

Unclassified

ENV/JM/MONO(2011)50/REV1/ANN

Organisation de Coopération et de Développement Économiques
Organisation for Economic Co-operation and Development

07-Sep-2016

English - Or. English

**ENVIRONMENT DIRECTORATE
JOINT MEETING OF THE CHEMICALS COMMITTEE AND
THE WORKING PARTY ON CHEMICALS, PESTICIDES AND BIOTECHNOLOGY**

**OECD GUIDANCE DOCUMENT ON CROP FIELD TRIALS: ANNEXES WITH ADDITIONAL
INFORMATION**

SECOND EDITION

Series on Pesticides - No. 66

Series on Testing & Assessment - No. 164

JT03400235

Complete document available on OLIS in its original format

This document and any map included herein are without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

ENV/JM/MONO(2011)50/REV1/ANN
Unclassified

English - Or. English

OECD Environment, Health and Safety Publications

Series on Pesticides

No. 66

and

Series on Testing and Assessment

No. 164

Guidance Document on Crop Field Trials

SECOND EDITION

IOMC

INTER-ORGANIZATION PROGRAMME FOR THE SOUND MANAGEMENT OF CHEMICALS

A cooperative agreement among **FAO, ILO, UNDP, UNEP, UNIDO, UNITAR, WHO, World Bank and OECD**

Environment Directorate
ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT
Paris 2016

About the OECD

The Organisation for Economic Co-operation and Development (OECD) is an intergovernmental organisation in which representatives of 35 industrialised countries in North and South America, Europe and the Asia and Pacific region, as well as the European Commission, meet to co-ordinate and harmonise policies, discuss issues of mutual concern, and work together to respond to international problems. Most of the OECD's work is carried out by more than 200 specialised committees and working groups composed of member country delegates. Observers from several countries with special status at the OECD, and from interested international organisations, attend many of the OECD's workshops and other meetings. Committees and working groups are served by the OECD Secretariat, located in Paris, France, which is organised into directorates and divisions.

The Environment, Health and Safety Division publishes free-of-charge documents in twelve different series: **Testing and Assessment; Good Laboratory Practice and Compliance Monitoring; Pesticides; Biocides; Risk Management; Harmonisation of Regulatory Oversight in Biotechnology; Safety of Novel Foods and Feeds; Chemical Accidents; Pollutant Release and Transfer Registers; Emission Scenario Documents; Safety of Manufactured Nanomaterials; and Adverse Outcome Pathways.** More information about the Environment, Health and Safety Programme and EHS publications is available on the OECD's World Wide Web site (www.oecd.org/chemicalsafety/).

This publication was developed in the IOMC context. The contents do not necessarily reflect the views or stated policies of individual IOMC Participating Organizations.

The Inter-Organisation Programme for the Sound Management of Chemicals (IOMC) was established in 1995 following recommendations made by the 1992 UN Conference on Environment and Development to strengthen co-operation and increase international co-ordination in the field of chemical safety. The Participating Organisations are FAO, ILO, UNDP, UNEP, UNIDO, UNITAR, WHO, World Bank and OECD. The purpose of the IOMC is to promote co-ordination of the policies and activities pursued by the Participating Organisations, jointly or separately, to achieve the sound management of chemicals in relation to human health and the environment.

This publication is available electronically, at no charge.

**For this and many other Environment,
Health and Safety publications, consult the OECD's
World Wide Web site (www.oecd.org/ehs)**

or contact:

**OECD Environment Directorate,
Environment, Health and Safety Division
2, rue André-Pascal
75775 Paris cedex 16
France**

Fax : (33-1) 44 30 61 80

E-mail : ehscont@oecd.org

© OECD 2016

Applications for permission to reproduce or translate all or part of this material should be made to: Head of Publications Service, RIGHTS@oecd.org, OECD, 2 rue André-Pascal, 75775 Paris Cedex 16, France

FOREWORD

This Guidance Document is an update of the first *Guidance Document on Crop Field Trials* published in 2011. It has been developed by the Residue Chemistry Expert Group of the OECD Working Group on Pesticides (WGP).

Crop Field Trials (CFT, also referred to as supervised field trials) are conducted to determine the magnitude of the pesticide residue in or on raw agricultural commodities, including feed items, and should be designed to reflect pesticide use patterns that lead to the highest possible residues. While the *OECD Guideline for the Testing of Chemicals on Crop Field Trial* (TG 509 published in September 2009) provides a harmonized approach to conducting and reporting crop field trials in OECD countries, this *Guidance Document on Crop Field Trials* helps in planning the trials in OECD countries and in interpreting the results.

Around the time the first Guidance Document was published, outstanding issues related to the CFT studies were raised following an OECD survey on Maximum Residue Level (MRL) policies in member countries (survey results published in 2010, Series on Pesticides, No. 51). Further work on these issues was discussed and agreed upon at the September 2011 Pesticides Registration Steering Group (RSG) Meeting (Ottawa, Canada) and then endorsed by the RSG's parent body, the WGP.

The Ottawa RSG Meeting agreed that the 2011 CFT Guidance Document should be updated with respect to the following points: i) crop groups and representative commodities; ii) considering the use of the proportionality principle for adjusting crop field trial values relative to application rate; iii) the independence of trials; iv) the composition of data sets; and v) further direction on the collection and preparation of field trial samples.

After two rounds of comments in 2014-2015 among the WGP and the Working Group of National Co-ordinators of the Test Guidelines Programme (WNT), the updated CFT Guidance Document was approved by the WGP and WNT in April 2016.

This publication is organised into two parts: the core document on guidance for conducting crop field trials ENV/JM/MONO(2011)50/REV1 and the three Annexes that are published together ENV/JM/MONO(2011)50/REV1/ANN.

This document is being published under the responsibility of the Joint Meeting of the Chemicals Committee and the Working Party on Chemicals, Pesticides and Biotechnology, which has agreed that it be declassified and made available to the public on 29 August 2016.

TABLE OF CONTENTS

ANNEX 1: Background information to Crop Grouping (Chapter 1).....	8
APPENDIX :1 Crop Grouping, Representative Commodities, Extrapolations.....	11
APPENDIX 2: Criteria for crop groups in national governments.....	31
ANNEX 2: Background information to Extrapolations (Chapter 2).....	35
ANNEX 3:Background information To Proportionality.....	39
APPENDIX 1: Relationship between application rates of pesticides and their residue levels in treated commodities: Further investigation of the proportionality principle.....	47
APPENDIX 2: Background Paper On Simulation.....	72
APPENDIX 3: Linear mixed effects model analysis – A statistical method to evaluate the proportionality principle: Residues vs. Application rate.....	91
APPENDIX 4: Possible impact of the proportionality approach on MRL setting.....	117

ANNEX 1 Background information to chapter 1. Crop Grouping

Background

1. Annex 1 describes the background as provided by OECD member countries before September 2014 to illustrate where the discussion started and to make transparent why certain conclusions and recommendations were given in the OECD Guidance Document on Crop Field Trials. An update is not foreseen.

Principles for Crop Grouping

National/Regional Approaches to Crop Groups

2. NAFTA has made extensive use of the crop group/subgroup MRL concept. The EU has tended to use extrapolations rather than the broader crop grouping. Extrapolations rely upon the data from one commodity to support another, e.g., the MRL for tomato is extended to aubergine/eggplant. Upon closer examination, however, it seems that the EU extrapolations are often very similar to NAFTA crop sub groupings.

3. Subgroups are primarily indicative of form and growth habit, and normally at least one commodity would be needed from each subgroup to set a group MRL. For example, citrus fruits are divided in the US into three subgroups (10-10A orange or tangerine/mandarine, 10-10B lemon or lime and 10-10C grapefruit). One commodity from each subgroup (e.g., orange, lemon and grapefruit) would be needed for a group MRL.

4. Consideration of form and growth habit can also lead to differences in subgroups among countries. For example, NAFTA subdivides fruiting cucurbit vegetables into melons and pumpkins/squashes/ cucumbers. The EU and Australia subdivide into edible peel and inedible peel. However, similar commodities are considered representative for the cucurbit vegetables (e.g. cucumber/ zucchini, melon/ watermelon/ winter squash).

5. The commodity consumed may also be reflected in the sub-grouping. For example, bulb vegetables are often grouped into subgroups 1: garlic, onion, shallot and 2: chives, spring onion, and leeks. The distinction is that only the bulbs of those in subgroup 1 are consumed, whereas the bulb and aerial portions of the subgroup 2 may be eaten. Different residue levels might be expected on the two sub-groupings for most pesticide applications. Thus, it might be possible to extrapolate from bulb onion to garlic and/or shallot, but not from bulb onion to spring onion.

6. Crop grouping, representative commodities, and extrapolations that were used in national/regional approaches are given in Appendix 1. Some of the criteria used by Japan, NAFTA, Australia and the EU in developing crop groups are summarized in Appendix 2.

Codex Approach to Commodity Groups

7. For the revision of the Codex commodity group/subgroup proposals the following principles used by the ICGCC/IR-4 are taken into account:

1. Botany and nomenclature of the commodity.

2. Geographical production and distribution of the commodity.
3. International trade of the commodity.
4. Cultural practices for the commodity.
5. Commercial importance of the commodity.
6. Possibilities of genetic improvement for the commodity.
7. Comparison of edible parts of the commodity.
8. If the commodity is used as a livestock feed item for beef and dairy cattle, poultry and swine.
9. If the commodity is used for processed products and/or fresh market as whole fruit/vegetable.
10. Comparison of pest problems of the commodity.
11. Comparison of potential residue levels on the commodity.
12. Existing classification of the commodity.
13. Justification for a Crop Group/Subgroup Definition.

Representative Commodities

National/Regional Approaches to Representative Commodities

8. When looking at national approaches for representative commodity (within the group) properties it seems that the following criteria are taken into account:

- major in terms of production and consumption; and
- most likely to contain the highest residue.

9. It is recognized that a major commodity may not have the highest residue. Although, there may be no definite resolution as there are no supervised residue trials data on all minor commodities of a crop group, it should not be acceptable that substantially higher residues in a minor commodity are ignored because residues of a major commodity from the same crop group support a lower MRL. In such cases, if appropriate data on the minor commodities are available, individual (higher) MRLs might be necessary. From a dietary exposure standpoint, using a major commodity as representative of the group is acceptable because of the small consumption of minor commodities. Nevertheless, one should bear in mind that this mainly refers to chronic exposure while large portion consumption relevant for acute exposure assessment is often in the same order of magnitude for minor commodities as for major commodities. Using major commodity residue situations which might not reflect highest residue in minor commodities might therefore result in an underestimation of the acute intake. In addition to dietary risk issues, there may be impacts on compliance with MRLs because a group/subgroup MRL may not reflect potential residues in one or more minor commodities. There exists the finite possibility of non-compliance for some commodities in the crop group. In such a case OECD countries have to take action on a case-by-case basis, a solution might be trials in some representative minor crops.

10. There may be some difference regionally in the desired representative crop/commodity. For example, aubergine (eggplant) is a major fruiting vegetable in Asia but not in NAFTA. In these situations, the selection of alternative representative commodities may be justified.

Codex Approach to Representative Commodities

11. Following the proposals made in Codex (CCPR 2010) representative commodities within each group and subgroup are selected and proposed, based on consideration of all available information. The following key principles are used for the selection of representative commodities:

- A representative commodity is most likely to contain the highest residues.
- A representative commodity is likely to be major in terms of production and/or consumption.
- A representative commodity is most likely similar in morphology, growth habit, pest problems and edible portion to the related commodities within a group or subgroup.

12. On the basis of these criteria one representative commodity for each group and subgroup may be sufficient. Nevertheless, to facilitate the global use of crop groups for MRL setting, alternative representative commodities may be selected giving flexibility for use of residue tests conducted in different countries or regions, given that representative commodities may vary due to regional differences in dietary consumption and/or areas of production for certain commodities.

13. The new proposed Codex commodity groups and subgroups together with proposed examples of representative commodities and the principles and guidance for selection of representative commodities were adopted by 35th Session of the Codex Alimentarius Commission in 2012 (July 2012, REP12/CAC) for fruits. A list of these commodities is given in table 1 of the main text. Further commodity groups are still under discussion and will be adopted by the Codex Alimentarius Commission at a later stage. They can be found in recent CCPR Reports and working papers.

Use of Crop Trial Data for Representative Commodities

14. Provided each authority uses the same representative commodities, crop trials which fulfil the data requirements of a regulatory authority may be used to the extent possible to replace trials required by another regulatory authority if the GAP and production conditions (e.g. cultural practices) are comparable. In those cases where the regulatory authorities in question have specified different representative commodities, the application of this approach will be made on a case-by-case basis.

APPENDIX 1
Crop Grouping, representative commodities, extrapolations

Existing Crop Groups and Extrapolations¹ (except Codex)

NAFTA Crop Group/Subgroup	NAFTA Crop Group/Subgroup (US numbering) ⁵	NAFTA Crop Group/Subgroup (Canadian numbering) ⁵	NAFTA Representative Crop (for group or subgroup)	EU Groups of Crops	EU Representative Crop and Extrapolation ³
10 Citrus Fruits	10-10 Citrus Fruits 10-10A Orange or tangerine / mandarine 10-10B Lemon or lime 10-10C Grapefruit	10- Revised Citrus Fruits 10-A Revised Orange or subgroup 10-B Revised Lemon/Lime subgroup 10-C Revised Grapefruit subgroup	Sweet orange or tangerine / mandarine Lemon or lime Grapefruit Sweet orange or tangerine / mandarine Lemon or lime Grapefruit	1 Fruits (i) Citrus Fruits	Oranges or oranges and grapefruits (8 trials, with a minimum of four trials on oranges) and mandarins and/or lemons (8 trials)→ group
11 Pome Fruits	11-10 Pome Fruits	11-09 Pome Fruits	Apple Pear	1 Fruits (iii) Pome Fruit	Apples OR Pears (with a minimum of 4 apple trials) → group
12 Stone Fruits	12-12 Stone Fruits —— 12-12A Cherry 12-12B Peach 12-12C Plum	12-09 Stone Fruits 12-09A Cherry subgroup 12-09B Peach subgroup 12-09C Plum subgroup	Cherry (sweet or tart) Peach Plum or prune plum Cherry (sweet or tart) Peach Plum or prune plum	1 Fruits (iv) Stone fruit	Peaches OR Apricots (with a minimum of 4 apricot trials) → nectarine, peach, apricot Sweet cherries ↔ Sour cherries plums
13-07 Berries			Blackberry	1 Fruit (v)	

NAFTA Crop Group/Subgroup	NAFTA Crop Group/Subgroup (US numbering) ⁵	NAFTA Crop Group/Subgroup (Canadian numbering) ⁵	NAFTA Representative Crop (for group or subgroup)	EU Groups of Crops	EU Representative Crop and Extrapolation ³
and Small Fruit			Raspberry Highbush blueberry, elderberry, or mulberry Grape Fuzzy kiwifruit Strawberry	Berries and small fruit	
13-07D Small fruit vine climbing subgroup			Grape and fuzzy kiwifruit	(a) grapes	Table ↔ Wine grapes
13-07E Small fruit vine climbing except grape, subgroup			fuzzy kiwifruit	(b) strawberries	None
13-07F Small fruit vine climbing except fuzzy kiwifruit, subgroup			grape		
13-07G Low growing berry subgroup			strawberry	(c) cane fruit	Raspberries (4 trials) → blackberries Raspberries alone OR two representatives (6 trials) → Whole group
13-07H Low growing berry, except strawberry, subgroup			cranberry		
13-07A Caneberry subgroup			Blackberry or Raspberry	(d) Other small fruits and berries (except wild)	6 trials on currants (black, red or white) alone or 6 trials on two representatives (must also
13-07B Bushberry subgroup			Blueberry, highbush		

NAFTA Crop Group/Subgroup	NAFTA Crop Group/Subgroup (US numbering) ⁵	NAFTA Crop Group/Subgroup (Canadian numbering) ⁵	NAFTA Representative Crop (for group or subgroup)	EU Groups of Crops	EU Representative Crop and Extrapolation ³
13-07C Large shrub/tree subgroup			Elderberry or mulberry		include a minimum of 4 trials on currants) or on grape and currant (must also include a minimum of 4 trials on currants)→ Whole group
tropical and subtropical fruits – edible peel ⁸				1 Fruits (vi)(a) Miscellaneous fruit – edible peel	table olives ↔ olives for oil production Cherries → Surinam cherries
tropical and subtropical fruits – inedible peel ⁹				1 Fruits (vi)(b) Miscellaneous fruit – inedible peel, small (c) Miscellaneous fruit – inedible peel, large	none none
3-07 Bulb vegetables 3-07A Onion, bulb subgroup 3-07B Onion, green subgroup			Onion, bulb Onion, green Onion, bulb Onion, green	2 Vegetables (ii) Bulb vegetables	Bulb onion → garlic, shallots Spring/salad onions → Welsh onion, chives Leek ↔ spring/salad onions
5 Brassica			Broccoli OR	2 Vegetables	

NAFTA Crop Group/Subgroup	NAFTA Crop Group/Subgroup (US numbering) ⁵	NAFTA Crop Group/Subgroup (Canadian numbering) ⁵	NAFTA Representative Crop (for group or subgroup)	EU Groups of Crops	EU Representative Crop and Extrapolation ³
(Cole) Leafy Vegetables 5A Head and stem brassica subgroup 5B Leafy Brassica greens ⁶ subgroup			Cauliflower Cabbage Mustard greens Broccoli OR Cauliflower Cabbage i Mustard	(iv) Brassica vegetables (a) Flowering brassicas. (b) Head brassicas (d) kohlrabi (c) Leafy brassicas	Cauliflower, broccoli (4 trials each) → whole group Brussels sprouts, head cabbage → None None Kale → Whole group
9 Cucurbit vegetables 9A Melon subgroup 9B Squash/cucumber subgroup			Cucumber Muskmelon Summer squash Cantaloupes Summer squash, Cucumber	2. Vegetables (iii) Fruiting vegetables (b) cucurbit edible peel (c) cucurbit inedible peel (d) sweet corn	Cucumber or courgette (if courgettes alone 8 trials) → Whole group Melons → Whole group Immature maize → sweet corn
8-10 Fruiting Vegetables (except cucurbit) 8-10A Tomato subgroup		8-09 Fruiting Vegetables (except cucurbits) 8-09A Tomato subgroup	Tomato Bell pepper Non-bell pepper Tomato (standard and one cultivar of small)	2. Vegetables (iii) Fruiting vegetables (a) Solanacea Tomatoes Peppers	Tomato → Aubergine Sweet peppers → Peppers

NAFTA Crop Group/Subgroup	NAFTA Crop Group/Subgroup (US numbering) ⁵	NAFTA Crop Group/Subgroup (Canadian numbering) ⁵	NAFTA Representative Crop (for group or subgroup)	EU Groups of Crops	EU Representative Crop and Extrapolation ³
8-10B Pepper/eggplant subgroup		8-09B Pepper/Eggplant subgroup	Bell pepper and one cultivar of nonbell pepper		
8-10C Nonbell pepper/eggplant subgroup		8-09C Nonbell pepper/eggplant subgroup	One cultivar of small nonbell pepper or one cultivar of small eggplant		
4. Leafy Vegetables (except Brassica) ⁶			Celery Head lettuce Leaf lettuce Spinach	2. Vegetables (v) Leaf vegetables and fresh herbs	
4A Leafy Greens subgroup			Head lettuce Leaf lettuce Spinach	(a) Lettuce and other salad plants including Brassicacea	Lettuce (8 trials on open leaf varieties) → Whole lettuce and other salad plants group
4B Leaf petioles ⁷ subgroup			Celery	(b) Spinach and similar (leaves)	Spinach → whole group Spinach → rocket, red mustard, leaves and sprouts of Brassica sp.
				(c) vine leaves (grape leaves)	Lettuce (8 trials, with a minimum of 4 trials on open leaf varieties) → group Spinach and similar None

NAFTA Crop Group/Subgroup	NAFTA Crop Group/Subgroup (US numbering) ⁵	NAFTA Crop Group/Subgroup (Canadian numbering) ⁵	NAFTA Representative Crop (for group or subgroup)	EU Groups of Crops	EU Representative Crop and Extrapolation ³
				(d) Water cress (e) Witloof	None None
6 Legume Vegetables (Succulent or Dried) 6A Edible-podded legume subgroup 6B Succulent shelled pea and bean subgroup 6C Dried shelled pea and bean except soybean, subgroup			Bean (one succulent and one dried) Pea (one succulent and one dried) Soybean (dry) Edible-podded bean Edible-podded pea shelled succulent bean, garden pea dried bean, dried pea	2. Vegetables (vi) Legume vegetables (fresh) Beans, green with pods Peas, green without pod	Beans, green with pods ↔ Peas with pods Consideration should be given to possible contamination from mechanical harvesting None
See above 6C			See above 6C	3. Pulses, dry	Beans (dry) and/or peas (dry) → Whole group
1. Root and Tuber Vegetables 1A Root vegetable subgroup 1B Root vegetable except sugar beet, subgroup			Carrot Potato Radish Sugar beet Carrot, radish, sugar beet Carrot, radish	2. Vegetables (i) Root and tuber vegetables	Carrots Sugar beet Fodder beet Swedes and turnips Potato, carrot, and sugar beet (8 trials each) → Whole group (root and tuber vegetables)

NAFTA Crop Group/Subgroup	NAFTA Crop Group/Subgroup (US numbering) ⁵	NAFTA Crop Group/Subgroup (Canadian numbering) ⁵	NAFTA Representative Crop (for group or subgroup)	EU Groups of Crops	EU Representative Crop and Extrapolation ³
1C Tuberous and corm vegetables subgroup			potato	(c)Other root and tuber vegetables except sugar beet	Carrot Carrots → Whole “other root and tuber vegetables except sugar beet”
1D Tuberous and corm vegetables except potato subgroup			Sweet potato		Carrots → roots of herbal infusion, spices,
2. Leaves of root and tuber vegetables (human food or animal feed)			Turnip tops Garden or sugar beet tops		Sugar beet → Beetroot, Swedes, turnips Swedes ↔ turnips Swede or turnip → celeriac, horseradish Potatoes → tropical root vegetables
				(a)Potatoes (b)Tropical root and tuber vegetables	Sweet potato and/or yam → tropical root vegetables Carrot or sugar beet → chicory roots
				9. SUGAR PLANTS	
see Group 4B			see Group 4B	2. Vegetables (vii) Stem vegetables	Leek ↔ spring/salad onions

NAFTA Crop Group/ Subgroup	NAFTA Crop Group/ Subgroup (US numbering) ⁵	NAFTA Crop Group/ Subgroup (Canadian numbering) ⁵	NAFTA Representative Crop (for group or subgroup)	EU Groups of Crops	EU Representative Crop and Extrapolation ³
					Celery → Fennel (bulb), cardoon, rhubarb
15. Cereal grains			Corn (fresh sweet corn and dried field corn) Rice Sorghum Wheat For Canada: field corn and sweet corn wheat barley	5. Cereals	Barley Maize Oats Rice Rye Sorghum Triticale Wheat For treatments applied during inflorescence emergence and post-inflorescence emergence: Barley → oats Wheat → rye Maize → millet, sorghum Immature wheat → immature spelt
14-12 Tree nut		14-11 Tree Nuts	Almond Pecan	1.Fruits (ii)Tree nuts (shelled or unshelled)	Any two representative (“closed nuts” and “open nuts” e.g. cashew nuts, pistachios) with the exception of coconuts (6 trials) → Group Any “closed nut” with the exception of

NAFTA Crop Group/ Subgroup	NAFTA Crop Group/ Subgroup (US numbering) ⁵	NAFTA Crop Group/ Subgroup (Canadian numbering) ⁵	NAFTA Representative Crop (for group or subgroup)	EU Groups of Crops	EU Representative Crop and Extrapolation ³
				(iii)Bark (iv) Roots or rhizome	None Any single cultivated crop → roots of herbal infusions and spices Carrots or any root and tuber vegetable → roots of herbal infusions and spices
21. Edible fungi			White button mushroom and Oyster mushroom Or Shiitake mushroom	2.Vegetables (viii)Fungi (a)Cultivated (b) Wild	Any single cultivated mushroom species → All cultivated mushrooms Any single wild mushroom species → All wild mushrooms
				7.Hops	None
				6 Tea, coffee, herbal infusions, and cocoa 6 (iii) herbal infusions (a) flowers (b) leaves (c) roots	Any single cultivated crop of (a), (b), or (c) → (a), (b), OR (c) of herbal infusions and spices

