal as
            select CropPest, Zone, Country_Trial, mean(Res) as Res, log(calculated
Res) as LogRes
            from combine
            group by CropPest, Zone, Country_Trial
            order by CropPest, Zone, Country_Trial;


quit;

%Macro RankSum_Cluster(datain=, cluster=, group=, Yvar=);
      Proc SQL;
            create table temp as
                  select *, count(*) as Ni              /* number of records in
cluster i */
                  from &datain
                  where &Yvar ^=.
                  group by &cluster;

            create table Ngroup as
                  select distinct &group
                  from temp
                  order by &group;
      quit;

      Data Ngroup;
            set Ngroup end=eos;
            GroupID = _N_;
            call symput("group"||trim(left(_N_)), GroupID);
            if eos then call symput("Ng", _N_);
      run;

      Proc SQL;
            create table temp1 as
            select a.*, GroupID
            from temp as a, Ngroup as b
            where a.&group = b.&group
            order by &cluster, GroupID;
      quit;

      Data temp;
            set temp1 end=eos;
            retain clusvar k;
            by &cluster;
            if first.&cluster = 1 then do;
                  clusvar+1;
                  k = 1;
            end;
            if first.&cluster = 0 then k + 1;
            if last.&cluster then call symput("N"||left(clusvar),k);
            call symput("Yvar"||trim(left(_N_)), &Yvar);
            call symput("Yvar"||trim(left(clusvar))||"_"||trim(left(k)), &Yvar);
            call symput("g"||trim(left(clusvar))||"_"||trim(left(k)), GroupID);
            if eos then do;
                  call symput("M",clusvar);
                  call symput("N",_N_);
            end;
      run;

      Data temp;
            set temp;
            Fikhat = 0;
            %do j = 1 %to &N;
```

```
                                Fikhat = Fikhat + ((&&Yvar&j < &Yvar) + (&&Yvar&j <=
&Yvar))/(2*&N);
                %end;

                Fik=0;
                %do v = 1 %to &Ng;    Pik&v = 0;      %end;

                %do i = 1 %to &M;
                        %do k = 1 %to &&N&i;
                                if clusvar = &i then do;
                                        Fik = Fik;
                                        %do v = 1 %to &Ng;    Pik&v = Pik&v;         %end;
                                end;

                                else do;
                                        Fik = Fik + ((&&Yvar&i._&k < &Yvar) + (&&Yvar&i._&k
<= &Yvar))/(2*&&N&i);
                                        %do v = 1 %to &Ng;     Pik&v = Pik&v + (&&g&i._&k =
&&group&v)/&&N&i; %end;
                                end;
                        %end;
                %end;
        run;

        Proc SQL;
                create table Wi as
                        select
                                %do v = 1 %to &Ng;
                                        sum((GroupID = &&group&v))/count(*) as Pi&v,
                                        sum((((&M-1)*(GroupID=&&group&v) -
Pik&v)*Fikhat)/(Ni*(&M+1))) as Whati&v,
                                %end;
                                clusvar
                        from temp
                        group by clusvar;

                create table ES as
                        select GroupID, sum((1+ Fik)/Ni)/(1+&M) as S, sum(1/Ni)/2 as ES
                        from temp
                        group by GroupID;
                %do v = 1 %to &Ng;
                        create table EW&v as
                                select Clusvar, Whati&v, (&M*Pi&v)/(2*(&M+1)) - ES/(&M+1)
as EW&v,
                                                Whati&v - calculated EW&v as Whati_EW&v
                                from Wi, ES(where=(GroupID=&&group&v));
                %end;
        quit;

        Data W_EW;
                merge %do v = 1 %to &Ng; EW&v(keep= Whati_EW&v clusvar) %end;;
                by clusvar;
        run;

        Proc SQL;
                %do v = 1 %to &Ng;
                        create table V&v as
                                select
                                        %do z = 1 %to &Ng;
                                                sum((Whati_EW&v)*(Whati_EW&z))/&M as COL&z,
                                        %end;
                                        &v as row
                                from W_EW;
                %end;
        quit;