NAFTA Crop Group/ Subgroup	NAFTA Crop Group/ Subgroup (US numbering) ⁵	NAFTA Crop Group/ Subgroup (Canadian numbering) ⁵	NAFTA Representative Crop (for group or subgroup)	EU Groups of Crops	EU Representative Crop and Extrapolation ³
				(d)other herbal infusions	Carrots or any root and tuber vegetable → Roots of herbal infusions and spices None
				6.Tea, coffee, herbal infusions and cocoa (i) Tea	None
7 Foliage of legume vegetables (animal feed)	Any cultivar of bean, field pea, and soybean				
7A Foliage of legume vegetables except soybean, subgroup	Any cultivar of bean, field pea				
17 Grass Forage, fodder, and hay	Bermuda grass Bluegrass Brome grass or fescue				
18 Nongrass animal feeds (forage, fodder, straw, and hay)	Alfalfa <i>Clover</i>				

Appendix 1 (continued): Existing Crop Groups and Extrapolations¹ (except Codex)

Australia Commodity Crops Groupings	Australia Possible Extrapolation From...	Australia Possible Extrapolation To...	Japan Group ⁴ Crop	Japan Representative Crop and Extrapolation
Subgroup 1 Lemon Lime Mandarin Subgroup 2 Grapefruit Oranges Tangelos	Oranges + Lemons Or Oranges + Limes Or Oranges + Mandarins	Whole group	Subgroup 1: Lemon and Limes Subgroup 2: Mandarins/orange Sweet, sour Subgroup 3: Pummelos	Satsuma Mandarin + Yuzu or Lime or Lemon + Natsudaidai → whole group
Apple Crab apple Loquat Nashi Pear Quince	Apples + Pears	Whole group	Pome fruits	Apple + Pears, or Apple + Persimmon, or Pears + Persimmon → whole group
Subgroup 1 Apricot Nectarine Peach Subgroup 2 Cherries Plums Prune	Peaches + Nectarines + Cherries Or Peaches + Plums + Cherries Peaches	Whole group Nectarines, plums	Subgroup 1: Peaches Subgroup 2: Apricots Subgroup 3: Plum/Nectarine Subgroup 4: Cherries	Peaches + Japanese Apricot + Cherries → whole group
Subgroup 1 Blackberry Boysenberry Cranberry Raspberry Subgroup 2 Blueberry Currants Gooseberry Other Grapes Strawberry	Grapes + strawberry and one other from subgroups 1 or 2 Raspberry Currants	Whole group Subgroup 1 Subgroup 2	Subgroup 1: Strawberry Subgroup 2: Grapes Subgroup 3: Currants/ Blueberry/ Raspberry	Strawberry + Grapes + Blueberries → whole group
Dates Figs	Olives + tamarillo (no	Whole group	Edible peel: Small:	Under consideration

Australia Commodity Crops Groupings	Australia Possible Extrapolation From...	Australia Possible Extrapolation To...	Japan Crop Group ⁴	Japan Representative Crop and Extrapolation
Olives Persimmon Tamarillo Carambola Grumichan Jaboticaba	extrapolation from one crop to another is possible although if data from these crops are consistent, a group MRL may be possible)		Acerola/ Table Olives/ Kiwiberry/ Date Medium to Large: Chocolate Vine/Five leaf Akebia/ Fig	
Avocado Babaco Banana Custard apple Feijoa Guava Jackfruit Kiwifruit Litchi Longans Mango Mangosteen Pawpaw Passion fruit Persimmon Pineapple Rambutan Sapodilla Sapote	Banana Avocado Kiwifruit Mango Papaw Pineapple (no extrapolation from one crop to another is possible although if data from these crops are consistent, a group MRL may be possible)	Whole group	Inedible peel: Small: Litchi Smooth peel: Avocado/ Banana/ Papaya/ Mango Rough or hairy peel: Pineapple	Under consideration
Subgroup 1 Garlic Onions Shallots Subgroup 2 Chives Spring onions Subgroup 3 Leeks Subgroup 4 Fennel bulb	Onions + Spring onions Or Onions + shallots Or Onions + Leeks Onions (green) or shallots	Whole group Subgroups 1, 2 and 3	No Group has been established	N/A
Subgroup 1 Cauliflower Broccoli	Cauliflower + Cabbage + Brussels sprouts	Whole group	Brassica vegetables (edible flower buds and	Any two species →group

Australia Commodity Crops Groupings	Australia Possible Extrapolation From...	Australia Possible Extrapolation To...	Japan Crop Group ⁴	Japan Representative Crop and Extrapolation
Subgroup 2 Cabbage Subgroup 3 Brussels sprouts	Or Broccoli + Cabbage + Brussels sprouts		stem): See Leafy vegetables (including Brassica leafy vegetables) (No other group has been established)	
Subgroup 1 Cucumber Chokos Bitter melon Zucchini Subgroup 2 Melons Marrow Pumpkin Squash Subgroup 3 Gherkin	Rock melon + Cucumber + Zucchini Melons	Whole group Subgroup 2	Cucurbits for pickles: Oriental pickling melon, Sponge gourd, Wax Gourd, Citron melon (No other group has been established)	Oriental pickling melon and any other one species →group Cucumber→ Zucchini
Subgroup 1 Egg plant Tomato Subgroup 2 Fungi Mushrooms Other Peppers Chilies Cape gooseberry Sweet corn Okra Roselle (Rosella)	Tomato + Capsicum (note it may be more appropriate to generate data as growing patterns and size vary widely) Maize	Whole group Sweet corn	Non-bell-shaped peppers: Chili pepper Long pepper Shishitou (<i>Capsicum annuum var.grossum Sendth</i>) (No other group has been established)	Shishitou (<i>Capsicum annum var.grossum Sendth</i>) and any one other species →group Cherry tomato →Tomato

Australia Commodity Crops Groupings	Australia Possible Extrapolation From...	Australia Possible Extrapolation To...	Japan Crop Group ⁴	Japan Representative Crop and Extrapolation
<p>Subgroup 1 Lettuce Mustard Cress</p> <p>Subgroup 2 Spinach Silverbeet</p> <p>Subgroup 3 Fennel</p> <p>Subgroup 4 Chinese cabbage Kale</p>	<p>Leafy lettuce + Spinach + Chinese cabbage</p> <p>Spinach</p> <p>Celery</p>	<p>Whole group</p> <p>Subgroup 2</p> <p>Silverbeet</p>	<p>Brassica Leafy vegetables : Kale, Komatsuna, Mizuna, Pak Choi, Rucola</p> <p>Leaf Lettuce: Leaf Lettuce</p> <p>Labiata Leafy vegetables: Labiata, Sage, Mint, Basil</p> <p>Apiaceous Leafy vegetables: Celery, Coriander (leaf), Japanese honeywort Parsley, Soup celery</p>	<p>Komatsuna, Mizuna and one other species →group</p> <p>Any two species from the group →group</p> <p>Labiata, sage or mint; and one other species from the group →group</p> <p>Soup celery, coriander (leaf) or Japanese honeywort; and one other species from the group →group</p>
<p>Beans (green) Peas (green)</p>	<p>Beans (green) + Peas (green)</p>	<p>Whole group</p>	<p>Legume Vegetables (Succulent seeds and/or immature pods): Soy bean (immature seeds) Garden pea (young pods and immature seeds) Common bean (pods and immature seeds)</p>	<p>Soy bean, garden pea and common bean → whole group</p>

Australia Commodity Crops Groupings	Australia Possible Extrapolation From...	Australia Possible Extrapolation To...	Japan Crop Group ⁴	Japan Representative Crop and Extrapolation
Peas Beans Chickpea Lentils Lupin Soybean	Field peas (dry) + faba beans (dry) + lupins Or Field peas (dry) + chickpeas + lupins Or Field peas (dry) + navy beans + lupins	Whole group	Pulses (Dried): Soybean (dry) Groundnut	Soybean (dry), groundnut and one other species →whole group
Subgroup 1 Carrot Parsnip Subgroup 2 Beetroot Swede Turnip Subgroup 3 Sweet potato Potato Yam Subgroup 4 Radish Horseradish Subgroup 5 Chicory	Potato + carrot + beetroot Or Potato + carrot + swede Or Potato + carrot + radish	Whole group	No Group has been established	N/A
Artichoke Asparagus Celery Witloof Rhubarb	Celery, asparagus, artichoke Celery	Whole group Rhubarb	No Group has been established	N/A
Subgroup 1 Wheat Triticale Cereal rye Subgroup 2 Barley Oats Subgroup 3 Maize	Wheat + barley + oats Maize + sorghum Rice Wheat or barley	Subgroups 1 and 2 Subgroup 3 Subgroup 4 Oats, rye, triticale, durum wheat,	Cereals group 1 (only those below): Oats, Barley, Wheat and Rye (NB: rice is not included in this group)	Barley and Wheat →group

Australia Commodity Crops Groupings	Australia Possible Extrapolation From...	Australia Possible Extrapolation To...	Japan Group ⁴ Crop	Japan Representative Crop and Extrapolation
Sorghum Millet Subgroup 4 Rice	Wheat	(treatments applied before GS32 only) Whole group except rice for post-harvest treatment only	Cereals group 2: Millets (No other group has been established)	Awa(<i>Setaria italica</i>) →group
Sugar cane			No Group has been established	N/A
Almonds Cashew Chestnuts Hazelnuts Macadamia Pecan Pistachios Walnuts	Almonds + Macadamia	Whole group	No Group has been established	N/A
Subgroup 1 Mustard seed Linseed Rape seed Subgroup 2 Poppy seed Safflower seed Sesame seed Sunflower seed Subgroup 3 Peanut Subgroup 4 Soybean Subgroup 5 Olive Subgroup 6 Maize Subgroup 7 Cottonseed	Canola (safflower, linseed or linola may replace canola in case of winter crops depending on use –pattern), cottonseed, peanut (summer crops, sunflower, soybean may replace peanuts depending on use-pattern). Rape seed	Whole group Mustard seed, poppy seed, sesame seed, linseed	No Group has been established	N/A
Coffee			No Group has been established	N/A
Many	Parsley, mint (extrapolations)	Whole group	See Labiate leafy vegetables and	

Australia Commodity Crops Groupings	Australia Possible Extrapolation From...	Australia Possible Extrapolation To...	Japan Crop Group ⁴	Japan Representative Crop and Extrapolation
	to a group on a case-by-case basis)		Apiaceous leafy vegetables (No other group has been established)	
Many	Ginger (extrapolations to a group on a case-by-case basis)	Whole group	No Group has been established	N/A
See fruiting vegetable			Edible fungi: Shiitake mushroom Enokitake (<i>Flammulina velutipes</i>) Oyster mushroom Nameko (<i>Pholiota nameko</i>) Hen of the woods (<i>Grifola frondosa</i>)	Shiitake mushroom and one other species →whole group
			No Group has been established	N/A
			No Group has been established	N/A

¹ The current situation is fluid. Revisions are occurring in Codex and NAFTA. The table attempts to represent the official situation at the moment (before September 2014).

² For fruits according to adopted new Codex Classification, see Table 1 in the main text.

³ Late season use. Separate criteria for early season use and for postharvest use.

⁴ The work is currently ongoing as a part of the review of pesticide registration scheme in Japan on the classification of all food commodities/crops for which there are registered uses of pesticides and/or MRLs. The work uses the Codex Classification as a basis with some Japanese-specific situations taken into consideration. New classification of citrus fruits, pome fruits, stone fruits, berries and other small fruits, assorted tropical and sub-tropical fruits–edible peel and assorted tropical and sub-tropical fruits – inedible peel (as of October 2015) is included in the above table. Only important crops are shown. Other crop groups are currently considered pending Codex revision.

⁵ The US EPA and Canadian PMRA numbering for some of the revised crop groups differ depending on the year they were established. In the second column only differences are indicated.

- ⁶ Under revision. It is anticipated that leafy Brassica greens (5B) will be combined with and leafy non-Brassica vegetables (4) will be combined in a revised leafy vegetables group, as follows: 4A- 40 commodities; Representatives- Head and Leaf Lettuce and Spinach. 4B- 20 commodities; Representative – Mustard greens.
- ⁷ A new crop group 22: Stalk, Stem, and Leaf Petiole Vegetable is anticipated. **17 commodities, 2 subgroups:**
22A Stalk and Stem Vegetable; Representative – Asparagus; 10 commodities (agave, asparagus, bamboo shoots, cactus, celtuce, florence fennel, edible fern, sea kale, kohlrabi, palm hearts).
22B Leaf Petiole Vegetable; Representative – Celery; 7 commodities (includes some commodities currently in 4B- Leaf petioles subgroup: Cardoon, celery, Chinese celery, fuki, rhubarb, udo, and zuiki).
- ⁸ A new crop group 23, tropical and subtropical fruits – edible peel, is anticipated.
- ⁹ A new crop group 24, tropical and subtropical fruits – inedible peel, is anticipated.

APPENDIX 2

Criteria for crop groups in national governments

Japan Criteria

Basis for Crop/Commodity Categorization in Japan:

The work is currently ongoing as a part of the review of pesticide registration scheme in Japan on the classification of all food commodities/crops for which there are registered uses of pesticides and/or MRLs. The work uses the Codex Classification as a basis with some Japanese specific situations taken into consideration.

NAFTA Criteria

The following 15 points are addressed in constructing rationale for a crop definition and/or group / subgroup proposal:

1. Botany and Nomenclature of Commodity:
 - Botanical Family and Family Characteristics of proposed commodities
 - Genus and Species
 - Common names and/or synonyms
 - Cultivars/hybrids where appropriate
2. Commodity Geographical Distribution and Production in the U.S.
3. Global Commodity Geographical Distribution and Production.
4. Commodity Imports/Exports.
5. Cultural Practices:
 - Planting Rate(s)
 - Planting Date(s)
 - Row or Broadcast Crop
 - Growing Season
 - Growth and development of crop and growth stages

- Irrigation
 - Worker practices
 - Harvesting practices
 - Post-harvest activities
 - Crop rotations
 - Processing of commodity
6. Commercial Importance of Commodity (Current and Projected)
 7. Possibilities for Genetic Improvement (Cultivars, Hybrids)
 8. Comparison of Edible Part(s):
 - Description of fruit/vegetable
 - What is consumed?
 - When harvested
 - How harvested
 - How often harvested
 - Uses of commodity such as livestock feed, syrup, jelly, production, foods, shampoos, biodiesels, medicines, adhesives)
 - Surface area to weight ratio of commodity
 - Leaf shape and area
 - Type of fruit/vegetable surface (smooth, hairy)
 - Weight of fruit/vegetable
 - Similarities to other commodities
 9. Livestock Feed Item(s) for Beef and Dairy Cattle, Poultry, and Swine (include Importance of Feedstuffs (>250,000 tons) and Percent of Livestock Diet)
 10. Processed Products (such as oil or flour) and/or Fresh Market as Whole Fruit/Vegetable
 11. Comparison of Pest Problems:
 - Insects
 - Diseases

- Nematodes
 - Weeds
 - Vertebrates (such as moles, rodents)
 - Other pests
12. Comparison of Potential Residue Levels (Tolerance/MRL)
13. Compare Codex Classification of Food and Feed Crops (Harmonization for International Considerations) with U.S.
14. Justification(s) for a Crop Group/Subgroup Definition
- Selection of Representative Crops Utilized for Residue Field Trials to Cover Entire Crop Group
 - Selection of Representative Crops Utilized for Residue Field Trials to Cover Crop Subgroup
15. References Including:
- Scientific Literature, world complete literature search [USDA National Agricultural Library Agricola]
 - Current Research Projects [USDA Current Research Information System (CRIS)]
 - Scientific names [USDA GRIN (<http://www.ars-grin.gov/cgi-bin/npgs/htm/taxecon/pl>)]
 - Specific Codex Classification of Foods and Animal Feeds.
 - Previous IR-4 Petitions for Commodity or Crop Group
 - Copies of Pertinent Reference Pages
 - Classic Monograph Reference – Adapted from Foods and Feed Crops of the United States. 1998. George Markle, Jerry Baron, and Bernard Schneider. Second Edition. Meisterpro Publication.

Australian Criteria

For crop groups no own criteria:

- Crop groups used as defined by CODEX.

Crop group are further divided into subgroups:

- These are primarily indicative of form and growth habit.
- The subgroups are based on differences in the size of the commodity, whether there are any covering leaves to protect the edible part of the crop and the nature of the commodity.

- The subgroups are intended to reflect factors which may contribute to varying residue levels across the whole crop group.
- Other criteria which may contribute to the subgroups include the surface of the crop, i.e. curly leaf vs straight leaf or hairy surface vs wrinkled surface vs smooth surface.

European Criteria

European criteria are not described. Some of the criteria taken into consideration are given below:

- Botanical characteristics
- Morphological aspects
- Surface area to weight ratio of commodity
- Codex Classification of Food and Feed Crops

ANNEX 2

Background information to chapter 2. Extrapolations

Background

1. 1 Annex 2 describes the background as provided by OECD member countries before September 2014 to illustrate where the discussion started and to make transparent why certain conclusions and recommendations were given in the OECD Guidance Document on Crop Field Trials. An update is not foreseen.

National/Regional Approaches for Extrapolation and Establishment of Crop Group MRLs

2. In general, extrapolation and/or establishment of crop group MRLs in the EU occur only where there are registered uses for all members of the crop group or subgroup. This is based on the precautionary principle, known as the ALARA (as low as reasonably achievable) principle. The procedure for MRL estimations for crop group or subgroup is based on a sufficient number of trials conducted on one or more representative crops/commodities from the crop group or subgroup.

3. Nevertheless, this approach might be too restrictive. In view of global trade nearly all crop groups or sub-groups include commodities not grown in the respective countries. Therefore a situation with all members of the group being covered by national GAPs is unlikely to occur. In this situation EU introduced the concept of related varieties or other products in Regulation (EC) No 396/2005. For example the MRL for the commonly grown commodity radish also applies to black radish, Japanese radish, small radish and similar varieties as well as tiger nut, from which Japanese radish and tiger nuts are normally not covered by European GAPs.

4. The situation in NAFTA is slightly different. Extrapolations may be made for use on only a few crops when the registrant is not interested in registration on the entire crop group. For crop group MRLs, cases exist where not all the crops are registered due to the manufacturer having concerns over efficacy or phytotoxicity on particular plants. Therefore, although all necessary data may have been generated on all the representative commodities and regulatory authority may have established a crop group tolerance, the registrant may not permit use on certain members of the group. Extrapolations may also involve crops that do not belong to the group.

5. The original underlying assumption for extrapolation is that the same critical GAP exists for all crops of a crop group or subgroup and the supporting residue trials have been conducted according to this critical GAP (i.e. within 25% of the nominal application rate, number of applications or PHI). The description of the differences in application rates between “horizontal” and “vertical” crops can be found in OECD Guidelines for the Testing of Chemicals – Crop Field Trial. No. 509 (OECD, Paris 2009). In case of “vertical” crops the 25% rule should be applied to the most sensitive factor for residues in case different descriptions are used for the application rates in residue trials data.

6. Appendix 1 of Annex 1 contains a table of the groups, subgroups, representative commodities, and extrapolations in EU, Australia, Japan, and NAFTA while the information for adopted Codex commodity groups is given in Table 1 of the main text.

7. In estimating crop group MRLs, two methodologies are possible. In the simplest approach, the residue datasets with the highest residue levels for individual representative commodities are used to estimate group/subgroup MRL (called 'single crop approach'). In this case the MRL should be evaluated for each commodity data set and the highest result selected for the group or subgroup. There must be adequate data for each commodity without consideration of combinations. In the second approach used in some cases in Europe the data sets from the various commodities of a group/subgroup are combined, and an MRL proposal is made from the combined data. Data sets for different commodities within a group/subgroup are considered for combination to estimate group MRLs in EU only if residues are similar in magnitude (belonging to a similar residue distribution) and have similar GAPS. It is recommended that if it can be shown by using the Mann-Whitney or Kruskal-Wallis tests (paragraph 16) that the residues belong to the same residue population, the residue data should be combined. It is known from work with the OECD Calculator that the more residue data are used for MRL calculation, the less uncertainty there will be in the resulting MRL. If residue data for different representative commodities within a group are significantly different according to statistical testing and deviate beyond the usual variability accepted (see next paragraphs), group MRLs may not be appropriate, or exceptions to the group may need to be specified. Different approaches are in place in various countries on combining data for dietary risk assessments.

8. The single crop approach is utilized in NAFTA and also in the EU. Nevertheless, the EU Guidance Document SANCO 7525/VI/95 describes an approach to address the allowed variability in residues among crops for purposes of setting a group MRL. When using the proposed calculator model as described in the EU document, residue levels for relevant different raw agricultural commodities are considered to be comparable:

1. if assuming a standard (normal) distribution of data the respective 'mean to one-sigma-limit' ranges overlap; and
2. if the resulting recommended maximum residue limits when calculated for each single commodity according to the recommended calculation procedure fall into the same or a neighbouring MRL class after rounding up or down to the nearest MRL class.

9. The situation in NAFTA is different. The maximum residue limit estimates for the representative commodities should not vary by more than a factor of 5X of the maximum residue in order to establish a group MRL.

10. A statistical method for determining if data sets are from similar populations for possible combination is described in the FAO Manual 2009 (see paragraph 16) (FAO, 2009b).

Codex Approach for Extrapolation and Establishment of Codex Commodity Group MRLs

11. Residue extrapolation is the process by which the residue levels on representative commodities are utilized to estimate residue levels on related commodities in the same commodity group or subgroup for which trials have not been conducted.

12. The establishment of commodity group MRLs as opposed to MRLs for individual commodities has long been considered an acceptable procedure since economics may not justify residue trials on all of the individual crops in a group. In principle the approach recognizes that adequate data for the major commodities of a group may be sufficient to estimate maximum residue levels for the whole group.

13. Some pesticides may behave differently in different circumstances. Consequently, it is not possible to define precisely those commodities on which trials will always provide data that can lead to a group MRL. If the "highest residue" situation can be identified, however, the relevant data can be

extrapolated to other commodities with confidence, although it is recognised that this approach may result in an over-estimate of residues in some commodities.

14. Extrapolation requires a detailed knowledge of local agricultural practices and growth patterns. For example, wheat is generally grown under similar practices around the world, but tomatoes may be grown utilising widely varying practices. For the latter, care must be taken to ascertain if the relevant GAPs are comparable. In view of the large differences in commodity surface texture, shape, plant growth habits, rate of growth and seasonal cultivation and the significant role played by the surface/weight ratio, the JMPR has emphasized that decisions to extrapolate should be made on a case-by-case basis when adequate relevant information is available.

15. As a general precondition, for reliable estimation of residue levels an adequate number of independent trials is required. Under practical conditions the number of trials which can be performed for a given commodity is limited. On the other hand, a larger data set representing statistically not different residue population provides more accurate estimation of the selected percentile of residue population than a small data set derived from trials representing the critical GAP.

16. In order to make the data assessment process transparent and facilitate its consistent application in various situations, the 2013 JMPR considered and evaluated past experience and decided on the following basic principles in estimation of residue levels for commodity groups.

- Group maximum residue levels are only estimated if the pesticide is registered for a group or sub-group of commodities, also allowing for the differences in Codex and national commodity group classifications.
- Residue datasets reflecting cGAP will be compiled. Once the data sets have been established for individual commodities, the recommendations for residue levels for commodity groups would be considered according to the following principles.
 - The establishment of a commodity group residue level will generally be considered if the median residues of the commodities are within the five times range;
 - i. Where the residues in individual commodities in the commodity group are statistically not different (Mann-Whitney or Kruskal-Wallis tests) the residue data can be combined for the estimation of group residue levels;
 - ii. Where the residue datasets in individual commodities are statistically different then the dataset leading to the highest maximum residue level would be used for the group, provided that sufficient residue data points are available;
 - iii. If the dataset identified under (ii) does not contain sufficient data points (preferably ≥ 8) required to estimate a group maximum residue level, the commodity should be considered as an exception.
 - If the median of residues in an individual commodity dataset differs more than 5 times than those of other commodities, that commodity would not be included in the group and indicated as an exception.
 - If the medians of residues in more than one commodity of the group differ larger than five times, then recommending group residue levels may not be appropriate and would require decision based on all information available

A spreadsheet for the Kruskal-Wallis test has been developed by US-EPA.

17. In view of the large diversity of residue data dependant on the pesticide and other factors, the case-by-case evaluation of the available residue data is considered necessary. Where the Meeting deviates from the above principles, the rational for the divergence will be provided in the report.