        Data ES;
                set ES;
                COL1=S-ES;
                keep COL1;
```

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```
                    run;

                    Data Cov(drop=row);
                            set %do v = 1 %to &Ng;V&v %end;;
                    run;

                    Proc IML;
                            use Cov;
                            read all into V;

                            use ES;
                            read all into S_ES;

                            T=t(S_ES)*ginv(V)*S_ES/&M;

                            create Statistic(rename = (COL1 =T)) from T;
                            append from T;
                    quit;

                    Data Statistic;
                            set Statistic;
                            df = &Ng-1;
                            pvalue =1-probchi(T,df);
                            label T = "Chi-square Statistic" pvalue="p-value";
                    run;

                    Proc print data = Statistic noobs label;
                            format T 12.3 pvalue pvalue5.;
                    run;

            %Mend;
            /*%RankSum_Cluster(datain=Kruskal, cluster=CropPest, group=Zone, Yvar=LogRes);*/
            %RankSum_Cluster(datain=Kruskal, cluster=CropPest, group=Zone, Yvar=Res);


            ods listing;
```

E – 5. SAS code of simulation to evaluate the impact of variation between crop-pesticide combinations on the significance of zone effects

```
*========================================================*
* Programmer: James Nguyen, US EPA                       *
*                                                        *
* Project: Global Zoning/Exchangeability Analysis        *
*                                                        *
* Purpose: Perform simulation to evaluate the impact of  *
*          variation between crop-pesticide combinations *
*          on the significance of zone effects           *
*                                                        *
* Data Sources: randomly generated                       *
*                                                        *
* Date: 2/2016                                           *
*========================================================*;
option formdlim="=" nonumber nodate ps=100 nomprint;
%Macro crop_variation (Sim=, GM=, CV=, ZSD=, Rate =, seed=);

    %let M = log(&GM);
    %let SD = sqrt(log(1+&CV**2));

    Data Sim;
       do Crop = 1 to 20;
               RandC = rannor(&seed);
               RandZC = rannor(&seed);
               CropM1 = &M + sqrt(0.00)*&SD*RandC;
               CropM2 = &M + sqrt(0.50)*&SD*RandC;
               CropM3 = &M + sqrt(1.00)*&SD*RandC;
               CropM4 = &M + sqrt(2.00)*&SD*RandC;
               CropM5 = &M + sqrt(4.00)*&SD*RandC;
               CropM6 = &M + sqrt(10.0)*&SD*RandC;

               do zone = 1 to 2;
                       ZEffect = (zone=1)*log(&Rate) + (zone=1)*&ZSD*&SD*RandZC;

                       do trial = 1 to round(3+5*RANUNI(&seed),1.0);
                               randT = rannor(&seed);
                               lgRes1 = CropM1 + ZEffect + &SD*RandT;
                               lgRes2 = CropM2 + ZEffect + &SD*RandT;
                               lgRes3 = CropM3 + ZEffect + &SD*RandT;
                               lgRes4 = CropM4 + ZEffect + &SD*RandT;
                               lgRes5 = CropM5 + ZEffect + &SD*RandT;
                               lgRes6 = CropM6 + ZEffect + &SD*RandT;
                               output;
                       end; *trial;
               end; *zone;
       end; *crop;
    run;

    ods listing close;
    Data Result; set _NULL_; run;
    %do i = 1 %to 6;
       Proc mixed data = Sim;
               Class Crop Zone Trial;
               model lgRes&i = Zone;
               random intercept zone/subject = crop;
               lsmeans zone/pdiff cl;
               ods output CovParms = CovParms&i diffs=diffs&i(drop=zone);
       run;quit;

       Proc transpose data = CovParms&i out=CovParms&i(drop=_NAME_);
               id CovParm;
               var estimate;
       run;
       Data Result&i;
               merge CovParms&i diffs&i;
               Ratio=compbl(compress(put(exp(Estimate), 5.3))||" ("||
```

```
                                              compress(put(exp(Lower), 5.3))||", "
                                              ||  compress(put(exp(Upper), 5.3))||")");
                    pvalue=put(probt, 5.3);
                    TrueTrialVar = log(1+&CV**2);
                    %if &i = 1 %then %do; CropVar_TrialVar = 0.0; %end;
                    %if &i = 2 %then %do; CropVar_TrialVar = 0.5; %end;
                    %if &i = 3 %then %do; CropVar_TrialVar = 1.0; %end;
                    %if &i = 4 %then %do; CropVar_TrialVar = 2.0; %end;
                    %if &i = 5 %then %do; CropVar_TrialVar = 4.0; %end;
                    %if &i = 6 %then %do; CropVar_TrialVar = 10.0; %end;
                    TrueRate = &Rate;
                    keep Intercept Zone Residual Ratio pvalue TrueRate CropVar_TrialVar
        TrueTrialVar;
            run;
            Data Result;
                    set Result result&i;
            run;
        %end;
        ods listing;
        title "Rate = &Rate; ZSD = &ZSD.*TSD";
        Proc print data = Result noobs label;
            label   TrueTrialVar = "True Trial Variance"
                            CropVar_TrialVar = "True Ratio Crop Variance/Trial Variance"
                            TrueRate = "True Residue Ratio"
                            Intercept = "Estimated Crop Variance"
                            Zone = "Estimated Zone Effect Variance among crops"
                            Residual = "Estiamted Trial Variance"
                            Ratio = "Estimated Residue Ratio";
            var TrueTrialVar CropVar_TrialVar TrueRate Intercept Zone Residual Ratio pvalue;
        run;
%mend;

%crop_variation (Sim=1, GM=1, CV=1, ZSD = 0.5, Rate=1.25, seed=14);
```