18. The 2014 JMPR Meeting concluded that for estimating a group maximum residue level, it is necessary to have data for those representative commodities of the subgroups likely to have the highest and the lowest residues. If there are sufficient data for a subgroup according to the new Codex classification, the Meeting agreed to estimate maximum residue levels for the subgroup only. For each crop group (or sub-group) critical commodities need to be identified.

Wider Extrapolations

19. The term 'wider extrapolations' (also referred to as 'cross group extrapolations') is used in this context for extrapolations that go beyond the bounds of a group or subgroup. Such extrapolations may be possible in special circumstances, on the basis of residue data. Consideration on a case-by-case basis may be given to commodities with very similar shapes, volumes, and weights. For example in Australia, apple, peach, and nectarine may be extrapolated to persimmon.

20. Wider extrapolations may also be considered, on a case-by-case basis, for:

- Situations where residues are expected to be <LOQ (e. g. pre-emergence herbicide uses, pre-flower treatments);
- Situations where the active substance is used early in the growing season (last application before consumable parts of the crop have started to form). (This kind of extrapolation should be used with caution since for some crops the edible part of the crop is always present either as a food or a feed item.);
- Seed treatments, if data from treatment of several different 'representative' seed types all report no detectable residues in the commodities from crops grown from the treated seed;
- Post harvest treatments for non-systemic pesticides to commodities of similar size and morphology on the basis of the same treatment regimes; and
- Soil treatments with granules (depending on extent of residue uptake and distribution in the plant as evidenced by data from different crop types including a root crop).

ANNEX 3

Background information to chapter 3. Proportionality

Background

1. This Annex 3 describes the background as provided by OECD member countries before September 2014 to illustrate where the discussion started and to make transparent why certain conclusions and recommendations were given in the OECD Guidance Document on Crop Field Trials. Especially the different statistical evaluations done to show the acceptability of the proportionality is described hereafter.
2. Proportionality means that when increasing or decreasing the application rate the residue level increases or decreases in the same ratio. In an ideal situation it means that doubling the application rate results in doubling the residue. Proportionality implies that the relationship between application rates and residues is linear.
3. In a publication by MacLachlan and Hamilton (2010) a proposal was made to use day zero data and residue decline studies to estimate median and highest anticipated residues in foliar-treated crops. In this model the residue levels were "normalised" for application rates, which assumes proportionality between application rates and residues. This and other tools may be developed in the future to assist MRL estimation.

Model and criteria for assessing the applicability of corrections based on proportionality

4. A proportional relation between application rate R and residue concentration C is described by the equation $C = k \times R$, or, equivalently, $\ln(C) = a + \ln(R)$, where $a = \ln(k)$. Based on proportionality, a residue level C_2 from a trial at application rate R_2 can be corrected to $C_1 = C_2 \times R_1/R_2$, where R_1 is the critical GAP application rate.
5. A more general model, including non-proportional relations, is given by the equation $C = k \times R^b$, or, equivalently, $\ln(C) = a + b \times \ln(R)$. Note that $b=1$ represents the proportionality assumption, and $b \neq 1$ corresponds to deviations from proportionality.
6. The proportionality assumption can be statistically tested by fitting a linear mixed effects model to available $\{\ln(C), \ln(R)\}$ data pairs of side-by-side trials conducted at different application rates, and testing the null hypothesis $b=1$. An alternative approach is the calculation of ratios $(C_2/C_1)/(R_2/R_1)$ as has been done by MacLachlan and Hamilton (2011). Under the general model this ratio is equal to $(R_2/R_1)^{b-1}$, and therefore would equal 1 if $b=1$.
7. Statistical significance of non-proportionality does not imply that corrected C values based on the proportionality assumption ($C_1 = C_2 \times R_1/R_2$) are wrong to a large degree. Small deviations are acceptable in view of larger errors that are expected to arise in practice. Deviations within a range of $\pm 25\%$ of the nominal application rate are considered acceptable without a need for correction of the residue values. A true linear relationship between dose rate and concentration, would allow for a corresponding acceptable deviation in concentration of $\pm 25\%$. In this guidance the maximum degree of acceptable non-

proportionality will be such that the deviation in the corrected value C_1 from the true value will be restricted within the limits of concern of $\pm 25\%$.

8. The remainder of this chapter is organised as follows. Paragraphs 9-14 and Appendix 1 describe comparison of side-by-side trials that differed only by application rate. Paragraphs 15-17 and Appendix 2 describe simulations to investigate the significance of deviations from proportionality. Paragraphs 18-21 and Appendix 3 describe the approach using the linear mixed effects model. Paragraphs 22-23 and Appendix 4 describe additional simulations to investigate impact on MRL estimates when there are varying degrees of non-proportionality.

Data Evaluation

9. In their publication about the impact of the application rate of pesticides on the residue levels in treated commodities (2011) MacLachlan and Hamilton identified a total of 1146 sets of side-by-side residue trials which were issued in JMPR reports between 2000 and 2009 and differed only by the application rate. The authors analysed this database with respect to a variety of factors including application rate, spray concentration, application type, formulation type, crop, and pesticide and concluded that residues generally scale proportionally with application rate (proportionality principle). They proposed to make use of this principle in regulatory evaluations of pesticides and for MRL calculations.

10. Although the data reviewed by MacLachlan and Hamilton covered a large range of pesticides, formulation types, application methods and crops, some specific pesticides and uses were less well represented. It was especially deemed necessary to review more side-by-side data for herbicides, soil applications, seed treatments, and post-harvest applications in order to determine whether the proportionality principle can be applied to these situations.

11. To this end, industry and regulatory authorities provided residue data from further side-by-side residue data conducted at different rates which had not been reviewed previously by MacLachlan and Hamilton (i.e. that were not included in the JMPR evaluations issued between 2000 and 2009). Data were provided (as Excel spreadsheets) by the governments of China and Japan, as well as by BASF, Bayer CropScience, Dow AgroSciences, DuPont, and Syngenta. The data were distinct from (i.e., supplemental to) that used by MacLachlan and Hamilton (2011). The data structure is given in the following table.

Data structure	Quantity
Trial	926
Crop	92
Active Ingredient	80
Formulation Type	14
Application Type	6
Country	36
PHIs per trial	1 to 7
Replicates per PHI	1 to 4

12. The new data allow further evaluation of the applicability of the proportionality principle to herbicides, plant growth regulators, soil applications, and seed treatments. Multiple statistical analyses were performed with the dataset using the MacLachlan/Hamilton approach and other statistical methods. For details see Appendix 1.

13. Since the new dataset includes a number of post-harvest trials, it was initially hoped that the dataset would allow further evaluation of the applicability of the proportionality concept to post-harvest treatments. It finally turned out that more data are needed for post-harvest uses.

14. Part of the MacLachlan/Hamilton approach involves comparing the ratio of residue values (C_2/C_1) with the ratio of the respective application rates (R_2/R_1), where R_1 is the lower application rate. If the residues are proportional to application rate, then $C_2/C_1 = R_2/R_1$. The second dataset was analysed in terms of $(C_2/C_1)/(R_2/R_1)$, which should equal 1 if residues are proportional to rate. The mean, RSD, and median of the $(C_2/C_1)/(R_2/R_1)$ ratio were calculated for different formulation types, application types, concentration ranges, pre-harvest intervals, crops, active substances and active substance types. Overall, the results of the second review are consistent with those of the original review, although the medians of the $(C_2/C_1)/(R_2/R_1)$ ratios for different application types are somewhat lower, in the range of 0.80 - 0.93 (Appendix 1, table 4b) against 0.86-1.10 in the original review (table 4a).

15. Simulations (Appendix 2) were conducted to determine in which range the median of the $(C_2/C_1)/(R_2/R_1)$ is expected to vary assuming strict proportionality between residues and application rates. The residue distribution was considered to be lognormal with a CV of 0.7, 1.0 or 1.3. Besides the ratio between the application rates R_2/R_1 and the number of individual $(C_2/C_1)/(R_2/R_1)$ ratios (i.e. the number of pairs of side-by-side trials), a key parameter of the simulation was the intra-class correlation ICC, which was defined as:

$$\text{ICC} = \frac{\text{between trials variance}}{\text{between trials variance} + \text{within trial variance}}$$

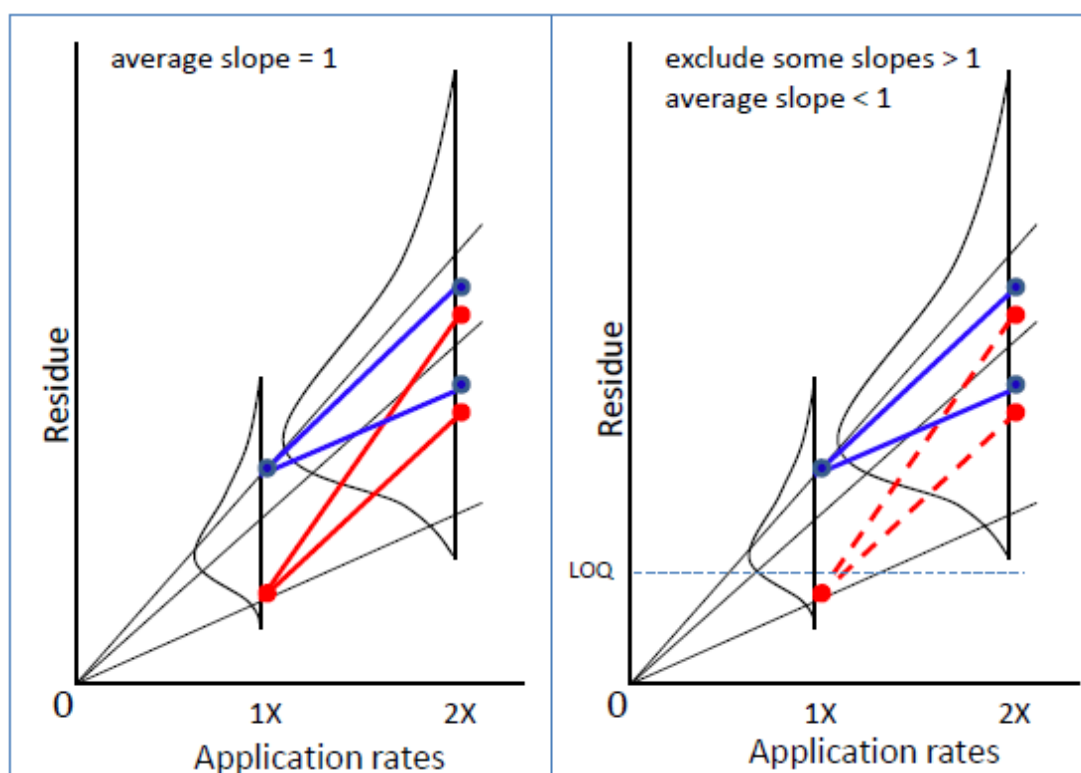
The simulations were conducted for ICCs of 0.5, 0.7 and 0.9. The expected range for the median $(C_2/C_1)/(R_2/R_1)$ ratios narrows as the ICC increases. Based on the simulation results it was concluded that most of the median $(C_2/C_1)/(R_2/R_1)$ ratios for the second review fall outside the range expected in case of strict proportionality. Comparison of the observed ratios from appendix 1 with the limit values obtained by the simulations in appendix 2, confirms that the relationship between application rates and residues is not strictly proportional and often shows a bias in one direction (systematic deviation).

16. It is important to note that the relationship between residue and application rate can only be calculated if residues are greater than or equal to the limit of quantification. Pairs of side-by-side trials where either C_1 or C_2 or both C_1 and C_2 are below the LOQ were not considered. However, this introduces a bias. Logically, if the residue levels are near the LOQ less residue levels are $> \text{LOQ}$ on the plot treated at the lower rate (R_1) than on the plot treated at the higher rate (R_2). Only the pairs of trials with comparatively high residues on the plot treated at the lower rate are selected. These comparatively high residues result from the trial parameters (crop variety, weather conditions, ...) and also from the sampling uncertainty. For the lower rate the selected data tend to be from trials where, due to sample uncertainty, the measured residues were greater than the mean residues on the plot. This is less true for the higher rate.

17. Figure 1 below visually illustrates why excluding trials with residues $< \text{LOQ}$ would result an estimated slope lower than 1, assuming that the relationship between residues vs. application rates is proportional and thus the slope is indeed truly 1. The left portion of the figure presents the proportional relationship between residues vs. application rates. The blue and red segments represent some random residues of field trials at 1X and 2X, respectively. As we see with blue trials, if a residue of a field trial at 1X is a high percentile, there is high probability it has a lower percentile at 2X; and the slopes from these field trials are more likely less than 1. Conversely for the red trials, if a residue of a field trial at 1X is a low percentile, there is high probability it has a higher percentile at 2X; and the slopes of these field trials are more likely greater than 1. The average slope will be 1. The right figure presents the scenario when all

field trials that have residues < LOQ are excluded. The field trials that have residues at low percentiles at 1X would be systematically excluded as shown in red dashed segments; and it is more likely that the field trials excluded in this way would have slopes greater than 1. Therefore, the average slope (estimated slope) will be biased and less than 1.

Figure 1:



18. The proportionality concept was investigated further to determine its potential utility in adjusting residues from higher to lower (or vice versa) application rates. Thus the relationship between residues and application rates was examined by performing a linear mixed effects model analysis (Appendix 53). For each set of side-by-side trials conducted at different application rates and each PHI the logarithm of residues (C) was expressed as a linear function of the logarithm of application rates (R): $\ln(C) = a + b \times \ln(R)$, which is equivalent to: $C = e^a \times R^b$. Hence the relationship between residues and application rates is proportional if the slope b is equal to 1. The slopes and their confidence intervals were calculated for different application types and crops.

19. As the application rate increases, the resulting residue increases. Foliar applications to rice had an exact linear proportional relationship between application rate and residue (100% increases in application rate would increase 100% in residue), while other crops with foliar application still had a significant relationship with slopes between 0.8 and 0.88 (the estimated residues from 2X to 1X are underestimated about 10% if using the proportionality principle). Similarly, soil applications and seed treatments also had a slope of 0.88 and 0.79, respectively. The linear effects model analysis (appendix 3) confirms the bias noted in the simulations (appendix 2) and in the second review of residue data (appendix 3). The number of results for postharvest uses (including dipping and direct treatment) is too small to give reliable evidence that the proportionality approach can be used in that case for the moment.

20. When applying the current 25% rule in one parameter like the dose rate, it is accepted to combine residues from trials that have application rates within the range 0.75-1.25 of the cGAP. When assuming a true linear relationship between dose rate and concentration, this would allow for a corresponding acceptable deviation in concentration of $\pm 25\%$. However, with a slope $b = 0.8$, the actual deviations of residue at application rates of 0.75 and 1.25 compared to normal (1x) rate are $(0.75 \text{ EXP } 0.8) - 1 = -21\%$ and $(1.25 \text{ EXP } 0.8) - 1 = +20\%$. So maximum deviations in residues due to the 25% rule are slightly smaller than assumed. In this guidance the maximum degree of acceptable non-proportionality will be such that a $\pm 25\%$ deviation between estimated and actual concentrations is considered acceptable, so slightly larger than the deviations obtained with the current 25% rule.

21. Calculations below show that with a slope of 0.8 (found in the logarithmic approach in the linear mixed effects model) and accepting an error of $\pm 25\%$ in residues the proportionality principle allows support of a given GAP based on trials conducted at application rates between 0.33 - 4.2 X the cGAP rate.

The true residue C_1 at application rate R_1 , given the slope b and residue C_2 at the application rate R_2 is $C_2 = C_1 \left(\frac{R_2}{R_1}\right)^b$. Assuming proportionality where $b=1$, the estimated residue C_1 at application rate R_1 (using proportionality principle), given the residue C_2 at the application rate R_2 is $C_1 = C_2 (R_1/R_2)$

Correction based on proportionality will result in a bias of $100 \cdot [(R_1/R_2)^{1-b} - 1] \%$.

Downward correction based on proportionality will lead to a negative bias if $b < 1$. For the case $b = 0.8$, equating the maximum acceptable negative bias of -25% to the above expression leads to $R_1/R_2 = (0.75)^{1/0.2} = 0.24$, or $R_2/R_1 = 4.2$.

Upward correction based on proportionality will lead to a positive bias if $b < 1$. For the case $b = 0.8$, equating the maximum acceptable positive bias of 25% to the above expression leads to $R_1/R_2 = (1.25)^{1/0.2} = 3.05$ (rounded 3.1), or $R_2/R_1 = 0.33$.

In other words, if we scale a residue at application rate range within 1x-4.2x down to 1x cGAP or scale a residue at application rate range within 0.33x-1x cGAP up to 1x cGAP, the amount of over/underestimation in the scaled residue will not exceed $+25\%/-25\%$. In other words, up-scaling of residues is possible up to a (residue multiplication) factor of 3.1 and down scaling up to a (residue dividing) factor of 4.2. The wordings are equivalent. The acceptable range in R_2/R_1 application rates will be broader for slopes being nearer to one.

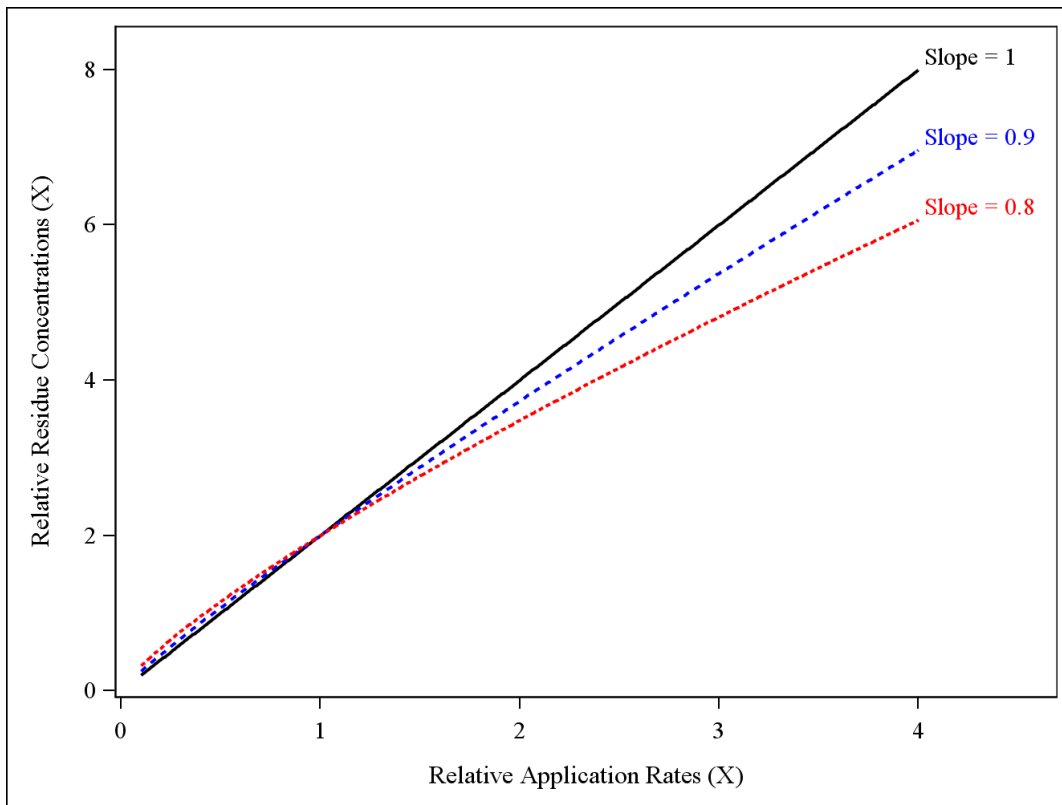


Figure 2A: graphical representation of the relative residues concentration vs. relative application rates (using 1X as reference) for different values of b. “Slope = 1” is the curve of estimated residues. “Slope= 0.9” and “Slope = 0.8” are the curves of actual residues. When scaling up (0.33X-1X up to 1X), the estimated residue is over-estimated. When scaling down (1X-4.2X down to 1X), the estimated residue is under-estimated.

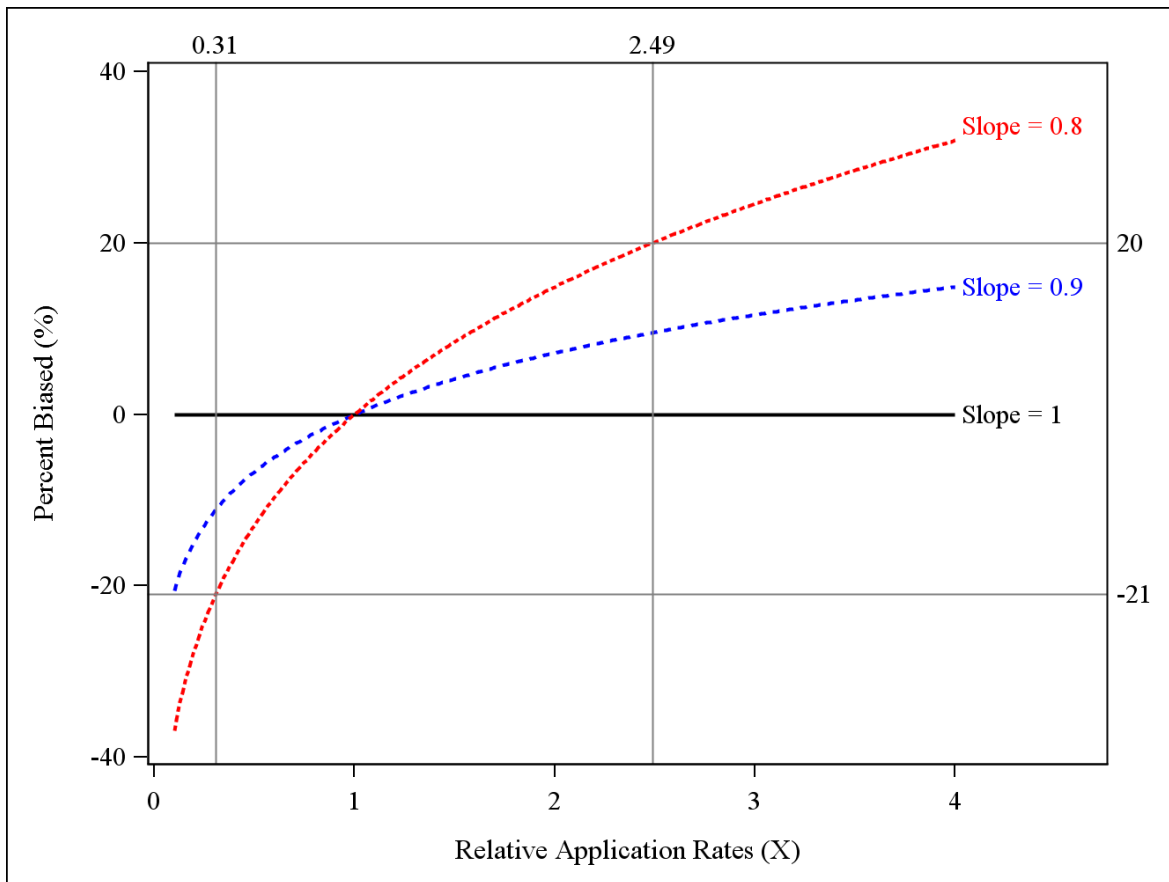


Figure 2B: graphical representation of percent biased when applying the proportionality principle to scale residues at application rate = 1X to other application rates \neq 1X. When scaling up (0.33X-1X up to 1X), the estimated residue is over-estimated. When scaling down (1X-4.2X down to 1X), the estimated residue is under-estimated.

22. On this basis the proportionality principle as adopted by the Codex Alimentarius Commission is accepted by the OECD: The proportionality concept can be applied to data from field trials conducted within a rate range of between 0.3x and 4x the GAP rate.” A further simulation was conducted in order to assess the impact on MRLs from applying the proportionality principle when the relationship “residue vs. application rate” is not perfectly proportional. As discussed in previous paragraphs, with a slope $b = 0.8$ and adjusting the application rate down up to a (dividing) factor of 3.2 or adjusting the application rate up to a (multiplication) factor of 2.4, the amount of over/under-estimation of the scaled residues would be less than 25% from the true value. MRLs were evaluated by calculating the MRLs from the scaled residues (which are under/over-estimated compared to the residues of GAP trials at application 1X). For calculation of MRLs the OECD Calculator was used.

- Scenario 1: calculation based on **4** random residues from the critical GAP rate field trials
- Scenario 2: calculation based on **8** random residues from the critical GAP rate field trials
- Scenario 3: calculation based on **16** random residues from the critical GAP rate field trials
- Scenario 4: calculation based on **4** random residues from the critical GAP rate field trials and **4** scaled residues from non-critical GAP field trials
- Scenario 5: calculation based on **8** random residues from the critical GAP rate field trials and **8** scaled residues from non-critical GAP field trials

- Scenario 6: calculation based on **8** scaled residues from non-critical GAP field trials

Note: In the simulation, the set-ups were only for extreme but simple scenarios, i. e. all the scaled residues causing either negative biased or positive biased. Scenarios of mixed scaled residues were not evaluated.

23. The simulation was performed using lognormal residue distribution. For each scenario, different CVs (0.7, 1.0, or 1.3) and different under/over estimation factors (-25%, -20%, -15%, -10%, +10%, +15%, +20%, or +25%) were used. The primary criterion to evaluate and compare the MRLs between scenarios is the proportion of MRLs \geq the true 95th percentile (typically, the aim is to have 95% of the estimated MRLs \geq the 95th percentile). The secondary criterion is the how close (or “tight”) the distribution of MRLs is to the true 95th percentile. As expected, adding more scaled residues (to increase sample size) generally results in better MRL estimates (scenario 4 vs. scenario 1, and scenario 5 vs. scenario 2); as the proportion of scaled residues increases, the MRL estimates become slightly worse (scenario 4 vs. scenario 2, and scenario 5 vs. scenario 3) but the MRL estimates are NOT substantially worse if the entire dataset consists of scaled residues, except the extreme scenario in which the entire dataset were all scaled residues and were 25% under- or over-estimated. However, this extreme scenario as done in the simulation with all scaled residues being under- or over-estimated by 25% does not apply if proportionality is limited to application rates between 4.2 \times to 0.33 \times label rate, respectively. With this range, the percent biased in the scaled residue will be within $\pm 25\%$. The 25% biased case gave acceptable results in the simulation, so using a full adjusted set of data (100%) is acceptable between 4.2x to 0.33x label rate.

24. Another important factor worth mentioning is that the estimated slope from the linear mixed-effects model analysis was underestimated as discussed in paragraph 16. For that reason, the actual amount of under/over-estimation in the scaled residues may be less than the values that were used in the simulation, and the MRL estimates calculated from using scaled residues may be better than what we see in the simulation results.

25. It might be reminded that the adopted proportionality principles by the Codex Alimentarius Commission stated that the concept “may be used where the dataset is otherwise insufficient to make an MRL recommendation. This is where the concept provides the greatest benefit”. Currently Codex and JMPR only use the proportionality principle in case an insufficient number of trials has been conducted at cGAP and an MRL cannot be derived based on this insufficient number (see general items in JMPR 2013 report). Proportionality is generally not used to increase the dataset when the number of trials at cGAP is sufficient to derive an MRL, although it could be used to develop a more comprehensive data set for international efforts (MRL harmonization). For harmonisation purposes, it is interesting to note that increasing sample size at 1X by applying the proportionality principle and scaling residue data from trials conducted at application rates in the range from 0.33X to 4.2X, would result in better MRL estimates, even if estimated slopes were as low as 0.8.

26. The above analysis was conducted with the use of the OECD Calculator. It results in MRL estimates that are not different to the use of the current $\pm 25\%$ rule and residue values from trials conducted at rates $\pm 25\%$.

APPENDIX 1

Relationship between Application Rates of Pesticides and their Residue Levels in Treated Commodities: Further Investigation of the Proportionality Principle

[Frank Laporte, Jane Stewart, 21 November 2012, includes a statistical evaluation for the combined datasets of 2011 and 2012]

MacLachlan and Hamilton recently investigated the impact of the application rate of pesticides on their residue levels in treated commodities (2011). A total of 1146 sets of side-by-side residue trials that differed only by the application rate were identified in the JMPR reports issued between 2000 and 2009 and used for this analysis. Based on these data the authors concluded that there is a proportional relationship between pesticide application rates and resulting residues in treated commodities and they proposed to make use of this principle in regulatory evaluations of pesticides and for MRL calculations.

Although the data reviewed by MacLachlan and Hamilton covered a large range of pesticides, formulation types, application methods and crops, some specific pesticides and uses were less well represented. It was especially deemed necessary to review more side-by-side data for herbicides, soil applications, seed treatments, and post-harvest applications in order to determine whether the proportionality principle can be applied to these situations.

To this end, industry and regulatory authorities were asked to provide residue data from further side-by-side residue data conducted at different rates which had not been reviewed previously by MacLachlan and Hamilton (i.e. that were not included in the JMPR evaluations issued between 2000 and 2009). Data were provided (as Excel spreadsheets) by the governments of China and Japan, as well as by BASF, Bayer CropScience, Dow AgroSciences, DuPont, and Syngenta. They were evaluated using the same approach as in the publication by MacLachlan and Hamilton (see below). In order to facilitate comparison, the results of this review are presented in the same format as those of the original review. The figures and tables framed in orange are excerpts from the publication of MacLachlan and Hamilton while the figures and tables framed in blue correspond to the supplementary dataset and the figures and tables framed in green correspond to the two combined datasets [important note: due to slight differences in the approaches used to evaluate the data, some apparent inconsistencies may be noticed when comparing the three tables; however, these inconsistencies are not expected to significantly impact the outcome of the evaluation].

Overall, the results of the second review are consistent with those of the original review. The new data allow to better evaluate the applicability of the proportionality principle to herbicides, plant growth regulators, soil applications, seed treatments, and post-harvest applications.

Approach used to evaluate the supplementary data (adapted from MacLachlan and Hamilton)

Figure 1b, Table 1b

To test for proportionality, residue data were obtained from pairs of trials that had been conducted at the same site and same time and where the application rate of one trial was 2.0 times that of the other. The logarithm (natural logarithm, \ln or \log_e) of the residue at the 2x rate was plotted as a function of the logarithm of the residue at the 1x rate. For proportionality, the slope should be 1 and the intercept should be the logarithm of 2 (i.e. 0.693). Pairs of trials where

one rate was 1.3x, 1.5x, 2x, 3x or 4x the other rate were similarly analysed, but there were far fewer trials than for the 2x case.

Tables 3b to 9b

To compare application rates further, the data were analysed as the ratio of residue values (C_2/C_1) compared with the ratio of the respective application rates (R_2/R_1), where R_1 is the lower application rate. If the residues are proportional to application rate, then $C_2/C_1 = R_2/R_1$. Data were analysed in terms of $(C_2/C_1)/(R_2/R_1)$, which should equal 1 if residues are proportional to rate. The mean, RSD, and median of the $(C_2/C_1)/(R_2/R_1)$ ratio were calculated for different formulation types (Table 3b), application types (Table 4b), concentration ranges (Table 5b), pre-harvest intervals (Table 6b), crops (Table 7b), active substances (Table 8b) and active substance types (Table 9b).

It is important to note that the ratio $(C_2/C_1)/(R_2/R_1)$ can only be calculated if both C_1 and C_2 are greater than or equal to the limit of quantification. Pairs of side-by-side trials where either C_1 or C_2 or both C_1 and C_2 are below the LOQ were not considered. However, this introduces a bias. Logically, if the residue levels are about the LOQ less residue levels are $> LOQ$ on the plot treated at the lower rate (R_1) than on the plot treated at the higher rate (R_2). Only the pairs of trials with comparatively high residues on the plot treated at the lower rate are selected. These comparatively high residues result from the trial parameters (crop variety, weather conditions, ...) and also from the sampling uncertainty. For the lower rate the selected data tend to be from trials where, due to sample uncertainty, the measured residues were greater than the mean residues on the plot. This is less true for the higher rate. As a matter of consequence the ratios $(C_2/C_1)/(R_2/R_1)$ tend to be lower than one. This can partly explain why the median ratio is frequently in the range of 0.8 to 1.0.

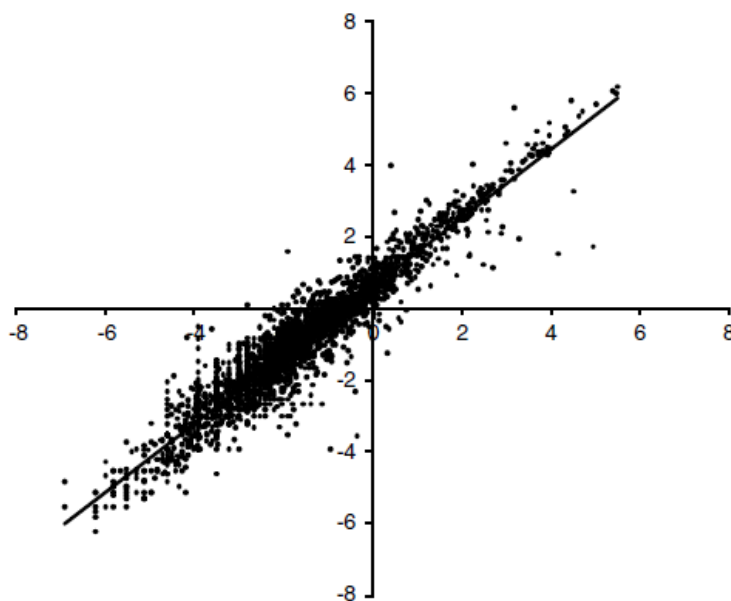


Figure 1a*. Data were available from 2792 datasets where residues were compared for a 1x and a 2x application rate (or spray concentration) at the same time and at the same site. The logarithm of the residue from the 2x application is plotted as a function of the logarithm of the residue from the 1x application. For proportionality, the slope should be one and the intercept should be the logarithm of two (i.e. 0.693). $\ln(C_2) = 0.956 \times \ln(C_1) + 0.610$, $r^2 = 0.91$.

* According to MacLachlan and Hamilton [*Pest Manag Sci* 2011; 67: 609-615].

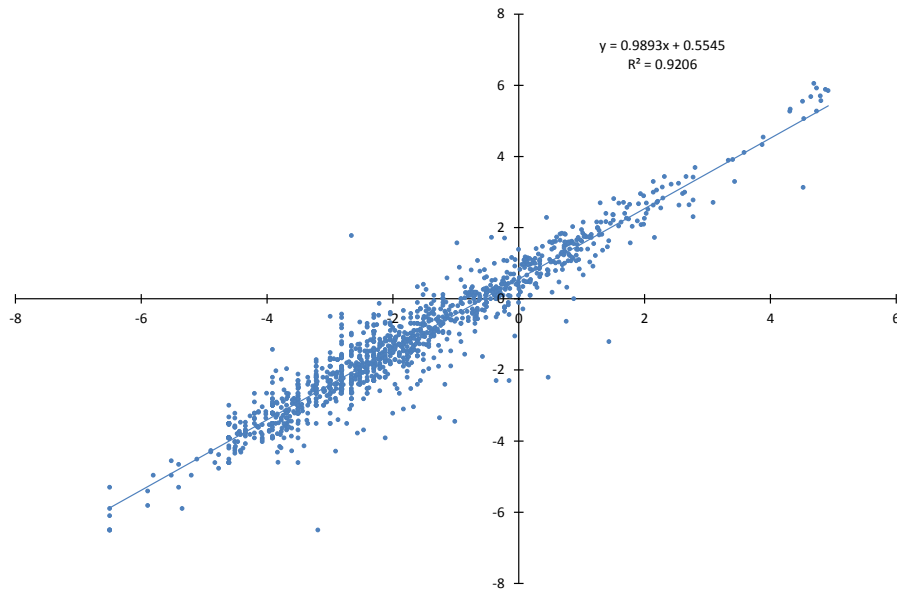


Figure 1b*. Data were available from 1297 datasets where residues were compared for a 1x and a 2x application rate (or spray concentration) at the same time and at the same site. The logarithm of the residue from the 2x application is plotted as a function of the logarithm of the residue from the 1x application. For proportionality, the slope should be one and the intercept should be the logarithm of two (i.e. 0.693). $\ln(C_2) = 0.989 \times \ln(C_1) + 0.555$, $r^2 = 0.92$.

* Evaluation of the supplementary dataset compiled in 2012.

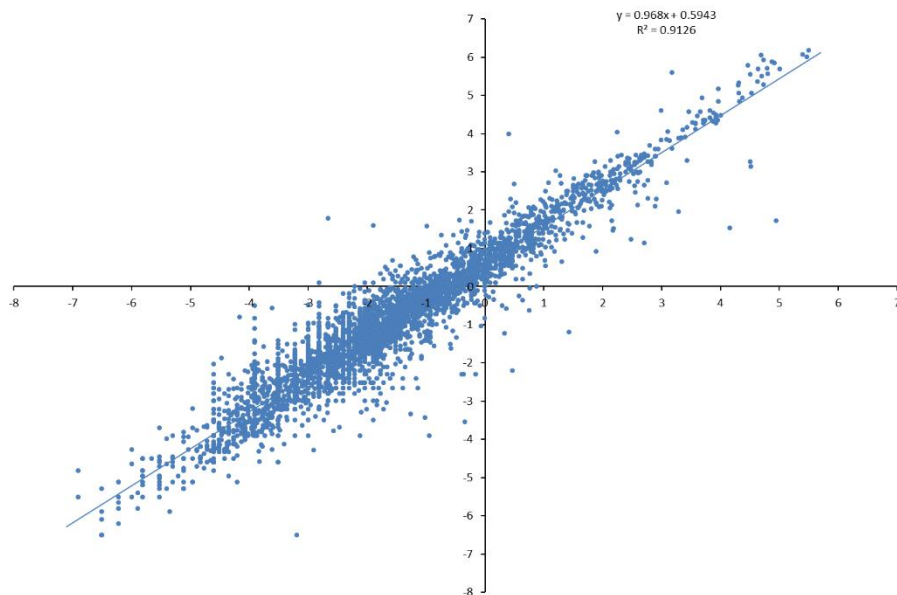


Figure 1c*. Data were available from 4090 datasets where residues were compared for a 1x and a 2x application rate (or spray concentration) at the same time and at the same site. The logarithm of the residue from the 2x application is plotted as a function of the logarithm of the residue from the 1x application. For proportionality, the slope should be one and the intercept should be the logarithm of two (i.e. 0.693). $\ln(C_2) = 0.968 \times \ln(C_1) + 0.594$, $r^2 = 0.91$.

* Combined datasets (2011 and 2012).

Table 1a*. The results of $\log_e - \log_e$ plots of residue data, residues from the higher application rate as a function of residues at the lower rate

R_2/R_1	Slope	Intercept	C_2/C_1 calculated from intercept	n	r^2
1.5	0.957	0.356	1.43	365	0.93
2.0	0.956	0.610	1.84	2792	0.91
4.0	1.016	1.286	3.62	203	0.89
6.0	0.899	1.683	5.38	45	0.79
8.0 – 8.18	1.107	2.025	7.58	65	0.87

* According to MacLachlan and Hamilton [*Pest Manag Sci* 2011; 67: 609-615].

Table 1b*. The results of $\log_e - \log_e$ plots of residue data, residues from the higher application rate as a function of residues at the lower rate

R_2/R_1	Slope	Intercept	C_2/C_1 calculated from intercept	n	r^2
1.3	0.933	0.273	1.31	133	0.94
1.5	0.953	0.351	1.42	700	0.88
2.0	0.989	0.555	1.74	1297	0.92
3.0	0.866	0.842	2.32	69	0.88
4.0	0.977	1.057	2.88	107	0.78

* Evaluation of the supplementary dataset compiled in 2012.

Table 1c*. The results of $\log_e - \log_e$ plots of residue data, residues from the higher application rate as a function of residues at the lower rate

R_2/R_1	Slope	Intercept	C_2/C_1 calculated from intercept	n	r^2
1.3	0.964	0.299	1.35	283	0.95
1.5	0.955	0.353	1.42	1065	0.90
2.0	0.968	0.594	1.81	4090	0.91
3.0	0.878	0.889	2.43	228	0.90
4.0	1.005	1.208	3.35	311	0.87
6.0	0.899	1.683	5.38	45	0.79
8.0	1.128	1.837	6.28	46	0.90

* Combined datasets (2011 and 2012).

Table 2a*. Descriptive statistics of C_2/C_1 values for different ratios of application rates

Rate ratio R_2/R_1	n	Mean residue ratio C_2/C_1	CV residue ratio C_2/C_1	Mean of residue ratios ÷ rate ratios	Median residue ratio C_2/C_1	Median of residue ratios ÷ rate ratios
1.3 (1.15 – 1.45)	158	1.30	0.46	1.00	1.18	0.91
1.5 (1.35 – 1.65)	397	1.73	0.49	1.16	1.56	1.04
2 (1.8 – 2.2)	3052	2.33	0.78	1.17	2.00	1.00
3 (2.7 – 3.3)	190	4.06	0.80	1.35	3.57	1.19
4 (3.6 – 4.4)	351	5.00	1.00	1.25	3.95	0.99
5 (4.5 – 5.5)	64	6.91	1.31	1.38	5.30	1.06
6 (5.4 – 6.6)	57	10.56	0.98	1.76	7.63	1.27
8 (7.2 – 8.8)	65	7.20	0.86	0.90	5.64	0.70
10 (9 – 11)	23	10.62	0.70	1.06	10.40	1.04

* According to MacLachlan and Hamilton [*Pest Manag Sci* 2011; 67: 609-615].

Table 2b*. Descriptive statistics of C_2/C_1 values for different ratios of application rates						
Rate ratio R_2/R_1	n	Mean residue ratio C_2/C_1	CV residue ratio C_2/C_1	Mean of residue ratios \div rate ratios	Median residue ratio C_2/C_1	Median of residue ratios \div rate ratios
1.3 (1.15 – 1.45)	191	1.52	0.67	1.14	1.29	0.97
1.5 (1.35 – 1.65)	747	1.91	1.23	1.28	1.50	1.00
2 (1.8 – 2.2)	1442	2.08	1.19	1.04	1.80	0.91
3 (2.7 – 3.3)	80	3.46	0.76	1.14	2.69	0.90
4 (3.6 – 4.4)	116	3.81	0.73	0.95	3.22	0.81

* Evaluation of the supplementary dataset compiled in 2012.

Table 2c*. Descriptive statistics of C_2/C_1 values for different ratios of application rates						
Rate ratio R_2/R_1	n	Mean residue ratio C_2/C_1	CV residue ratio C_2/C_1	Mean of residue ratios \div rate ratios	Median residue ratio C_2/C_1	Median of residue ratios \div rate ratios
1.3 (1.15 – 1.45)	351	1.52	0.57	1.14	1.33	1.00
1.5 (1.35 – 1.65)	1139	1.85	1.06	1.24	1.53	1.02
2 (1.8 – 2.2)	4485	2.25	0.91	1.13	1.93	0.96
3 (2.7 – 3.3)	259	3.88	0.81	1.29	3.28	1.09
4 (3.6 – 4.4)	468	4.70	0.97	1.17	3.79	0.95
5 (4.5 – 5.5)	83	6.18	1.31	1.23	4.96	0.99
6 (5.4 – 6.6)	45	10.56	0.98	1.76	7.63	1.27
8 (7.2 – 8.8)	68	6.99	0.88	0.87	5.39	0.68
10 (9 – 11)	30	16.87	2.26	1.69	9.40	0.94

* Combined datasets (2011 and 2012).

Note : A slight inconsistency between the three tables is observed for rate ratios about 1.3 (first line) which might be due to the fact that two additional results for the original dataset were taken into account ($n = 160$, the median for $(C_2/C_1)/(R_2/R_1)$ was found to be 1.03).

Table 3a*. Descriptive statistics of $(C_2/C_1)/(R_2/R_1)$ values for different formulation types				
Formulation type	$(C_2/C_1)/(R_2/R_1)$			
	n	Mean	RSD	Median
Not specified	216	0.98	0.58	0.88
CS (capsule suspension)	10	1.17	0.26	1.15
EC (emulsifiable concentrate)	549	1.15	0.78	1.00
EO (emulsion, water in oil)	34	0.96	0.31	0.97
EW (emulsion, oil in water)	12	0.87	0.39	0.83
FS (flowable concentrate for seed treatment)	33	0.85	0.39	0.86
GR (granule)	11	1.01	0.56	0.81
SC (suspension concentrate)	622	1.20	0.75	1.00
SE (suspo-emulsion)	37	1.56	1.08	1.17
SL (soluble concentrate)	319	1.23	0.96	1.00
SP (water-soluble powder)	147	1.16	0.62	0.97
UL (ultralow-volume liquid)	84	1.16	1.05	0.83
WG (water-dispersible granule)	431	1.09	0.61	0.92
WP (wettable powder)	293	1.37	0.63	1.16
WS (water-dispersible powder for slurry seed treatment)	10	1.26	0.70	0.92

* According to MacLachlan and Hamilton [*Pest Manag Sci* 2011; 67: 609-615].

Table 3b*. Descriptive statistics of $(C_2/C_1)/(R_2/R_1)$ values for different formulation types				
Formulation type	$(C_2/C_1)/(R_2/R_1)$			
	<i>n</i>	Mean	RSD	Median
Not specified or several types	13	0.84	0.20	0.83
DF (dry flowable formulation)	5	0.76	0.28	0.78
DP (dispersible powder)	6	1.02	0.76	0.77
EC (emulsifiable concentrate)	813	1.05	0.71	0.93
EW (emulsion, oil in water)	137	1.29	1.12	1.03
FC (flowable concentrate)	59	1.63	0.81	1.33
FS (flowable concentrate for seed treatment)	184	0.91	0.59	0.81
GR (granule)	11	0.83	0.39	0.83
ME (micro-emulsion)	24	0.93	0.30	0.89
OD (oil dispersion)	9	1.86	0.60	1.85
SC (suspension concentrate)	514	1.07	1.12	0.90
SL (soluble concentrate)	508	1.16	1.68	0.94
WG (water-dispersible granule)	154	1.00	0.52	0.93
WP (wettable powder)	294	1.23	1.25	0.99
WS (water-dispersible powder for slurry seed treatment)	11	0.96	0.28	1.00

* Evaluation of the supplementary dataset compiled in 2012.

Table 3c*. Descriptive statistics of $(C_2/C_1)/(R_2/R_1)$ values for different formulation types				
Formulation type	$(C_2/C_1)/(R_2/R_1)$			
	<i>n</i>	Mean	RSD	Median
Not specified or several types	229	0.97	0.57	0.87
CS (capsule suspension)	11	1.13	0.28	1.13
DF (dry flowable formulation)	8	0.77	0.22	0.79
DP (dispersible powder)	6	1.02	0.76	0.77
EC (emulsifiable concentrate)	1431	1.09	0.74	0.96
EO (emulsion, water in oil)	34	0.96	0.31	0.97
EW (emulsion, oil in water)	149	1.26	1.11	1.00
FC (flowable concentrate)	59	1.63	0.81	1.33
FS (flowable concentrate for seed treatment)	257	0.91	0.57	0.81
GR (granule)	34	0.93	0.47	0.83
ME (micro-emulsion)	24	0.93	0.30	0.89
OD (oil dispersion)	9	1.86	0.60	1.85
SC (suspension concentrate)	1585	1.19	0.96	1.00
SE (suspo-emulsion)	37	1.56	1.08	1.17
SL (soluble concentrate)	1276	1.22	1.33	1.00
SP (water-soluble powder)	173	1.21	0.60	1.01
UL (ultralow-volume liquid)	267	1.25	0.72	1.07
WG (water-dispersible granule)	835	1.01	0.60	0.89
WP (wettable powder)	687	1.30	0.91	1.07
WS (water-dispersible powder for slurry seed treatment)	21	1.10	0.58	0.93

* Combined datasets (2011 and 2012).

Table 4a*. Descriptive statistics of $(C_2/C_1)/(R_2/R_1)$ values for different application types				
Application type	$(C_2/C_1)/(R_2/R_1)$			
	<i>n</i>	Mean	RSD	Median
Foliar per hectare basis (kg AI ha ⁻¹)	3441	1.19	0.90	1.00
Foliar spray concentration basis (kg AI hL ⁻¹)	869	1.20	0.51	1.06
Seed treatment	78	0.91	0.51	0.86
Soil treatment	13	1.06	0.53	1.10

* According to MacLachlan and Hamilton [*Pest Manag Sci* 2011; 67: 609-615].

Table 4b*. Descriptive statistics of $(C_2/C_1)/(R_2/R_1)$ values for different application types				
Application type	$(C_2/C_1)/(R_2/R_1)$			
	<i>n</i>	Mean	RSD	Median
Foliar**	2120	1.15	1.21	0.96
Soil treatment	266	1.04	0.60	0.90
Post-harvest	147	0.79	0.51	0.80
Seed treatment	200	0.91	0.56	0.83

* Evaluation of the supplementary dataset compiled in 2012.

** Corrected (in the previous versions of the report the so-called broadcast foliar and post-emergence treatments were erroneously omitted).