E – 6.   SAS code of simulation to evaluate zone impact on global and zone-specific MRLs

```
*=============================================================*
* Programmer: James Nguyen, US EPA                            *
*                                                             *
* Project: Global Zoning Analysis                             *
*                                                             *
* Purpose: Perform Simulation to evaluate the impact on MRLs  *
*          when pooling FT residues from different zones       *
*                                                             *
* Data Source:                                                *
*     - simulation                                            *
*                                                             *
* Descriptions:                                               *
*      - generate data from lognormal, given GM=0.5 and CV=1  *
*      - zone effects = -25%                                  *
*      - calculate MRL for each dataset of each scenario      *
*      - created box-plot MRL for each scenario               *
*      - caculated proportion of MRL > 95%-tile               *
*                                                             *
* Date Started: 1/17/2016                                     *
*                                                             *
*=============================================================*;
Option FormDlim = "=" NoDate NoNumber nomprint;
ods noptitle;

Data OECD_RoundRule;
      input actual proposed @@;
      datalines;
      0.000001  0.01  0.0105  0.015  0.0155  0.02  0.021  0.03
      0.031  0.04  0.041  0.05  0.051  0.06  0.061  0.07
      0.071  0.08    0.081  0.09  0.091  0.1  0.105  0.15
      0.155  0.2  0.21  0.3  0.31  0.4  0.41  0.5  0.51  0.6
      0.61  0.7  0.71  0.8  0.81  0.9  0.91  1  1.05  1.5
      1.55  2  2.1  3  3.1  4  4.1  5  5.1  6  6.1  7  7.1  8
      8.1  9  9.1  10  10.5  15  15.5  20  21  30  31  40
      41  50  51  60  61  70  71  80  81  90  91  100  105  150
      155  200  210  300  310  400  410  500  510  600  610  700
      710  800  810  900  910  1000  1050  1500  1550  2000
      2100  3000  3100  4000  4100  5000  5100  6000  6100  7000
      7100  8000  8100  9000  9100  10000  10500  15000
      15500  20000  21000  30000  31000  40000  41000  50000
      51000  60000  61000  70000  71000  80000  81000  90000
      91000  100000
      ;
run;

Data OECD_RoundRule;
      set OECD_RoundRule end=lastrow;
      call symputx("act"||left(_N_ -1),actual);
      call symputx("pro"||left(_N_),proposed);
      if lastrow then call symput('nround', _N_);
run;

title;

%Macro MRL(case=,size=);
      create table case&case.a as
            select "&case.a" as Cas, Sim, compbl("&size "||Zone) as Scenario,
                 max(MaxV, MeanV*3, MeanV + SD*4) as MRL
            from (select Sim, Zone, avg(Res) as MeanV, max(res) as MaxV, std(res) as
SD
                    from Simmer
                    where Trial <= &size
                    group by Sim, Zone);
      create table case&case.b as
            select "&case.b" as Cas, Sim, compbl("&size "||"AUNZ"||" +"||"&size