Table 4c*. Descriptive statistics of $(C_2/C_1)/(R_2/R_1)$ values for different application types				
Application type	$(C_2/C_1)/(R_2/R_1)$			
	<i>n</i>	Mean	RSD	Median
Foliar per hectare basis (kg AI ha ⁻¹)	5021	1.16	1.01	0.97
Foliar spray concentration basis (kg AI hL ⁻¹)	911	1.19	0.52	1.06
Foliar not specified	497	1.37	1.14	1.08
Soil treatment	281	1.04	0.60	0.90
Post-harvest	147	0.79	0.51	0.80
Seed treatment	277	0.91	0.55	0.83

* Combined datasets (2011 and 2012).

Table 5a*. Descriptive statistics of $(C_2/C_1)/(R_2/R_1)$ values for different residue concentration ranges for C_1				
Residue range for C_1	$(C_2/C_1)/(R_2/R_1)$			
	<i>n</i>	Mean	RSD	Median
<0.05 mg kg ⁻¹	625	1.36	1.84	1.05
0.05 to <0.1 mg kg ⁻¹	462	1.21	0.62	1.03
0.1 to <0.2 mg kg ⁻¹	500	1.15	0.82	0.97
0.2 to <0.5 mg kg ⁻¹	468	1.10	0.54	1.00
0.5 to <1 mg kg ⁻¹	257	1.03	0.53	0.93
1 to <2 mg kg ⁻¹	211	1.08	1.19	0.91
2 to <10 mg kg ⁻¹	225	1.01	0.42	0.96
10+ mg kg ⁻¹	60	1.00	0.53	0.97

* According to MacLachlan and Hamilton [*Pest Manag Sci* 2011; 67: 609-615].

Table 5b*. Descriptive statistics of $(C_2/C_1)/(R_2/R_1)$ values for different residue concentration ranges for C_1				
Residue range for C_1	$(C_2/C_1)/(R_2/R_1)$			
	<i>n</i>	Mean	RSD	Median
<0.05 mg kg ⁻¹	707	1.20	1.26	0.95
0.05 to <0.1 mg kg ⁻¹	551	1.22	1.57	0.95
0.1 to <0.2 mg kg ⁻¹	456	1.08	0.85	0.94
0.2 to <0.5 mg kg ⁻¹	360	1.01	0.60	0.90
0.5 to <1 mg kg ⁻¹	215	0.93	0.53	0.88
1 to <2 mg kg ⁻¹	165	1.03	0.54	0.92

2 to <10 mg kg ⁻¹	195	0.95	0.54	0.88
10+ mg kg ⁻¹	95	0.94	0.36	0.89

* Evaluation of the supplementary dataset compiled in 2012.

Table 5c*. Descriptive statistics of $(C_2/C_1)/(R_2/R_1)$ values for different residue concentration ranges for C_1				
Residue range for C_1	$(C_2/C_1)/(R_2/R_1)$			
	n	Mean	RSD	Median
<0.05 mg kg ⁻¹	1915	1.30	1.04	1.00
0.05 to <0.1 mg kg ⁻¹	1230	1.22	1.15	1.00
0.1 to <0.2 mg kg ⁻¹	1171	1.13	0.79	0.97
0.2 to <0.5 mg kg ⁻¹	1027	1.06	0.55	0.96
0.5 to <1 mg kg ⁻¹	582	0.99	0.52	0.91
1 to <2 mg kg ⁻¹	445	1.12	1.30	0.93
2 to <10 mg kg ⁻¹	512	1.03	0.69	0.96
10+ mg kg ⁻¹	263	0.97	0.54	0.95

* Combined datasets (2011 and 2012).

Table 6a*. Descriptive statistics of $(C_2/C_1)/(R_2/R_1)$ values for different preharvest intervals				
Preharvest intervals	$(C_2/C_1)/(R_2/R_1)$			
	n	Mean	RSD	Median
Day 0	702	1.08	0.72	0.99
Day 1	389	1.24	1.28	0.97
Day 2	96	1.12	0.76	0.87
Day 3	475	1.18	0.73	1.00
Day 4	98	1.31	0.61	1.08
Day 5	71	1.49	1.27	1.09
Day 7	701	1.19	1.87	1.01
Day 10	48	1.05	0.52	0.88
Day 14	554	1.24	0.76	1.06
Day 21	228	1.20	0.74	1.04
Day 28	245	1.22	0.79	1.00
Days 33 to 37	40	1.33	1.05	1.00
Days 38 to 46	62	0.92	0.55	0.86
Days 47 to 52	17	1.22	0.64	0.98
Days 52 to 294	341	1.11	0.54	1.00

* According to MacLachlan and Hamilton [*Pest Manag Sci* 2011; 67: 609-615].

Table 6b*. Descriptive statistics of $(C_2/C_1)/(R_2/R_1)$ values for different preharvest intervals				
Preharvest intervals	$(C_2/C_1)/(R_2/R_1)$			
	n	Mean	RSD	Median
Day 0	279	0.98	0.38	0.94
Day 1	61	0.98	0.44	0.93
Day 2	15	1.02	0.62	0.88
Day 3	110	1.03	0.55	0.93
Day 4	15	0.95	0.40	1.06
Day 5	54	1.01	0.66	0.84
Day 6	26	1.03	0.56	1.07
Day 7	371	1.10	1.08	0.90
Days 8-14	445	1.10	1.31	0.86
Days 15-21	320	1.34	1.93	1.00

Days 22-28	149	1.04	0.74	0.89
Days 29-35	187	1.18	0.59	1.00
Days 36-50	202	1.06	0.84	0.90
Days 51-100	323	1.15	0.72	0.93
Days 101-150	73	1.07	0.56	1.00
Days 151-200	51	0.88	0.45	0.84
Days 201-400	24	1.13	0.56	1.03

* Evaluation of the supplementary dataset compiled in 2012.

Table 6c*. Descriptive statistics of $(C_2/C_1)/(R_2/R_1)$ values for different preharvest intervals				
Preharvest intervals	$(C_2/C_1)/(R_2/R_1)$			
	<i>n</i>	Mean	RSD	Median
Day 0	981	1.05	0.65	0.97
Day 1	451	1.20	1.24	0.96
Day 2	111	1.11	0.74	0.87
Day 3	557	1.15	0.71	0.99
Day 4	113	1.26	0.60	1.07
Day 5	125	1.28	1.18	0.92
Day 6	43	1.14	0.61	1.10
Day 7	1072	1.16	0.94	0.98
Days 8-14	1131	1.18	0.98	1.00
Days 15-21	642	1.28	1.51	1.00
Days 22-28	513	1.20	0.81	0.97
Days 29-35	261	1.22	0.69	1.00
Days 36-50	284	1.03	0.78	0.88
Days 51-100	589	1.14	0.66	0.98
Days 101-150	144	1.04	0.50	0.95
Days 151-200	59	0.94	0.49	0.85
Days 201-400	30	1.09	0.53	1.02

* Combined datasets (2011 and 2012).

Table 7a*. Descriptive statistics of $(C_2/C_1)/(R_2/R_1)$ values for different crops				
Commodity	$(C_2/C_1)/(R_2/R_1)$			
	<i>n</i>	Mean	RSD	Median
Alfalfa	65	1.01	0.38	0.96
Apple	568	1.14	0.53	1.00
Apricot	68	1.40	0.49	1.22
Asparagus	17	1.36	1.10	1.04
Avocado	13	1.32	0.40	1.14
Barley forage	63	0.94	0.30	0.94
Barley grain	8	0.87	0.21	0.90
Barley straw	17	1.03	0.30	0.95
Bean pulse	43	1.11	0.41	1.10
Bean forage	12	1.26	0.59	0.98
Broccoli	135	0.95	0.63	0.82
Brussels sprouts	37	1.22	0.61	1.00
Cabbage	149	0.91	0.56	0.85
Carrot	8	1.40	0.46	1.31
Cauliflower	115	0.87	0.71	0.69
Celery	30	0.92	0.46	0.85
Cherry	80	1.30	0.48	1.18
Chickpea forage	30	1.00	0.27	1.00
Chilli pepper	11	0.84	0.27	0.97
Chinese cabbage	7	0.85	0.48	0.77
Coffee bean	17	1.14	0.54	1.00
Cotton trash	34	0.99	0.38	0.94

Table 7a*. Descriptive statistics of $(C_2/C_1)/(R_2/R_1)$ values for different crops				
Commodity	$(C_2/C_1)/(R_2/R_1)$			
	<i>n</i>	Mean	RSD	Median
Cotton seed	160	1.31	0.82	1.10
Cranberry	30	1.03	0.44	0.98
Cucumber	83	1.02	0.37	0.97
Custard apple	11	1.08	0.43	0.97
Eggplant	8	0.83	0.47	0.76
Grape	233	1.28	0.48	1.14
Grapefruit	12	0.67	0.33	0.68
Grass	442	1.46	1.41	1.05
Kiwifruit	60	0.95	0.47	0.93
Leaf lettuce	27	0.99	0.70	0.88
Leafy brassica	7	1.01	0.43	1.13
Lemon	37	1.25	0.57	1.21
Lettuce	14	1.43	0.83	1.14
Lima beans	5	1.38	0.45	1.16
Litchi	4	0.77	0.43	0.66
Maize	4	1.06	0.40	1.04
Mandarin	34	1.47	1.85	0.89
Mango	46	1.03	0.52	0.84
Melon	40	0.93	0.55	0.77
Mushroom	6	0.68	0.11	0.69
Nectarine	38	1.10	0.76	0.94
Oat forage	36	1.07	0.28	0.99
Oat grain	14	1.09	0.22	1.08
Oat straw	9	1.10	0.28	1.13
Onion	5	1.17	0.27	1.25
Orange	129	1.35	0.58	1.20
Papaya	46	1.09	0.36	1.00
Pulses	6	0.81	0.12	0.81
Peach	104	1.20	0.52	1.07
Peanut	5	0.93	0.27	0.86
Peanut forage	23	1.35	0.59	1.08
Peanut hay	7	1.32	0.49	1.20
Peanut shell	6	1.13	0.36	0.98
Pear	134	1.28	0.57	1.13
Peas, green	21	1.61	0.59	1.38
Pepper	115	1.14	0.61	1.01
Pineapple	135	1.58	0.83	1.25
Plum	32	1.24	0.42	1.17
Potato	13	1.07	0.42	1.00
Sorgham	96	1.07	0.54	0.92
Sorgham forage	75	1.42	0.62	1.18
Soyabean	46	1.16	0.59	1.00
Soyabean forage	9	0.98	0.49	0.85
Spinach	49	1.16	0.61	1.00
Summer squash	12	0.74	0.35	0.67
Strawberry	13	1.14	0.27	1.13
Sugarcane	14	1.56	0.59	1.21

Table 7a*. Descriptive statistics of $(C_2/C_1)/(R_2/R_1)$ values for different crops				
Commodity	$(C_2/C_1)/(R_2/R_1)$			
	<i>n</i>	Mean	RSD	Median
Tea, black	18	0.95	0.07	0.96
Tomato	205	1.19	0.64	1.00
Wheat forage	97	0.98	0.40	0.89
Wheat grain	43	1.37	0.69	1.00
Wheat straw	23	1.05	0.50	0.95
Zucchini	6	0.67	0.98	0.40

* According to MacLachlan and Hamilton [*Pest Manag Sci* 2011; 67: 609-615].

Table 7b*. Descriptive statistics of $(C_2/C_1)/(R_2/R_1)$ values for different crops				
Commodity	$(C_2/C_1)/(R_2/R_1)$			
	<i>n</i>	Mean	RSD	Median
Alfalfa (forage, hay, seed)	5	1.29	0.66	0.92
Apple fruit	38	0.87	0.34	0.89
Apple leaf	12	0.90	0.57	0.71
Asparagus	3	1.34	0.51	1.14
Avocado	4	1.25	0.06	1.24
Banana (peel, pulp)	149	0.79	0.52	0.80
Barley (forage)	35	1.26	0.54	1.04
Barley (straw)	35	1.04	0.61	0.92
Barley (grain)	32	2.29	3.18	1.00
Bean (forage, hay, straw)	34	1.22	0.87	1.00
Bean (with and without pod)	84	0.91	0.47	0.86
Beetroot	5	0.70	0.56	0.83
Blackberry	6	0.84	0.41	0.81
Broccoli	2	0.75	0.02	0.75
Brussels sprouts	2	0.43	0.68	0.43
Cabbage	69	1.00	0.80	0.83
Cacao	2	1.13	0.16	1.13
Carrot	3	1.06	0.38	1.00
Cauliflower	31	0.91	0.64	0.81
Celery	4	0.72	0.67	0.57
Cherry	2	0.84	0.57	0.84
Chickpea (forage, straw)	26	0.80	0.36	0.79
Chicory	7	0.88	0.41	0.67
Clover	10	1.11	0.34	1.17
Coffee bean (green, dry)	30	0.72	0.80	0.63
Corn/maize (forage, silage, fodder, stover)	208	1.08	0.48	1.00
Corn/maize (cob, grain, kernel)	11	1.17	0.34	1.00
Cotton (seed)	30	0.92	0.52	0.84
Cotton (lint, trash)	11	1.69	0.98	1.19
Cucumber	41	0.87	0.44	0.84
Currant	6	1.07	0.31	1.01
Egg plant	3	1.48	0.34	1.45
Fig	6	0.78	0.20	0.81
Flax (seed)	3	1.14	0.59	1.23
Gooseberry	6	0.92	0.24	0.82

Table 7b*. Descriptive statistics of $(C_2/C_1)/(R_2/R_1)$ values for different crops				
Commodity	$(C_2/C_1)/(R_2/R_1)$			
	<i>n</i>	Mean	RSD	Median
Grape	64	1.35	0.72	1.08
Grass (forage, hay)	81	1.02	0.43	0.97
Guava	3	1.58	0.09	1.50
Hops	6	1.37	0.35	1.47
Leek	3	0.88	0.64	0.73
Lentil	3	1.08	0.21	1.07
Lettuce	59	1.10	0.60	0.90
Lucerne	4	0.74	0.50	0.84
Lupin (forage, straw)	46	0.81	0.30	0.82
Mandarin	13	0.77	0.34	0.66
Melon	33	0.83	0.32	0.80
Mushroom	3	1.53	0.87	1.20
Mustard	2	1.13	0.86	1.13
Oat (forage)	18	1.09	0.67	0.92
Oat (straw)	2	0.90	0.16	0.90
Oat (grain)	2	0.83	0.28	0.83
Oilseed rape (seed)	14	0.97	0.34	0.90
Olive	7	0.51	0.92	0.23
Orange (fruit, peel)	24	0.89	0.73	0.77
Pea (forage)	38	1.08	0.97	0.72
Pea (with and without pod)	7	0.89	0.59	0.74
Peach	4	1.40	0.18	1.43
Pineapple	10	1.17	0.45	1.04
Potato	36	1.26	0.85	1.00
Raspberry	3	1.07	0.02	1.08
Rice (forage, straw)	155	1.39	0.81	1.04
Rice (grain)	585	1.29	1.31	1.00
Rice (bran, hulls)	56	1.26	0.63	1.02
Rye (straw)	2	0.95	0.27	0.95
Rye (grain)	2	1.81	0.03	1.81
Sorghum (forage)	17	1.05	0.32	1.01
Sorghum (grain, panicle)	32	1.17	0.61	0.93
Soybean (forage, hay)	35	0.79	0.37	0.81
Soybean (seed, seed with pods, hulls)	29	1.02	0.44	0.89
Spinach	10	1.42	0.31	1.34
Strawberry	36	0.98	0.29	0.95
Sugarbeet (tops)	10	1.28	0.24	1.34
Sugarbeet (root)	2	1.01	0.14	1.01
Sugarcane	3	0.67	0.53	0.70
Sunflower (seed)	9	0.94	0.45	1.00
Swede (tops)	2	0.62	0.63	0.62
Swede (root)	2	0.84	0.27	0.84
Sweet pepper	54	0.84	0.39	0.75
Tea (dried leaves)	7	0.98	0.59	0.81
Tobacco (green, dried, and cured leaves)	20	1.11	0.46	0.96
Tomato (incl. cherry tomato)	96	0.93	0.48	0.83
Turnip (leaf)	4	0.95	0.41	0.92

Table 7b*. Descriptive statistics of $(C_2/C_1)/(R_2/R_1)$ values for different crops				
Commodity	$(C_2/C_1)/(R_2/R_1)$			
	<i>n</i>	Mean	RSD	Median
Turnip (root)	2	0.94	0.06	0.94
Wheat (forage)	53	0.95	0.60	0.76
Wheat (straw)	15	0.91	0.36	0.90
Wheat (ear, grain)	15	1.22	0.67	0.97
Wheat (processed)	8	1.02	0.09	1.05
Zucchini / Summer squash	5	0.94	0.66	0.70

* Evaluation of the supplementary dataset compiled in 2012.

Table 7c*. Descriptive statistics of $(C_2/C_1)/(R_2/R_1)$ values for different crops				
Commodity	$(C_2/C_1)/(R_2/R_1)$			
	<i>n</i>	Mean	RSD	Median
Alfalfa (forage, hay, seed)	62	1.06	0.41	0.96
Almond hulls	3	1.20	0.88	0.67
Apple fruit	490	1.11	0.53	0.95
Apple leaf	12	0.90	0.57	0.71
Apricot	68	1.40	0.49	1.22
Artichoke globe	4	3.69	1.04	2.68
Asparagus	20	1.36	1.02	1.04
Avocado	17	1.31	0.35	1.17
Banana (peel, pulp)	149	0.79	0.52	0.80
Barley (forage)	98	1.06	0.47	0.99
Barley (straw)	54	1.04	0.52	0.94
Barley (grain)	40	2.01	3.25	0.95
Bean (forage, hay, straw)	52	1.48	1.45	1.00
Bean (with and without pod)	144	1.00	0.44	0.93
Beet leaves	5	0.87	0.51	0.75
Beetroot	5	0.70	0.56	0.83
Blackberry	9	1.21	0.86	1.03
Blueberry	2	1.05	0.24	1.05
Broccoli	137	0.95	0.63	0.82
Brussels sprouts	39	1.18	0.63	0.96
Cabbage	200	0.97	0.64	0.86
Cacao	2	1.13	0.16	1.13
Carrot	11	1.31	0.45	1.07
Cauliflower	164	0.85	0.70	0.69
Celery	34	0.90	0.47	0.81
Cherry	82	1.29	0.48	1.18
Chickpea	4	1.96	1.30	0.79
Chickpea (forage, straw)	58	0.92	0.31	0.91
Chicory	7	0.88	0.41	0.67
Chili pepper	11	0.84	0.27	0.97
Chinese cabbage	7	0.85	0.48	0.77
Clover	10	1.11	0.34	1.17
Coffee bean (green, dry)	49	0.89	0.69	0.71
Collards	3	0.83	0.39	0.66
Corn/maize (forage, silage, fodder, stover)	208	1.08	0.48	1.00

Table 7c*. Descriptive statistics of $(C_2/C_1)/(R_2/R_1)$ values for different crops				
Commodity	$(C_2/C_1)/(R_2/R_1)$			
	<i>n</i>	Mean	RSD	Median
Corn/maize (cob, grain, kernel)	15	1.14	0.34	1.00
Cotton (seed)	190	1.25	0.81	1.00
Cotton (lint, trash)	45	1.16	0.78	1.00
Cranberry	30	1.03	0.44	0.98
Cucumber	124	0.97	0.40	0.91
Currant	6	1.07	0.31	1.01
Custard apple	11	1.08	0.43	0.97
Egg plant	11	1.01	0.49	0.88
Fig	6	0.78	0.20	0.81
Flax (seed)	3	1.14	0.59	1.23
Garlic	2	0.88	0.20	0.88
Gooseberry	6	0.92	0.24	0.82
Grape	297	1.29	0.54	1.14
Grapefruit	12	0.67	0.33	0.68
Grass (forage, hay)	529	1.38	1.38	1.03
Guava	3	1.58	0.09	1.50
Japanese radish	12	0.78	0.33	0.71
Japanese radish leaves	6	1.48	0.40	1.42
Hops	6	1.37	0.35	1.47
Kiwifruit	60	0.95	0.47	0.93
Leafy brassica	7	1.01	0.43	1.13
Leek	3	0.88	0.64	0.73
Lentil	3	1.08	0.21	1.07
Lemon	37	1.25	0.57	1.21
Lettuce	100	1.12	0.69	0.93
Litchi	4	0.77	0.43	0.66
Lucerne	4	0.74	0.50	0.84
Lupin (forage, straw)	46	0.81	0.30	0.82
Mandarin	47	1.28	1.83	0.87
Mango	46	1.03	0.52	0.84
Melon	73	0.89	0.47	0.78
Mushroom	9	0.96	0.82	0.71
Mustard	2	1.13	0.86	1.13
Nectarine	38	1.10	0.76	0.94
Oat (forage)	54	1.08	0.45	0.99
Oat (straw)	11	1.06	0.27	1.00
Oat (grain)	10	1.03	0.25	1.00
Oilseed rape (seed)	20	0.98	0.30	0.93
Oilseed rape (fodder)	4	1.03	0.30	0.96
Oilseed rape (forage)	3	0.42	0.84	0.24
Olive	7	0.51	0.92	0.23
Onion	5	1.17	0.27	1.25
Onion plant	6	1.63	0.63	1.32
Orange (fruit, peel)	153	1.28	0.61	1.10
Papaya	46	1.09	0.36	1.00
Pea (with and without pod)	35	1.31	0.65	0.95
Pea hay	8	1.10	0.24	1.05

Table 7c*. Descriptive statistics of $(C_2/C_1)/(R_2/R_1)$ values for different crops				
Commodity	$(C_2/C_1)/(R_2/R_1)$			
	<i>n</i>	Mean	RSD	Median
Pea (forage)	44	1.04	0.94	0.75
Peach	110	1.18	0.53	1.07
Peanut	5	0.93	0.27	0.86
Peanut foliage, forage	23	1.35	0.59	1.08
Peanut hay	7	1.32	0.49	1.20
Peanut nutmeat	1	1.13	#DIV/0!	1.13
Peanut shell	6	1.13	0.36	0.98
Peanut straw	3	0.98	0.27	0.88
Pear	134	1.28	0.57	1.13
Pepper	167	1.06	0.58	0.93
Pineapple	145	1.55	0.82	1.22
Plum	32	1.24	0.42	1.17
Potato	49	1.21	0.78	1.00
Raspberry	3	1.07	0.02	1.08
Rhubarb	4	0.92	0.39	0.85
Rice (forage, straw)	157	1.38	0.81	1.04
Rice (grain)	587	1.29	1.31	1.00
Rice (bran, hulls)	56	1.26	0.63	1.02
Rye (straw)	2	0.95	0.27	0.95
Rye (grain)	2	1.81	0.03	1.81
Sorghum (forage)	92	1.35	0.61	1.12
Sorghum (grain, panicle)	130	1.09	0.56	0.92
Sorghum stover	15	1.11	0.27	1.15
Soybean (seed, seed with pods, hulls)	66	1.12	0.56	0.99
Soybean (forage, hay, fodder)	55	0.84	0.40	0.85
Spinach	59	1.20	0.56	1.12
Strawberry	49	1.02	0.29	1.00
Sugarbeet (tops)	10	1.28	0.24	1.34
Sugarbeet (root)	2	1.01	0.14	1.01
Sugarcane	17	1.41	0.65	1.10
Summer squash / zucchini	23	0.76	0.60	0.64
Sunflower (seed)	13	0.96	0.48	1.00
Swede (tops)	2	0.62	0.63	0.62
Swede (root)	2	0.84	0.27	0.84
Sweetcorn forage/fodder	4	1.85	0.88	1.31
Tangerine	2	1.21	0.22	1.21
Tea (dried leaves)	25	0.96	0.31	0.93
Tea, green	5	1.01	0.08	1.00
Tobacco (green, dried, and cured leaves)	20	1.11	0.46	0.96
Tomato (incl. cherry tomato)	301	1.11	0.62	0.95
Triticale forage	2	0.73	0.59	0.73
Turnip (leaf)	4	0.95	0.41	0.92
Turnip (root)	2	0.94	0.06	0.94
Wheat (forage)	150	0.97	0.48	0.87
Wheat (straw)	38	0.99	0.46	0.95
Wheat (ear, grain)	58	1.33	0.68	1.00
Wheat (processed)	8	1.02	0.09	1.05

* Combined datasets (2011 and 2012).