"||"NA"||
```

```
                                                " +"||"&size "||"SA"||" +"||"&size "||"EU")
            as Scenario,
                                 max(MaxV, MeanV*3, MeanV + SD*4) as MRL
                   from (select Sim, avg(Res) as MeanV, max(res) as MaxV, std(res) as SD
                         from Simmer
                         where Trial <= &size
                         group by Sim);
        %Mend;

        * EU_GM  = Geometric mean of residues in EU;
        * R_AUNZ = residue ratio of AUNZ/EU;
        * R_NA   = residue ratio of NA/EU;
        * R_SA   = residue ratio of SA/EU;
        * N_AUNZ  = number of field trials from AU-NZ;
        * N_NA    = number of field trials from NA;
        * N_SA    = number of field trials from SA;
        * N_EU    = number of field trials from EU;

        %Macro Simulation(NSim=,EU_GM=, CV=, R_AUNZ=, R_NA=, R_SA=, values=, seed=);

            %let MY = log(&EU_GM);
            %let SY = sqrt(log(1+&CV**2));

            Data P95;
                EUP975 = exp(&MY + 1.96*&SY);                          call
        symput('EUP975',EUP975);
                NAP975 = exp(&MY + log(&R_NA) + 1.96*&SY);         call
        symput('NAP975',NAP975);
                SAP975 = exp(&MY + log(&R_SA) + 1.96*&SY);         call
        symput('SAP975',SAP975);
                AUNZP975 = exp(&MY + log(&R_AUNZ) + 1.96*&SY);     call
        symput('AUNZP975',AUNZP975);
                EUP95 = exp(&MY + 1.645*&SY);                         call
        symput('EUP95',EUP95);
                NAP95 = exp(&MY + log(&R_NA) + 1.645*&SY);         call
        symput('NAP95',NAP95);
                SAP95 = exp(&MY + log(&R_SA) + 1.645*&SY);         call
        symput('SAP95',SAP95);
                AUNZP95 = exp(&MY + log(&R_AUNZ) + 1.645*&SY);     call
        symput('AUNZP95',AUNZP95);
            run;

            Data Parm;
                Zone = "AUNZ";        lgGM = log(&EU_GM*&R_AUNZ); N1=2; output;
                Zone = "NA";    lgGM = log(&EU_GM*&R_NA);   N1=3; output;
                Zone = "SA";    lgGM = log(&EU_GM*&R_SA);   N1=2; output;
                Zone = "EU";    lgGM = log(&EU_GM);               N1=3; output;
            run;

            Data Simmer;
                set Parm;
                do sim = 1 to &NSim;
                    do Trial = 1 to 10;
                        Res = exp(lgGM + &SY*rannor(&seed));
                        output;
                    end;
                end;
            run;

            Proc SQL;
                %MRL(case=1,size=9);
                %MRL(case=2,size=7);
                %MRL(case=3,size=5);
                %MRL(case=4,size=4);
                %MRL(case=5,size=3);

                create table case6 as
                    select "6" as Cas, Sim, compbl("2 "||"AUNZ"||" +"||"3 "||"NA"||
                                        " +"||"2 "||"SA"||" +"||"3 "||"EU")
            as Scenario,
```

```
                                              max(MaxV, MeanV*3, MeanV + SD*4) as MRL
                              from (select Sim, avg(Res) as MeanV, max(res) as MaxV, std(res) as
SD
                                      from Simmer
                                      where Trial <= N1
                                      group by Sim);
        quit;

        Data AllCases;
                length cas $2. Scenario $30.;
                set case1a case1b case2a case2b case3a case3b case4a case4b case5a case5b
case6;

                *==> apply OECD rounding rules;
                if MRL > 91000 then MRL = 100000;
                %do i = 1 %to %eval(&nround-1);
                        else if MRL < &&act&i then MRL = &&pro&i;
                %end;

                P95AUNZ=(MRL<&AUNZP95);

                P95EU=(MRL<&EUP95);
                if index(Scenario,"AUNZ")= 0 then P95AUNZ = .;
                else if index(Scenario,"EU")=0 then P95EU = .;
/*              P975AUNZ=(MRL<&AUNZP975);*/
/*              P975EU=(MRL<&EUP975);*/
        run;

        ods listing close;
        Proc SGPLOT data = AllCases;
                where cas in ("1a","1b","2a","2b","5a","5b");
                VBOX MRL/group = Scenario nomean;
                yaxis type= log label= "MRLs" logbase= 10 logstyle= logexpand  values =
&values;
                xaxis OFFSETMIN= 0.02 OFFSETMAX= 0.02;
/*              refline &EUP975 /axis=y label = "EU 97.5%-tile" LINEATTRS=(pattern=1
color=blue thickness=1);*/
/*              refline &AUNZP975/axis=y label = "AU-NZ 97.5%-tile"  LINEATTRS=(pattern=1
color=black thickness=1);*/
                refline &EUP95 /axis=y label = "EU 95%-tile" LINEATTRS=(pattern=2
color=blue thickness=2);
                refline &AUNZP95/axis=y label = "AU-NZ 95%-tile" LINEATTRS=(pattern=2
color=black thickness=2);
        run;
        Proc SGPLOT data = AllCases;
                where cas in ("3a","3b","4a","4b","3a","3b","5a","5b");
                VBOX MRL/group = Scenario nomean;
                yaxis type= log label= "MRLs" logbase= 10 logstyle= logexpand  values =
&values;
                xaxis OFFSETMIN= 0.02 OFFSETMAX= 0.02;
/*              refline &EUP975 /axis=y label = "EU 97.5%-tile" LINEATTRS=(pattern=1
color=blue thickness=1);*/
/*              refline &AUNZP975/axis=y label = "AU-NZ 97.5%-tile"  LINEATTRS=(pattern=1
color=black thickness=1);*/
                refline &EUP95 /axis=y label = "EU 95%-tile" LINEATTRS=(pattern=2
color=blue thickness=2);
                refline &AUNZP95/axis=y label = "AU-NZ 95%-tile" LINEATTRS=(pattern=2
color=black thickness=2);
        run;
        Proc SQL;
                select Scenario, avg(P95AUNZ) as P95AUNZ, avg(P95EU) as P95EU
                from AllCases
                where cas in ("1a","1b","2a","2b","3a","3b","5a","5b")
                group by Scenario;
        quit;
        Proc datasets nolist;
                save sasmacr AllCases;
        quit;
```

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```
%Mend;

ods rtf file = "C:\Users\JNguyen\Desktop\Junks\zone plots2.rtf" startpage=no;
%Simulation(NSim=1000,EU_GM=0.5, CV=1, R_AUNZ=0.70, R_NA=1, R_SA=1,
        values=(0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9,1,2,3,4,5,6,7,8,9,10,20,30,40,50),
seed=3562);
ods rtf close;
```