Table 8a*. Descriptive statistics of $(C_2/C_1)/(R_2/R_1)$ values for different pesticides				
Pesticide ^a	$(C_2/C_1)/(R_2/R_1)$			
	<i>n</i>	Mean	RSD	Median
Acephate I, s	164	1.17	0.73	1.00
alpha-Cypermethrin I	31	0.80	0.39	0.88
Aminopyralid H, s	421	1.21	1.31	1.00
Azoxystrobin F, s	45	1.02	0.38	0.86
Boscalid F, s	7	0.89	0.34	0.79
Buprofezin I	146	1.34	0.57	1.18
Captan F	63	1.14	0.72	0.88
Chlorantraniliprole I	85	1.04	0.34	1.00
Chlorpyrifos I	94	1.40	0.56	1.22
Clofentezine I	79	1.11	0.50	1.00
Cyprodinil F, s	44	1.34	0.44	1.20
Cyromazine I, s	141	0.90	0.57	0.79
Deltamethrin I	5	1.45	0.48	1.05
Difenoconazole F, s	11	1.09	0.21	1.06
Diflubenzuron I	62	1.30	0.71	0.94
Dimethomorph F, s	8	1.63	0.58	1.44
Disulfoton I, s	23	0.98	0.49	0.81
Endosulfan I	131	1.16	1.26	0.92
Fenbuconazole F	27	1.06	0.55	1.00
Fenproparthrin I	23	0.97	0.08	0.96
Fenvalerate I	17	0.94	0.36	0.96
Fipronil I	588	1.19	1.13	0.91
Flusilazole F, s	49	1.28	0.59	1.08
Haloxifop H, s	180	1.03	0.35	0.98
Imidacloprid I, s	153	1.13	0.62	1.00
Indoxacarb I	377	1.12	0.71	0.96
Iprodione F	26	0.96	0.73	0.77
Kresoxim-methyl F	31	1.27	0.56	1.21
lambda-Cyhalothrin I	10	1.17	0.26	1.15
Methomyl I, s	149	1.35	0.71	1.05
Methoxyfenozide I	24	1.10	0.86	0.83
Oxamyl I, s	300	1.29	0.79	1.02
Parathion I	15	1.30	0.70	1.03
Phosmet I	7	1.23	0.58	1.19
Profenofos I	33	1.42	0.64	1.21
Propiconazole F, s	19	1.29	0.55	1.14
Pyraclostrobin F, s	8	1.04	0.33	1.13
Quinoxifen F, s	57	1.37	0.35	1.30
Spinetoram I	332	1.23	0.42	1.16
Spinosad I	165	1.27	1.03	1.01
Spirodiclofen I	5	0.87	0.04	0.88
Tebuconazole F, s	46	1.02	0.26	1.00
Tebufenozide I	68	1.32	0.51	1.11

Table 8a*. Descriptive statistics of $(C_2/C_1)/(R_2/R_1)$ values for different pesticides				
Pesticide ^a	$(C_2/C_1)/(R_2/R_1)$			
	<i>n</i>	Mean	RSD	Median
Thiodicarb I, s	68	1.22	0.50	1.17
Triadimefon/triadimenol F, s	29	1.03	0.64	0.85
Zoxamide F	28	1.64	0.71	1.25

^a I = insecticide or acaricide; H = herbicide; F = fungicide; s = systemic, partially systemic compounds or those that are translamellarly transported.

* According to MacLachlan and Hamilton [*Pest Manag Sci* 2011; 67: 609-615].

Table 8b*. Descriptive statistics of $(C_2/C_1)/(R_2/R_1)$ values for different pesticides				
Pesticide ^a	$(C_2/C_1)/(R_2/R_1)$			
	<i>n</i>	Mean	RSD	Median
Acetamiprid I, s	35	1.21	0.24	1.23
Acetochlor H, s	29	1.25	0.76	1.00
Azoxystrobin F, s	21	0.79	0.36	0.81
Beta-cyfluthrin I	107	1.05	0.60	0.96
Bitertanol F, s	2	1.19	0.57	1.19
Buprofezin I	2	1.16	0.22	1.16
Chlorimuron ethyl H, s	16	1.25	0.21	1.26
Chlormequat chloride G, s	10	0.90	0.29	0.90
Chlorpyrifos/chlorpyrifos-methyl I	55	1.30	1.49	1.06
Clopyralid H, s	2	1.10	0.65	1.10
CY86 I, s	89	1.34	0.87	1.00
Cyclanilide G	9	0.82	0.28	0.84
Cycloxydim H, s	6	0.82	0.27	0.77
Cyfluthrin I	192	1.17	0.75	0.94
Cyhalofop H, s	29	0.98	0.41	0.94
Cyproconazole F, s	23	0.63	0.61	0.59
Deltamethrin I	18	1.96	0.84	1.31
Diclocymet F, s	8	0.82	0.25	0.82
Difenoconazole F, s	36	1.28	0.24	1.24
Emamectin benzoate I	24	0.93	0.30	0.89
Endosulfan I	4	1.05	0.21	1.03
Epoxiconazole F, s	16	3.01	1.95	1.07
Ethephon G, s	39	1.00	0.55	0.88
Ethiprole I, s	11	0.77	0.17	0.75
Famoxadone F, s	17	0.99	0.37	0.97
Fenamiphos N, s	3	0.52	0.64	0.36
Fenobucarb I	2	2.33	0.52	2.33
Fenoxanil F, s	36	0.96	0.14	0.96
Fenoxaprop-(P)-ethyl H, s	22	1.00	0.74	0.83
Fenpyroximate I	8	1.02	0.44	1.04
Ferimzone F, s	2	1.06	0.34	1.06
Fluazifop H, s	60	1.06	0.71	0.95
Flubendiamide I, s	12	0.95	0.24	0.89
Fluopicolide F, s	24	0.84	0.27	0.75
Flutolanil F, s	2	0.49	0.69	0.49

Table 8b*. Descriptive statistics of $(C_2/C_1)/(R_2/R_1)$ values for different pesticides				
Pesticide ^a	$(C_2/C_1)/(R_2/R_1)$			
	<i>n</i>	Mean	RSD	Median
Fosetyl-Al F, s	51	0.95	0.42	0.89
Glufosinate-ammonium H, s	295	1.14	0.68	0.99
Glyphosate-trimesium H, s	46	1.78	3.43	0.93
Haloxypop H, s	30	1.11	0.50	1.01
Hexaconazole F, s	23	1.22	0.43	1.16
Imazamox H, s	7	1.04	0.35	1.11
Imazapyr H, s	4	0.65	0.54	0.71
Imidacloprid I, s	221	0.96	0.61	0.81
Iprodione F	2	0.56	0.11	0.56
Iprovalicarb F, s	3	1.28	0.35	1.51
Isoprocarb I	19	3.86	1.33	1.27
Isoxaflutole H, s	68	1.03	0.57	0.90
Mefenpyr-diethyl S, s	30	0.94	0.44	0.88
Methiocarb I	3	3.01	0.46	3.30
Myclobutanil F	321	0.90	0.47	0.86
Oxadiazon H	20	1.11	0.46	1.06
Oxydemeton-methyl I, s	2	0.79	0.07	0.79
Pencycuron F	2	0.77	0.13	0.77
Pendimethalin H	3	1.57	0.68	1.29
Penflufen F, s	32	0.94	0.67	0.70
Penoxsulam H, s	9	1.86	0.60	1.85
Phthalide F	4	0.82	0.03	0.82
Prochloraz F	18	1.09	0.40	0.99
Profenofos I	15	1.11	0.65	0.71
Propamocarb F, s	31	0.92	0.49	0.80
Propiconazole F, s	37	0.81	0.46	0.67
Propineb F, s	22	0.93	0.47	0.84
Prothioconazole F, s	4	0.88	0.29	1.00
Quinclorac H, s	5	0.76	0.28	0.78
Silafluofen I	2	1.69	0.54	1.69
Spinosad I	30	1.18	0.40	0.97
Spirodiclofen I	5	0.87	0.04	0.88
Spiromesifen I	10	1.05	0.25	1.00
Sulfoxaflor I, s	95	0.90	0.39	0.84
Tebuconazole F, s	78	0.98	0.30	0.96
Teflubenzuron I	7	1.06	0.50	0.90
Tepraloxydim H, s	5	1.12	0.21	1.14
Thiacloprid I, s	26	0.92	0.35	0.87
Thidiazuron G, s	2	0.81	0.17	0.81
Thiodicarb I, s	3	1.08	0.35	1.00
Tolylfluandil F	24	0.84	0.46	0.83
Triadimefon/triadimenol F, s	21	0.89	0.46	0.88
Triazophos I	37	1.58	0.80	1.13
Tribufos G	4	1.00	0.84	0.82
Tricyclazole F, s	61	1.53	0.92	1.13
Trifloxystrobin F, s	17	1.10	0.79	0.85
Triflumuron I	13	1.00	0.65	0.90

Table 8b*. Descriptive statistics of $(C_2/C_1)/(R_2/R_1)$ values for different pesticides				
Pesticide ^a	$(C_2/C_1)/(R_2/R_1)$			
	<i>n</i>	Mean	RSD	Median
^a F = fungicide; G = plant growth regulator; H = herbicide; I = insecticide or acaricide; N = nematocide; S = safener; s = systemic, partially systemic compounds or those that are translamellarly transported (includes also substances with systemic metabolites).				

* Evaluation of the supplementary dataset compiled in 2012.

Table 8c*. Descriptive statistics of $(C_2/C_1)/(R_2/R_1)$ values for different pesticides				
Pesticide ^a	$(C_2/C_1)/(R_2/R_1)$			
	<i>n</i>	Mean	RSD	Median
Acephate I, s	164	1.17	0.73	1.00
Acetamiprid I, s	35	1.21	0.24	1.23
Acetochlor H, s	29	1.25	0.76	1.00
alpha-Cypermethrin I	31	0.80	0.39	0.88
Aminopyralid H, s	427	1.19	1.33	1.00
Azoxystrobin F, s	67	0.96	0.41	0.84
Beta-cyfluthrin I	107	1.05	0.60	0.96
Bitertanol F, s	2	1.19	0.57	1.19
Boscalid F, s	7	0.90	0.34	0.79
Buprofezin I	148	1.33	0.57	1.18
Captan F	64	1.14	0.72	0.88
Chlorantraniliprole I	85	1.04	0.34	1.00
Chlorimuron ethyl H, s	16	1.25	0.21	1.26
Chlormequat chloride G, s	11	0.85	0.35	0.80
Chlorpyrifos/chlorpyrifos-methyl I	149	1.36	0.97	1.10
Clofentezine I	79	1.11	0.50	1.00
Clopyralid H, s	2	1.10	0.65	1.10
CY86 I, s	89	1.34	0.87	1.00
Cyclanilide G	9	0.82	0.28	0.84
Cycloxydim H, s	6	0.82	0.27	0.77
Cyfluthrin I	192	1.17	0.75	0.94
Cyhalofop H, s	29	0.98	0.41	0.94
Cyproconazole F, s	23	0.63	0.61	0.59
Cyprodinil F, s	44	1.34	0.44	1.20
Cyromazine I, s	141	0.90	0.57	0.79
Deltamethrin I	23	1.85	0.81	1.05
Diclocymet F, s	8	0.82	0.25	0.82
Difenoconazole F, s	47	1.23	0.24	1.20
Diiflubenzuron I	62	1.30	0.71	0.94
Dimethomorph F, s	8	1.63	0.58	1.44
Disulfoton I, s	23	0.98	0.49	0.81
Emamectin benzoate I	24	0.93	0.30	0.89
Endosulfan I	135	1.16	1.24	0.92
Epoxiconazole F, s	16	3.01	1.95	1.07
Ethephon G, s	39	1.00	0.55	0.88
Ethiprole I, s	11	0.77	0.17	0.75
Famoxadone F, s	17	0.99	0.37	0.97

Table 8c*. Descriptive statistics of $(C_2/C_1)/(R_2/R_1)$ values for different pesticides				
Pesticide ^a	$(C_2/C_1)/(R_2/R_1)$			
	<i>n</i>	Mean	RSD	Median
Fenamiphos N, s	3	0.52	0.64	0.36
Fenobucarb I	2	2.33	0.52	2.33
Fenbuconazole F	27	1.06	0.55	1.00
Fenproparthrin I	23	0.97	0.08	0.96
Fenoxanil F, s	36	0.96	0.14	0.96
Fenoxaprop-(P)-ethyl H, s	22	1.00	0.74	0.83
Fenpyroximate I	8	1.02	0.44	1.04
Fenvalerate I	19	0.93	0.34	0.95
Ferimzone F, s	2	1.06	0.34	1.06
Fipronil I	588	1.19	1.13	0.91
Fluazifop H, s	60	1.06	0.71	0.95
Flubendiamide I, s	12	0.95	0.24	0.89
Fluopicolide F, s	24	0.84	0.27	0.75
Flutolanil F, s	2	0.49	0.69	0.49
Flusilazole F, s	49	1.28	0.59	1.08
Fosetyl-Al F, s	51	0.95	0.42	0.89
Glufosinate-ammonium H, s	295	1.14	0.68	0.99
Glyphosate-trimesium H, s	46	1.78	3.43	0.93
Haloxfop H, s	210	1.04	0.38	0.98
Hexaconazole F, s	23	1.22	0.43	1.16
Imazamox H, s	7	1.04	0.35	1.11
Imazapyr H, s	4	0.65	0.54	0.71
Imidacloprid I, s	377	1.03	0.62	0.88
Indoxacarb I	379	1.11	0.71	0.96
Iprodione F	28	0.93	0.74	0.76
Iprovalicarb F, s	3	1.28	0.35	1.51
Isoprocarb I	19	3.86	1.33	1.27
Isoxaflutole H, s	68	1.03	0.57	0.90
Kresoxim-methyl F	31	1.27	0.56	1.21
lambda-Cyhalothrin I	10	1.17	0.26	1.15
Mefenpyr-diethyl S, s	30	0.94	0.44	0.88
Methiocarb I	3	3.01	0.46	3.30
Methomyl I, s	149	1.35	0.71	1.05
Methoxyfenozide I	24	1.10	0.86	0.83
Myclobutanil F	321	0.90	0.47	0.86
Oxadiazon H	20	1.11	0.46	1.06
Oxamyl I, s	300	1.29	0.79	1.02
Oxydemeton-methyl I, s	2	0.79	0.07	0.79
Parathion I	15	1.30	0.70	1.03
Pencycuron F	2	0.77	0.13	0.77
Pendimethalin H	3	1.57	0.68	1.29
Penflufen F, s	32	0.94	0.67	0.70
Penoxsulam H, s	9	1.86	0.60	1.85
Phosmet I	7	1.23	0.58	1.19
Phthalide F	4	0.82	0.03	0.82
Prochloraz F	18	1.09	0.40	0.99
Profenofos I	48	1.32	0.65	1.10

Table 8c*. Descriptive statistics of $(C_2/C_1)/(R_2/R_1)$ values for different pesticides				
Pesticide ^a	$(C_2/C_1)/(R_2/R_1)$			
	<i>n</i>	Mean	RSD	Median
Propamocarb F, s	31	0.92	0.49	0.80
Propiconazole F, s	56	0.98	0.57	0.86
Propineb F, s	22	0.93	0.47	0.84
Prothioconazole F, s	4	0.88	0.29	1.00
Pyraclostrobin F, s	8	1.04	0.33	1.13
Quinclorac H, s	5	0.76	0.28	0.78
Quinoxifen F, s	57	1.37	0.35	1.30
Silafluofen I	2	1.69	0.54	1.69
Spinetoram I	313	1.22	0.43	1.15
Spinosad I	195	1.26	0.97	1.01
Spirodiclofen I	10	0.87	0.04	0.88
Spiromesifen I	10	1.05	0.25	1.00
Sulfoxaflor I, s	95	0.90	0.39	0.84
Tebuconazole F, s	124	0.99	0.29	1.00
Tebufenozide I	68	1.32	0.51	1.11
Teflubenzuron I	7	1.06	0.50	0.90
Tepraloxydim H, s	5	1.12	0.21	1.14
Thiacloprid I, s	28	0.92	0.34	0.87
Thidiazuron G, s	2	0.81	0.17	0.81
Thiodicarb I, s	71	1.21	0.49	1.16
Tolyfluanid F	24	0.84	0.46	0.83
Triadimefon/triadimenol F, s	50	0.97	0.59	0.88
Triazophos I	38	1.62	0.78	1.15
Tribufos G	4	1.00	0.84	0.82
Tricyclazole F, s	61	1.53	0.92	1.13
Trifloxystrobin F, s	17	1.10	0.79	0.85
Triflumuron I	13	1.00	0.65	0.90
Zoxamide F	28	1.64	0.71	1.25

^a F = fungicide; G = plant growth regulator; H = herbicide; I = insecticide or acaricide; N = nematocide; S = safener; s = systemic, partially systemic compounds or those that are translamellarly transported (includes also substances with systemic metabolites).

* Combined datasets (2011 and 2012).

Table 9a*. Descriptive statistics of $(C_2/C_1)/(R_2/R_1)$ values for different pesticide types				
Pesticide type	$(C_2/C_1)/(R_2/R_1)$			
	<i>n</i>	Mean	RSD	Median
Fungicides	505	1.21	0.56	1.04
Herbicides	607	1.14	1.17	0.99
Insecticides (incl. acaricides)	3288	1.19	0.80	1.00

* For the dataset evaluated by MacLachlan and Hamilton [*Pest Manag Sci* 2011; 67: 609-615].

Table 9b*. Descriptive statistics of $(C_2/C_1)/(R_2/R_1)$ values for different pesticide types				
Pesticide type	$(C_2/C_1)/(R_2/R_1)$			
	<i>n</i>	Mean	RSD	Median
Fungicides	938	1.00	0.96	0.89
Growth regulators	64	0.95	0.51	0.86
Herbicides	661	1.16	1.51	0.97
Insecticides (incl. acaricides)	1048	1.17	0.99	0.93
Safeners	30	0.94	0.44	0.88

* Evaluation of the supplementary dataset compiled in 2012.

Table 9c*. Descriptive statistics of $(C_2/C_1)/(R_2/R_1)$ values for different pesticide types				
Pesticide type	$(C_2/C_1)/(R_2/R_1)$			
	<i>n</i>	Mean	RSD	Median
Fungicides	1443	1.08	0.82	0.95
Growth regulators	65	0.94	0.52	0.85
Herbicides	1268	1.15	1.36	0.98
Insecticides (incl. acaricides)	4336	1.19	0.85	1.00
Safeners	30	0.94	0.44	0.88

* Combined datasets (2011 and 2012).

APPENDIX 2

Background Paper On Simulation

[Prepared by US EPA, Office of Pesticide Programs, 21 November 2012]

Introduction and Background

MacLachlan and Hamilton (2011) obtained side-by-side residue trial data reported by the Joint FAO/WHO Meeting on Pesticide Residues (JMPR) to investigate whether or not the resulting residues in harvested commodities are proportional to the pesticide application rate used on the crop. Numerous sets of trials were identified where the only parameter varied was application rate or spray concentration. The authors analyzed this database with respect to a variety of factors including application rate, spray concentration, application type, formulation type, crop, and pesticide and concluded that residues scale proportionally with application rate (proportionality principle). The authors expressed their belief that pesticide risk assessment would be improved by the use of the proportionality principle by regulators and others interested in pesticide residues.

In follow-up work to the MacLachlan and Hamilton paper, Stewart and LaPorte (Relationship between Application Rate of Pesticides and Their Residue Levels in Treated Commodities: Further Investigation of the Proportionality Principle, 2012) recently used additional side-by-side crop residue data sets provided by the Chinese and Japanese governments as well as data provided by BASF, Bayer CropScience, Dow AgroSciences, DuPont, and Syngenta and evaluated the concept of proportionality using the same approach as that described in MacLachlan and Hamilton's paper. The data used by Stewart and LaPorte were distinct from (i.e., supplemental to) that used by MacLachlan and Hamilton and involved a total of 81 different active substances, 14 different formulation types, 4 different application types (foliar, seed treatment, post harvest, soil treatment), and 88 different commodities. Stewart and LaPorte performed multiple analyses using simple linear regression, regressing the natural log residues at a higher application rate vs. 1x application rate using the aforementioned side-by-side trial data. From the available residue data from these side-by-side trials with multiple application rates, Stewart and LaPorte computed the ratio of residue concentrations ($C2/C1$) and compared this to the ratio of application rates ($R2/R1$). Theoretically, if the proportionality concept is true, the expected ratio of residue ratio over application rate ratio ($(C2/C1)/(R2/R1)$) resulting from these side-by-side trials is equal or close to 1, and the median ($(C2/C1)/(R2/R1)$) is expected to be 1.

In a conference call held among US, Dutch, Canadian, French, and Australian participants held in November 2012, further discussion of the Stewart and LaPorte analysis occurred. Specifically, some concern was expressed by call participants that the work by Stewart and LaPorte – while very valuable in extending the work of MacLachlan and Hamilton – did not evaluate the distribution of these ratios using formal statistical tests. Thus, while appropriately estimated ratios would indeed be expected to cluster around 1 if proportionality were true, no formal statistical tests of these resulting ratios were presented to determine if they differed significantly from 1. Specifically, the group from the Netherlands stated that:

The presented document closely follows the paper of MacLachlan and Hamilton (2011). In this respect all statistical comments below are just as much comments on that original paper. The authors present figures and tables suggesting strongly that proportionality seems to be a valid

assumption on average, and also when stratified for application rates, formulation types, application types, concentration ranges, crops and pesticides. *However, no formal test results are shown.*

In other words: while the Stewart and LaPorte findings did indeed suggest that proportionality was at least approximately (or “on average”) correct with the ratios clustering near (and both above and below) 1, the findings did not include an examination of how much these ratios would be expected to deviate from 1 or how much “off” from 1 a specific ratio needed to be in order to suggest that proportionality for that strata or grouping did not hold. Thus, the Stewart and LaPorte data analysis made it difficult to conclude exactly what “close enough” was since no information was provided how much deviation from 1 (aka error) would be expected.

During the conference call, the US agreed to investigate this further by conducting a statistical simulation of what kind (read: amounts) of deviations from the ideal value of 1 would be expected given the nature of the residue distribution and the number of field trials conducted. Specifically, we agreed to develop a short follow-on document that would help to characterize and put into context the Stewart-LaPorte findings and assist in deciding how much of the variation might be to natural (and expected) variability in the ratio and how much might be considered systematic (i.e., truly different from 1 because proportionality did not hold). The following three goals for this exercise were established:

1. To understand the expected range of ratios $(C_2/C_1)/(R_2/R_1)$. For this goal, we set the number of iterations = 10,000 for each simulation (i.e., 10,000 ratios of $(C_2/C_1)/(R_2/R_1)$).
2. To understand the expected range of the median of ratios $(C_2/C_1)/(R_2/R_1)$ for some specific fixed number of trials (number of trials = 10, 20, 30, 50, 100, 200, etc.). These sample sizes can represent for the number of trials per crop, per application type, etc. For this goal, we set the number of medians = 1000 for each simulation (i.e., 1000 sets of 10 trials, 1000 set of 20 trials, etc.)
3. Comparing the residue ratio and ratio of $(C_2/C_1)/(R_2/R_1)$ of the JMPR trials, generated by Stewart-LaPorte with the theoretical distribution of ratios generated from the simulation (see Appendix 3).

Conceptual Approach – Introduction

The conceptual approach that was decided upon was to compute, for multiple application rates, the ratio of residues from the available residue data for the side-by-side trials to the ratio of application rates. Theoretically, if the proportionality concept is true, the expected “ratio of the ratios” – that is the ratio of the residue ratio to application rate ratio $(C_2/C_1)/(R_2/R_1)$ – resulting from these side-by-side trials is equal or close to 1, and the median $(C_2/C_1)/(R_2/R_1)$ is expected to be 1. However, some observed individual ratios in Stewart and LaPorte (as in MacLachlan and Hamilton) of residues C_2/C_1 occasionally are substantially different from the ratio of application rates R_2/R_1 (i.e. $(C_2/C_1)/(R_2/R_1)$ is not close to 1), and the median of residue ratio C_2/C_1 from a number of trials are occasionally not close to the ratio of application rates R_2/R_1 (i.e. $(C_2/C_1)/(R_2/R_1) \neq 1$). The difference causes us to question 1) whether the proportionality principle may be not hold in general (or the proportionality may be not true for some specific strata or scenarios); or 2) whether difference between ratio of residues (or the median of residue ratio) and ratio of application rates is just a result of sampling error (i.e., random noise of residues) given the proportionality concept is valid.

The first question regarding whether proportionality holds in general can be relatively easily addressed by statistically analysing the observed residue data and comparing these observed ratios to ratios

derived from simulations. For the latter question relating the median of the ratios and whether this is equal to 1, it is worthwhile to develop simulations to gain insight into the expected distribution/range of $(C_2/C_1)/(R_2/R_1)$ from side-by-side trials with different application rates R_2 and R_1 , given the proportionality is true. This document is the result of efforts to provide the insight of about $(C_2/C_1)/(R_2/R_1)$: what was found by Stewart/LaPorte using the methods of MacLachlan and Hamilton and how this compares to what would be expected if proportionality were to hold.

Method

Assuming that the proportionality concept is valid, we randomly generated using SAS software (see code in Addendum) a large number of residues and compute the ratios $(C_2/C_1)/(R_2/R_1)$, where each pair C_1 - C_2 represents residues from a side-by-side trial with different application rate R_1 - R_2 . For example, C_1 is randomly generated from a distribution of residue at application R_1 , and C_2 is randomly generated from a distribution of residue at application R_2 , given a stated degree of similarity ICC (intra-class-correlation) after adjustment for application rate between the residue C_1 and residue C_2 since these residues are from a side-by-side trial and are thus correlated. Mathematically, the ICC is calculated as:

$$ICC = \frac{\text{between trials variance}}{\text{between trials variance} + \text{within trial variance}}$$

where variances are calculated for log-transformed residue values

If the degree of similarity of residues from same trial is strong (compared to residues from different trials *after adjustment for application rate*), the ICC is close to 1. If there is a weak similarity between the residues from the same trials (compared to residues from different trials), the ICC is close to 0. Since the ICC may be different for different crops, different pesticides, different applications, different formulations, different locations, or a combination of these different factors, we set ICC = 0.5, 0.7, 0.9, and 1.0 in our simulation to cover a range of moderate to strong correlation¹. If the conclusions we reach regarding the $(C_2/C_1)/(R_2/R_1)$ approximating 1 do not meaningfully differ when these different ICCs are used, we can have greater confidence in any conclusions reached (or, more specifically, that any conclusions are not sensitive to a reasonable range of ICCs chosen).

In addition to assuming an ICC (or, more accurately, a set of ICCs), we also needed to make assumptions for this simulation regarding the distributional form (or family) of the residues (e.g., normal, lognormal) as well as its “spread”, or variance. It is generally recognized that the distribution of crop residues is right-skewed with an approximate lognormal distribution and that the coefficient of variation

¹ The distribution of estimated ICC values in two different databases provided by Dow AgroSciences and PMRA:

ICC	Dow AgroSciences		PMRA	
	Number of Commodity-Pesticide combinations	PERCENT (%)	Number of Commodity-Pesticide combinations	PERCENT (%)
< 0.5	0	0	22	11
0.5 - 0.6	0	0	7	3
0.6 - 0.7	0	0	15	7
0.7 - 0.8	2	9	23	11
0.8 - 0.9	4	17	44	20
0.9 - 1.0	17	74	108	49

(standard deviation/mean) is about 1². Without loss of generality we assume a geometric mean (GM) residue concentration $C_1 = 1$ at application rate $R_1 (= 1X \text{ critical GAP rate})$. Further we assume the distribution of residue at application $R_1 = 1X$ is a lognormal distribution with geometric mean = 1 and CV = 1; the distribution of residue at application $R_2 = 2X$ is a lognormal distribution with GM = 2 and CV = 1; the distribution of residue at application $R_2 = 4X$ is a lognormal distribution with GM = 4 and CV = 1; etc. Similar simulations are also performed with all same assumptions as having been described, except CV=0.7 and then CV=1.3.

Results of Simulation

1. Range of ratio $(C_2/C_1)/(R_2/R_1)$

Table A and Figure 1 present the ratio $(C_2/C_1)/(R_2/R_1)$ for ICCs of 0.5, 0.7, 0.9 and 1.0. As the correlation approaches 1, it can be seen that the distribution of ratio $(C_2/C_1)/(R_2/R_1)$ becomes narrower and asymptotic to 1, and the ratio $(C_2/C_1)/(R_2/R_1)$ does not depend on the ratio of application rates. For example, when the intra-class correlation = 0.5 (i.e., 50% of the variation of the residue data is from the variation between trials, and 50% of the variation of the residue is from the variation of the residues from same trials), 50% of the ratios $(C_2/C_1)/(R_2/R_1)$ are outside the range of (0.6, 1.7) and 20% of the ratios are outside the range (0.3, 2.9). For a strong correlation with ICC = 0.9, 50% of the ratios $(C_2/C_1)/(R_2/R_1)$ are outside the range of (0.8, 1.3) and 20% are outside the range of (0.6, 1.6)

2. Range of median of ratio $(C_2/C_1)/(R_2/R_1)$

Tables B, C, and D present the distribution of medians of $(C_2/C_1)/(R_2/R_1)$ when CV = 1.0, 0.7, and 1.3, respectively.

Figures 2 and 3 visually present the distribution of median of $(C_2/C_1)/(R_2/R_1)$ when CV = 1.

As the sample size increases, the distribution of median of $(C_2/C_1)/(R_2/R_1)$ becomes narrower and is asymptotic to 1. The same characteristic is applied to the ICC: as the ICC increases and becomes closer to 1, the distribution of the median of $(C_2/C_1)/(R_2/R_1)$ becomes narrower and is asymptotic to 1. The distribution of the median of $(C_2/C_1)/(R_2/R_1)$ is independent from the ratio R_2/R_1 . For example, when ICC = 0.5 and sample size = 30 trials, 95% of the medians of $(C_2/C_1)/(R_2/R_1)$ are within (0.67, 1.40). However, for the same ICC = 0.5 but with sample size increasing to 500, 95% of the medians of $(C_2/C_1)/(R_2/R_1)$ are within (0.91, 1.09).

Validate Proportionality Concept

The results of simulations (Tables A and B) can be used as a tool to evaluate whether the proportionality principle is invalid for crop residues in general (i.e., “on average) or invalid for some specific scenarios (for example, seed treatment, soil treatment, etc.). If the median of the ratios observed by Stewart-LaPorte is within the range of the 95% sampling interval of the median in Table B, there is no evidence (at $p=0.05$) to reject the proportionality concept. However, if the Stewart-LaPorte median of the ratios is outside the range of 95% sampling interval of the median in Table B, there is evidence (again at p

² Descriptive statistics of estimated CV values in two different databases provided by Dow AgroSciences and PMRA:

Database	Number of Commodity-Pesticide combinations	Values of CV at percentile								
		min	P5	P10	P25	P50	P75	P90	P95	max
Dow AgroSciences	23	0.37	0.54	0.55	0.88	1.14	1.81	2.33	2.44	2.48
PMRA	219	0.05	0.24	0.46	0.50	0.75	1.06	1.44	1.98	5.93

= 0.05) to reject the proportionality principle for that specific scenario (application type, formulation type, etc.).

Stewart and LaPorte have done an excellent job of generating multiple tables of ratios $(C_2/C_1)/(R_2/R_1)$ for a large number of crops, application types, formulation types, etc.; we would use these available ratios and compare them with the theoretical (simulation) distribution of ratio $(C_2/C_1)/(R_2/R_1)$ and we use these here as the observed data. The most appropriate for comparison are the medians of the ratio $(C_2/C_1)/(R_2/R_1)$ in Stewart-LaPorte's tables (3b, 4b, 5b, 6b, 7b, 8b, and 9b) vs. the distribution of median of $(C_2/C_1)/(R_2/R_1)$ in Table B of this current document. For example, for most of the formulation types, the medians of ratio $(C_2/C_1)/(R_2/R_1)$ in Stewart-LaPorte's Table 3b (see below) are within the range 95% sampling intervals of the simulation, assuming the ICC of residues = 0.5. The only few exceptions are FS (flowable concentrate for seed treatment, n=184), FC (flowable concentrate, n=59), and OD (oil dispersion, n = 9). For example, FS: the observed median of $(C_2/C_1)/(R_2/R_1)$ is 0.81, which is equal the 2.5th percentile when sample size = 100, but less than 0.86 (the 2.5th percentile when the sample size = 200). For FC and OD, the observed ratios of 1.33 (n=59) and 1.85 (n=9) are outside the 95% CI of roughly (0.8 , 1.2) and (0.5, 1.8). This suggests the relationship of "double application rate would double residue" does not apply to this specific scenario, but applies to all the remaining. Further investigation should be performed to determine whether proportionality principle does not apply to flowable concentration, seed treatment, or only the combination of these two variables.

Alternatively, if we assume that the ICCs are 0.7, we find that a greater number of formulations "fall outside" the 95% confidence range described in Table B. Specifically, the following formulations fall outside this range: FS (flowable concentrate for seed treatment, n = 184): observed = 0.81 (95% CI = 0.9 to 1.1); FC (flowable concentration, n = 59): observed = 1.33 (95% CI = 0.8 to 1.3); OD (oil dispersion, n = 9): observed= 1.85 (95% CI = 0.6 to 1.6); EC (emulsifiable concentration, n = 813): observed = 0.93 (95% CI = 0.9 to 1.1); and SC (suspension concentration, n = 514): observed = 0.90 (95% CI (0.9 to 1.1)). In addition to the mentioned formulations, SL (soluble concentrate, n = 508) would also fall out of the expected range if we assume an ICC of 0.9: observed ratio = 0.94 (95% CI = 0.96 to 1.04). Thus, we might question the extent to which these formulations indeed follow proportionality. While this might suggest further investigation of why the relationship of "double application would double residue" for formulation does not hold *precisely*, it does suggest that the value is usually very close to (but less than) the ideal value of 1. For example, one exception is an OD formulation with an observed ratio of 1.85.

Another interest is related to application type as expressed by the Stewart-LaPorte Table 4b in which four strata were established by application type: foliar; soil treatment; post-harvest; and seed treatment. For foliar application (n=1681), the observed median of $(C_2/C_1)/(R_2/R_1)$ is 0.93 which is outside the 95% CI range of (0.95, 1.05) which would be expected with an ICC of 0.5 and n= 1500 for the simulated median $(C_2/C_1)/(R_2/R_1)$. For ICCs of 0.7 and 0.9 respectively, the corresponding 95% CIs are (0.96, 1.04) and (0.98, 1.02), and the observed median value of 0.93 is similarly outside of these range.

Conclusion

In a conference call held among US, Dutch, Canadian, French, and Australian participants regarding work by Stewart and LaPorte, some concern was expressed that the $(C_2/C_1)/(R_2/R_1)$ ratios they generated to test proportionality were not evaluated using formal statistical tests. That is, while appropriate estimated ratios would indeed be expected to cluster around one if proportionality were true, no formal statistical tests of these resulting ratios were presented to determine if they differed significantly from one.

During the conference call, the US agreed to investigate this further by conducting a statistical simulation and agreed to develop a short follow-on document that would help to characterize and put into context the Stewart-LaPorte findings and assist in deciding how much of the variation might be to natural

(and expected) variability in the ratio and how much might be considered systematic (i.e., truly different from 1 because proportionality did not hold). This analysis was performed using what we believe to be reasonable assumptions regarding the distributional family, the CV, and the ICC. Based on these simulation results, it appears that the Steward-LaPorte results for the $(C_2/C_1)/(R_2/R_1)$ ratio fall outside the expected range of variability for this ratio.

(Excerpt from Stewart-LaPorte document)

Table 3b*. Descriptive statistics of $(C_2/C_1)/(R_2/R_1)$ values for different formulation types				
Formulation type	$(C_2/C_1)/(R_2/R_1)$			
	<i>n</i>	Mean	RSD	Median
Not specified or several types	13	0.84	0.20	0.83
DF (dry flowable formulation)	5	0.76	0.28	0.78
DP (dispersible powder)	6	1.02	0.76	0.77
EC (emulsifiable concentrate)	813	1.05	0.71	0.93
EW (emulsion, oil in water)	137	1.29	1.12	1.03
FC (flowable concentrate)	59	1.63	0.81	1.33
FS (flowable concentrate for seed treatment)	184	0.91	0.59	0.81
GR (granule)	11	0.83	0.39	0.83
ME (micro-emulsion)	24	0.93	0.30	0.89
OD (oil dispersion)	9	1.86	0.60	1.85
SC (suspension concentrate)	514	1.07	1.12	0.90
SL (soluble concentrate)	508	1.16	1.68	0.94
WG (water-dispersible granule)	154	1.00	0.52	0.93
WP (wetable powder)	294	1.23	1.25	0.99
WS (water-dispersible powder for slurry seed treatment)	11	0.96	0.28	1.00

* Evaluation of the supplementary dataset compiled in 2012.

Table A: Distribution of ratio $(C_1/C_2)/(R_2/R_1)$

Distribution of ratio: $(C_2/C_1)/(R_2/R_1)$						
ICC	R2/R1	10th Pctl	25th Pctl	Median	75th Pctl	90th Pctl
0.5	2	0.3	0.6	1.0	1.7	2.9
	4	0.3	0.6	1.0	1.7	2.9
0.7	2	0.4	0.6	1.0	1.5	2.2
	4	0.4	0.6	1.0	1.6	2.3
0.9	2	0.6	0.8	1.0	1.3	1.6
	4	0.6	0.8	1.0	1.3	1.6

Figure 1: Distribution of ratio $(C_2/C_1)/(R_2/R_1)$

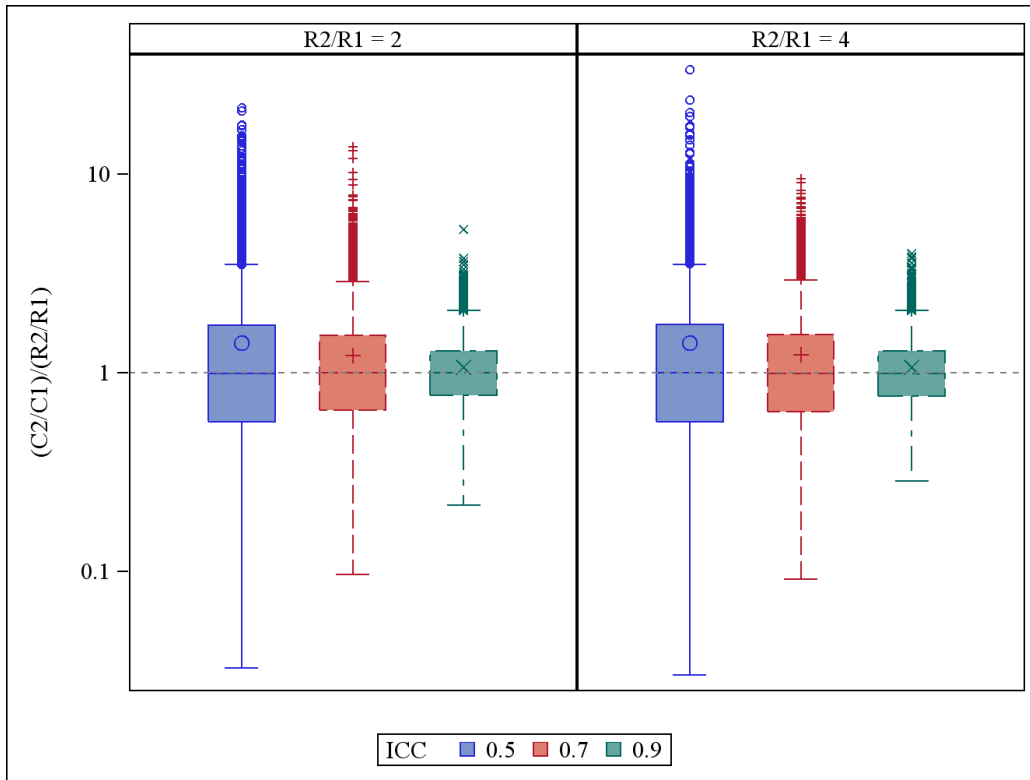


Table B: Distribution of Median of ratio $(C_2/C_1)/(R_2/R_1)$ when CV = 1

Distribution of Median of ratio $(C_2/C_1)/(R_2/R_1)$ when CV = 1											
ICC	R2/R1	Number of Trials	2.5 pctl	5 pctl	10 pctl	25 pctl	50 pctl	75 pctl	90 pctl	95 pctl	97.5 pctl
0.5	2	10	0.54	0.60	0.67	0.81	0.99	1.22	1.49	1.65	1.82
		20	0.63	0.69	0.74	0.87	1.01	1.16	1.33	1.43	1.53
		30	0.67	0.72	0.78	0.88	1.00	1.12	1.26	1.38	1.47
		50	0.75	0.78	0.83	0.90	1.00	1.10	1.20	1.26	1.32
		100	0.81	0.84	0.88	0.94	1.00	1.07	1.13	1.18	1.21
		200	0.86	0.88	0.91	0.95	1.00	1.05	1.10	1.13	1.15
		500	0.91	0.93	0.95	0.97	1.00	1.03	1.06	1.08	1.09
		1000	0.93	0.95	0.96	0.98	1.00	1.02	1.04	1.05	1.06
		1500	0.95	0.96	0.97	0.98	1.00	1.02	1.04	1.05	1.05
0.5	4	10	0.53	0.59	0.68	0.80	1.00	1.25	1.49	1.63	1.79
		20	0.64	0.71	0.76	0.86	1.01	1.17	1.35	1.44	1.57
		30	0.68	0.73	0.79	0.88	1.00	1.13	1.29	1.40	1.48
		50	0.74	0.79	0.83	0.90	1.00	1.10	1.19	1.24	1.32
		100	0.82	0.84	0.87	0.93	1.00	1.07	1.14	1.18	1.22

Distribution of Median of ratio $(C_2/C_1)/(R_2/R_1)$ when $CV = 1$											
ICC	R2/R1	Number of Trials	2.5 pctl	5 pctl	10 pctl	25 pctl	50 pctl	75 pctl	90 pctl	95 pctl	97.5 pctl
		200	0.87	0.89	0.92	0.96	1.00	1.05	1.10	1.13	1.16
		500	0.91	0.92	0.94	0.97	1.00	1.03	1.07	1.08	1.10
		1000	0.94	0.95	0.96	0.98	1.00	1.02	1.04	1.05	1.06
		1500	0.95	0.96	0.97	0.98	1.00	1.02	1.03	1.05	1.06
0.7	2	10	0.64	0.68	0.75	0.86	1.01	1.19	1.36	1.47	1.61
		20	0.69	0.74	0.79	0.88	0.99	1.11	1.25	1.35	1.41
		30	0.75	0.78	0.82	0.90	0.99	1.11	1.20	1.26	1.30
		50	0.80	0.83	0.86	0.92	0.99	1.07	1.15	1.20	1.23
		100	0.86	0.88	0.91	0.95	1.00	1.06	1.11	1.15	1.17
		200	0.89	0.91	0.93	0.96	1.00	1.04	1.08	1.10	1.12
		500	0.94	0.95	0.96	0.98	1.00	1.03	1.05	1.06	1.08
		1000	0.95	0.96	0.97	0.98	1.00	1.02	1.03	1.04	1.05
0.7	4	10	0.63	0.67	0.73	0.85	0.99	1.17	1.36	1.49	1.61
		20	0.71	0.75	0.80	0.89	0.99	1.12	1.25	1.35	1.44
		30	0.75	0.79	0.82	0.91	1.00	1.09	1.19	1.27	1.30
		50	0.80	0.83	0.86	0.93	1.00	1.08	1.16	1.20	1.24
		100	0.85	0.87	0.90	0.94	0.99	1.04	1.11	1.14	1.17
		200	0.89	0.91	0.93	0.96	1.00	1.04	1.07	1.10	1.12
		500	0.93	0.94	0.95	0.97	1.00	1.03	1.05	1.06	1.08
		1000	0.95	0.96	0.97	0.98	1.00	1.02	1.03	1.04	1.05
0.9	2	10	0.78	0.80	0.84	0.92	1.01	1.10	1.19	1.27	1.33
		20	0.81	0.84	0.88	0.94	1.00	1.07	1.14	1.18	1.22
		30	0.86	0.88	0.90	0.95	1.00	1.06	1.11	1.14	1.17
		50	0.88	0.90	0.92	0.95	1.00	1.04	1.09	1.11	1.13
		100	0.91	0.93	0.94	0.97	1.00	1.03	1.06	1.08	1.10
		200	0.94	0.95	0.96	0.98	1.00	1.02	1.04	1.06	1.07
		500	0.96	0.97	0.97	0.99	1.00	1.02	1.03	1.03	1.04
		1000	0.97	0.98	0.98	0.99	1.00	1.01	1.02	1.03	1.03
0.9	4	10	0.77	0.80	0.84	0.91	1.01	1.11	1.21	1.27	1.33
		20	0.82	0.84	0.88	0.93	1.00	1.07	1.14	1.19	1.23
		30	0.85	0.88	0.90	0.95	1.01	1.06	1.11	1.14	1.17
		50	0.88	0.90	0.92	0.96	1.00	1.05	1.09	1.11	1.14
		100	0.92	0.93	0.94	0.97	1.00	1.03	1.06	1.08	1.10
		200	0.94	0.95	0.96	0.98	1.00	1.02	1.04	1.05	1.06
		500	0.96	0.97	0.97	0.99	1.00	1.01	1.03	1.04	1.04

Distribution of Median of ratio $(C_2/C_1)/(R_2/R_1)$ when $CV = 1$											
ICC	R2/R1	Number of Trials	2.5 pctl	5 pctl	10 pctl	25 pctl	50 pctl	75 pctl	90 pctl	95 pctl	97.5 pctl
		1000	0.97	0.98	0.98	0.99	1.00	1.01	1.02	1.02	1.03
		1500	0.98	0.98	0.98	0.99	1.00	1.01	1.02	1.02	1.03

Table C: Distribution of Median of ratio $(C_2/C_1)/(R_2/R_1)$ when $CV = 0.7$

Expected of median of $(C_2/C_1)/(R_2/R_1)$ when $CV = 0.7$											
ICC	R2/R1	Number of Trials	2.5 pctl	5 pctl	10 pctl	25 pctl	50 pctl	75 pctl	90 pctl	95 pctl	97.5 pctl
0.5	2	10	0.63	0.68	0.74	0.85	0.99	1.17	1.35	1.46	1.57
		20	0.70	0.75	0.80	0.90	1.00	1.12	1.24	1.31	1.38
		30	0.74	0.78	0.83	0.91	1.00	1.09	1.19	1.28	1.34
		50	0.80	0.83	0.86	0.92	1.00	1.07	1.15	1.19	1.23
		100	0.85	0.88	0.91	0.95	1.00	1.05	1.10	1.13	1.15
		200	0.89	0.91	0.93	0.96	1.00	1.04	1.08	1.10	1.11
		500	0.93	0.95	0.96	0.98	1.00	1.02	1.05	1.06	1.07
		1000	0.95	0.96	0.97	0.98	1.00	1.02	1.03	1.04	1.05
		1500	0.96	0.97	0.97	0.99	1.00	1.01	1.03	1.04	1.04
0.5	4	10	0.61	0.67	0.75	0.84	1.00	1.18	1.35	1.45	1.55
		20	0.71	0.77	0.81	0.89	1.01	1.12	1.25	1.32	1.41
		30	0.75	0.79	0.83	0.91	1.00	1.10	1.22	1.29	1.35
		50	0.80	0.84	0.87	0.93	1.00	1.08	1.14	1.18	1.24
		100	0.86	0.88	0.90	0.95	1.00	1.05	1.10	1.13	1.17
		200	0.90	0.92	0.94	0.97	1.00	1.04	1.08	1.10	1.12
		500	0.93	0.94	0.96	0.98	1.00	1.02	1.05	1.06	1.07
		1000	0.95	0.96	0.97	0.98	1.00	1.02	1.03	1.04	1.05
		1500	0.96	0.97	0.97	0.99	1.00	1.01	1.02	1.03	1.04
0.7	2	10	0.71	0.74	0.80	0.89	1.01	1.14	1.26	1.34	1.43
		20	0.75	0.79	0.83	0.91	1.00	1.08	1.19	1.25	1.30
		30	0.80	0.83	0.86	0.92	0.99	1.08	1.15	1.19	1.22
		50	0.85	0.87	0.89	0.94	0.99	1.06	1.11	1.15	1.17
		100	0.89	0.91	0.93	0.96	1.00	1.04	1.09	1.11	1.13
		200	0.92	0.93	0.95	0.97	1.00	1.03	1.06	1.07	1.09
		500	0.95	0.96	0.97	0.98	1.00	1.02	1.04	1.05	1.06
		1000	0.96	0.97	0.98	0.99	1.00	1.01	1.02	1.03	1.04
		1500	0.97	0.97	0.98	0.99	1.00	1.01	1.02	1.03	1.03
0.7	4	10	0.70	0.74	0.79	0.89	0.99	1.13	1.26	1.36	1.44
		20	0.77	0.80	0.84	0.91	0.99	1.09	1.18	1.26	1.32
		30	0.80	0.83	0.86	0.93	1.00	1.07	1.14	1.20	1.22

Expected of median of (C2/C1)/(R2/R1) when CV = 0.7											
ICC	R2/R1	Number of Trials	2.5 pctl	5 pctl	10 pctl	25 pctl	50 pctl	75 pctl	90 pctl	95 pctl	97.5 pctl
		50	0.85	0.87	0.89	0.94	1.00	1.06	1.12	1.15	1.18
		100	0.89	0.90	0.92	0.96	0.99	1.03	1.08	1.11	1.13
		200	0.92	0.93	0.95	0.97	1.00	1.03	1.05	1.07	1.09
		500	0.95	0.95	0.96	0.98	1.00	1.02	1.03	1.05	1.06
		1000	0.97	0.97	0.98	0.99	1.00	1.01	1.03	1.03	1.04
		1500	0.97	0.98	0.98	0.99	1.00	1.01	1.02	1.03	1.03
0.9	2	10	0.82	0.84	0.87	0.93	1.01	1.08	1.14	1.20	1.24
		20	0.85	0.87	0.91	0.95	1.00	1.06	1.10	1.13	1.16
		30	0.89	0.90	0.93	0.96	1.00	1.04	1.08	1.10	1.13
		50	0.91	0.92	0.94	0.97	1.00	1.03	1.07	1.08	1.09
		100	0.93	0.94	0.96	0.98	1.00	1.03	1.05	1.06	1.07
		200	0.95	0.96	0.97	0.98	1.00	1.02	1.03	1.04	1.05
		500	0.97	0.97	0.98	0.99	1.00	1.01	1.02	1.03	1.03
		1000	0.98	0.98	0.99	0.99	1.00	1.01	1.02	1.02	1.02
		1500	0.98	0.98	0.99	0.99	1.00	1.01	1.01	1.01	1.01
0.9	4	10	0.82	0.85	0.88	0.93	1.01	1.08	1.16	1.20	1.24
		20	0.86	0.88	0.91	0.95	1.00	1.06	1.11	1.14	1.17
		30	0.89	0.91	0.93	0.96	1.00	1.05	1.08	1.10	1.13
		50	0.91	0.92	0.94	0.97	1.00	1.03	1.07	1.08	1.10
		100	0.94	0.94	0.96	0.98	1.00	1.03	1.05	1.06	1.07
		200	0.95	0.96	0.97	0.98	1.00	1.02	1.03	1.04	1.05
		500	0.97	0.98	0.98	0.99	1.00	1.01	1.02	1.03	1.03
		1000	0.98	0.98	0.99	0.99	1.00	1.01	1.01	1.02	1.02
		1500	0.98	0.98	0.99	0.99	1.00	1.01	1.01	1.02	1.02

Table D: Distribution of Median of ratio $(C_2/C_1)/(R_2/R_1)$ when $CV = 1.3$

Expected of median of $(C_2/C_1)/(R_2/R_1)$ when $CV = 1.3$											
ICC	R2/R1	Number of Trials	2.5 pctl	5 pctl	10 pctl	25 pctl	50 pctl	75 pctl	90 pctl	95 pctl	97.5 pctl
0.5	2	10	0.48	0.54	0.62	0.78	0.99	1.28	1.61	1.82	2.04
		20	0.57	0.64	0.70	0.85	1.01	1.20	1.41	1.54	1.67
		30	0.62	0.68	0.74	0.86	1.00	1.15	1.32	1.47	1.58
		50	0.71	0.75	0.80	0.88	1.00	1.11	1.25	1.32	1.39
		100	0.78	0.81	0.86	0.93	1.00	1.08	1.16	1.21	1.25
		200	0.83	0.86	0.89	0.94	1.00	1.06	1.13	1.16	1.18
		500	0.90	0.92	0.93	0.96	1.00	1.04	1.07	1.09	1.11
		1000	0.92	0.94	0.95	0.97	1.00	1.03	1.05	1.06	1.08
		1500	0.94	0.95	0.96	0.98	1.00	1.02	1.04	1.06	1.06
0.5	4	10	0.46	0.53	0.63	0.77	1.01	1.32	1.62	1.80	2.01
		20	0.59	0.67	0.72	0.84	1.02	1.20	1.43	1.54	1.71
		30	0.63	0.69	0.75	0.86	1.00	1.16	1.36	1.49	1.61
		50	0.70	0.76	0.80	0.89	1.00	1.12	1.24	1.30	1.40
		100	0.78	0.81	0.85	0.92	1.00	1.09	1.17	1.22	1.27
		200	0.85	0.87	0.90	0.95	1.00	1.06	1.12	1.16	1.19
		500	0.90	0.91	0.93	0.96	1.00	1.04	1.08	1.10	1.12
		1000	0.93	0.94	0.95	0.97	1.00	1.03	1.05	1.07	1.08
		1500	0.94	0.95	0.96	0.98	1.00	1.02	1.04	1.05	1.07
0.7	2	10	0.58	0.63	0.71	0.84	1.02	1.23	1.45	1.59	1.76
		20	0.64	0.69	0.75	0.86	0.99	1.14	1.31	1.43	1.51
		30	0.70	0.74	0.79	0.88	0.99	1.13	1.24	1.32	1.37
		50	0.77	0.80	0.83	0.91	0.99	1.09	1.18	1.25	1.28
		100	0.83	0.86	0.89	0.94	1.00	1.07	1.14	1.18	1.21
		200	0.87	0.89	0.92	0.95	1.00	1.05	1.09	1.12	1.14
		500	0.92	0.94	0.95	0.97	1.00	1.03	1.06	1.08	1.09
		1000	0.94	0.95	0.96	0.98	1.00	1.02	1.04	1.05	1.06
		1500	0.95	0.96	0.97	0.98	1.00	1.02	1.03	1.04	1.05
0.7	4	10	0.57	0.62	0.69	0.83	1.00	1.21	1.44	1.62	1.77
		20	0.67	0.71	0.76	0.87	0.99	1.14	1.31	1.43	1.54
		30	0.71	0.75	0.79	0.90	1.00	1.11	1.24	1.33	1.37
		50	0.77	0.80	0.84	0.91	1.00	1.10	1.19	1.24	1.29
		100	0.83	0.85	0.88	0.93	0.99	1.05	1.13	1.17	1.21
		200	0.87	0.89	0.92	0.95	1.00	1.05	1.09	1.12	1.14
		500	0.92	0.93	0.94	0.97	1.00	1.03	1.06	1.07	1.09
		1000	0.95	0.95	0.96	0.98	1.00	1.02	1.04	1.05	1.06
		1500	0.95	0.96	0.97	0.98	1.00	1.02	1.03	1.04	1.05

Expected of median of (C2/C1)/(R2/R1) when CV = 1.3											
ICC	R2/R1	Number of Trials	2.5 pctl	5 pctl	10 pctl	25 pctl	50 pctl	75 pctl	90 pctl	95 pctl	97.5 pctl
0.9	2	10	0.74	0.77	0.81	0.90	1.01	1.13	1.23	1.33	1.41
		20	0.78	0.81	0.86	0.92	1.00	1.09	1.17	1.22	1.27
		30	0.83	0.85	0.89	0.94	1.00	1.07	1.13	1.16	1.21
		50	0.86	0.88	0.90	0.95	1.00	1.05	1.11	1.13	1.15
		100	0.90	0.91	0.93	0.96	1.00	1.04	1.07	1.10	1.12
		200	0.93	0.94	0.95	0.98	1.00	1.03	1.05	1.07	1.08
		500	0.95	0.96	0.97	0.98	1.00	1.02	1.03	1.04	1.05
		1000	0.96	0.97	0.98	0.99	1.00	1.01	1.02	1.03	1.04
		1500	0.97	0.98	0.98	0.99	1.00	1.01	1.02	1.02	1.03
0.9	4	10	0.74	0.77	0.81	0.90	1.01	1.13	1.26	1.34	1.41
		20	0.79	0.81	0.86	0.92	1.00	1.09	1.17	1.24	1.28
		30	0.83	0.86	0.89	0.94	1.01	1.07	1.13	1.17	1.21
		50	0.86	0.88	0.90	0.95	1.01	1.06	1.11	1.13	1.16
		100	0.90	0.91	0.93	0.97	1.00	1.04	1.07	1.10	1.12
		200	0.93	0.94	0.95	0.97	1.00	1.02	1.05	1.06	1.07
		500	0.95	0.96	0.97	0.98	1.00	1.02	1.03	1.04	1.05
		1000	0.97	0.97	0.98	0.99	1.00	1.01	1.02	1.03	1.03
		1500	0.97	0.97	0.98	0.99	1.00	1.01	1.02	1.02	1.03

Figures 2 and 3: Distribution of Median of ratio $(C2/C1)/(R2/R1)$ when $CV = 1$

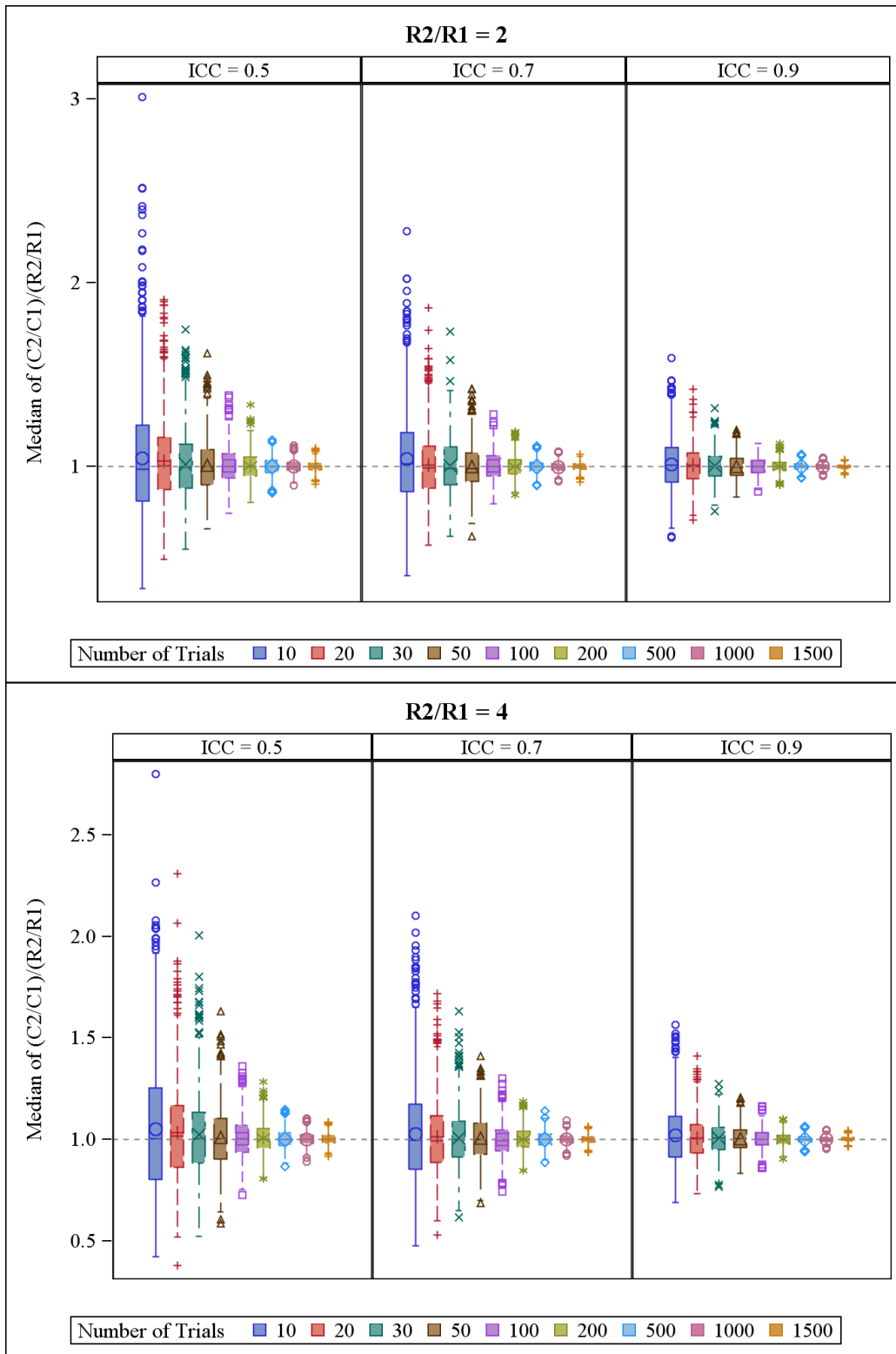
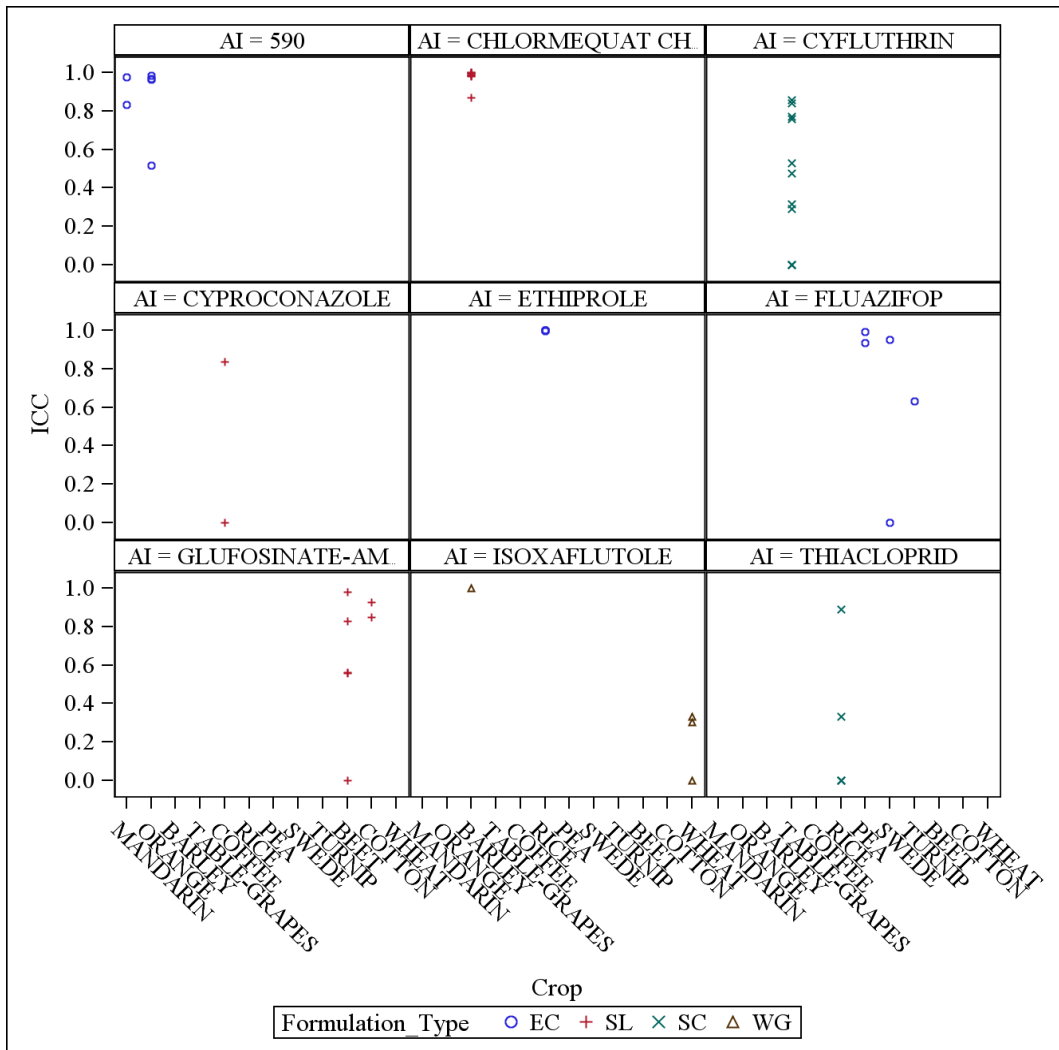


Figure 4: Scatter-plot of ICC estimated from the data that Stewart-LaPorte used in their analysis



ADDENDUM

SAS code

```

%Macro Simulation(NSim=,GM=, CV=, ListICC=, ListAR=, seed=);

* at application rate AR1:
- mean MY1 = log(&GM)
- stand. deviation SY = (log(1+&CV**2))**.5
- stand. deviation b/w trial mean is = (&ICC*log(1+&CV**2))**.5
- stand. deviation within trial is = ((1-&ICC)*log(1+&CV**2))**.5;

* at application rate AR2 (the CV is still the same):
- mean MY2 = log[&AR1/&AR2]*&GM]
- stand. deviation SY = (log(1+&CV**2))**.5
- stand. deviation b/w trial mean is = (&ICC*log(1+&CV**2))**.5
- stand. deviation within trial is = ((1-&ICC)*log(1+&CV**2))**.5;
%let MY1 = log(&GM);

%let nicc = 1;
%let ICC&nicc = %nrquote(%scan(&ListICC,&nicc,%str( )));
%Do %while (&ICC&nicc ^=);
  %let SYB&nicc = (&ICC&nicc*log(1+&CV**2))**.5;
  %let SYW&nicc = ((1-&ICC&nicc)*log(1+&CV**2))**.5;
  %let nicc = %eval(&nicc+1);
  %let ICC&nicc = %nrquote(%scan(&ListICC,&nicc,%str( )));
%end;
%let nicc = %eval(&nicc - 1);

%let nar = 1;
%let AR&nar = %nrquote(%scan(&ListAR,&nar,%str( )));
%Do %while (&AR&nar ^=);
  %let nar = %eval(&nar + 1);
  %let AR&nar = %nrquote(%scan(&ListAR,&nar,%str( )));
%end;
%let nar = %eval(&nar - 1);

Data Simulation; set _NULL_; run;
Data Simulation;
Sim = &NSim;
AR1 = &AR1;
%do r = 2 %to &nar;
  AR2 = &AR&r;
  %do i = 1 %to &nicc;
    ICC = &ICC&i;
    do pair = 1 to &NSim;
      M1 = &MY1 + &SYB&i*rannor(&seed);
      Rand1 = &SYW&i*rannor(&seed);
      M2 = log(&AR&r/&AR1) + M1;
      Rand2 = &SYW&i*rannor(&seed);
      output;
    end;
  end;
end;

```

```

    %end;
  %end;
run;
Data Simulation;
set Simulation;
Res1= exp(M1+Rand1);
Res2= exp(M2+Rand2);
Ratio=Res2/Res1;
Ratio1 = Ratio/AR2;
label AR2 = "R2/R1" Ratio = "C2/C1" Ratio1="(C2/C1)/(R2/R1)";
run;

title;
title1 "Distribution of [residue ratio/a.rate ratio] (Per &NSim simulations)";
Proc means data = Simulation P10 P25 Median P75 P90 maxdec=1 nonobs;
  class ICC AR2;
  var Ratio1;
run;

Proc SGPanel data = Simulation;
  PANELBY AR2 /columns=%eval(&nar-1);
  VBOX ratio1/group = ICC;
  rowaxis type = log label = "(C2/C1)/(R2/R1)" logbase = 10 logstyle = logexpand;
  refline 1/lineattrs =(pattern = 2) ;
run;

%Mend;

%Simulation(NSim=10000, GM=1, CV=1, ListICC= 0.5 0.7 0.9, ListAR= 1 2 4, seed=25451);

%Macro Simulation1(NSim=,GM=, CV=, ListICC=, ListAR=, ntrial=, seed=);

* at application rate AR1:
- mean MY1 = log(&GM)
- stand. deviation SY = (log(1+&CV**2))**.5
- stand. deviation b/w trial mean is = (&ICC*log(1+&CV**2))**.5
- stand. deviation within trial is = ((1-&ICC)*log(1+&CV**2))**.5;

* at application rate AR2 (the CV is still the same):
- mean MY2 = log[&AR1/&AR2]*&GM]
- stand. deviation SY = (log(1+&CV**2))**.5
- stand. deviation b/w trial mean is = (&ICC*log(1+&CV**2))**.5
- stand. deviation within trial is = ((1-&ICC)*log(1+&CV**2))**.5;
%let MY1 = log(&GM);

%let nicc = 1;
%let ICC&nicc = %nrquote(%scan(&ListICC,&nicc,%str( )));
%Do %while (&&ICC&nicc ^=);
  %let SYB&nicc = (&&ICC&nicc*log(1+&CV**2))**.5;

```

```

%let SYW&nicc = ((1-&&ICC&nicc)*log(1+&CV**2))**.5;
%let nicc = %eval(&nicc+1);
%let ICC&nicc = %nrquote(%scan(&ListICC,&nicc,%str( )));
%end;
%let nicc = %eval(&nicc - 1);

%let nar = 1;
%let AR&nar = %nrquote(%scan(&ListAR,&nar,%str( )));
%Do %while (&&AR&nar ^=);
  %let nar = %eval(&nar + 1);
  %let AR&nar = %bquote(%scan(&ListAR,&nar,%str( )));
%end;
%let nar = %eval(&nar - 1);

%let NN = 1;
%let ntrial&NN = %nrquote(%scan(&ntrial,&NN,%str( )));
%Do %while (&&ntrial&NN ^=);
  %let NN = %eval(&NN + 1);
  %let ntrial&NN = %bquote(%scan(&ntrial,&NN,%str( )));
%end;
%let NN = %eval(&NN - 1);

```

```

Data Simulation; set _NULL_; run;
Data Simulation;
  Sim = &NSim;
  AR1 = &AR1;
  %do r = 2 %to &nar;
    AR2 = &&AR&r;
    %do i = 1 %to &nicc;
      ICC = &&ICC&i;
      %do N = 1 %to &NN;
        do Sim = 1 to &NSim;
          NTrial = &&ntrial&N;
          do pair = 1 to &&ntrial&N;
            M1 = &MY1 + &&SYB&i*rannor(&seed);
            Rand1 = &&SYW&i*rannor(&seed);
            M2 = log(&&AR&r/&AR1) + M1;
            Rand2 = &&SYW&i*rannor(&seed);
            output;
          end; *pair;
        end; *Sim;
      %end; *N;;
    %end; *i;
  %end; *r;
run;
Data Simulation;
  set Simulation;
  Res1= exp(M1+Rand1);
  Res2= exp(M2+Rand2);
  Ratio=Res2/Res1;

```

```

Ratio1 = Ratio/AR2;
label AR2 = "R2/R1" Ratio = "C2/C1" Ratio1="(C2/C1)/(R2/R1)";
run;

Proc means data = Simulation N median;
class ICC AR2 Sim NTrial;
var Ratio1;
ods output Summary=Summary1;
run;
Data Summary1;
set summary1;
label Ratio1_Median="Median of (C2/C1)/(R2/R1)" NTrial = "Number of Trials";
run;
Proc Univariate data = Summary1 noprint;
by ICC;
class AR2 NTrial;
var Ratio1_Median;
output out = Pctls1 pctlpts=2.5 5 10 25 50 75 90 95 97.5 PCTLPRE=median;
run;

title1 "Distribution of [(C2/C1)/(R2/R1)] (Per &NSim simulations)";
Proc Print data = Pctls1 noobs label;
var ICC AR2 NTrial median2_5 median5 median10 median25 median50 median75 median90
median95 median97_5;
format median2_5 median5 median10 median25 median50 median75 median90 median95
median97_5 6.2;
label median2_5= "2.5 pctl" median5= "5 pctl" median10= "10 pctl" median25= "25 pctl"
median50= "50 pctl" median75= "75 pctl" median90= "90 pctl" median95= "95 pctl"
median97_5= "97.5 pctl";
run;

title;
%do i = 1 %to %eval(&nar-1);
%let j = %eval(&i+1);
title "R2/R1 = &&AR&j";
Proc SGPanel data = Summary1;
where AR2 = &&AR&j;
PANELBY ICC /columns=&nicc;
VBOX Ratio1_Median/group = NTrial;
refline 1/lineattrs =(pattern = 2) ;
run;
%end;
ods rtf close;
%Mend;

%Simulation1(NSim=1000, GM=1, CV=1, ListICC= 0.5 0.7 0.9,
ListAR= 1 2 4,
ntrial= 10 20 30 50 100 200 500 1000 1500 ,
seed=25451);

```

APPENDIX 3

Linear Mixed Effects Model Analysis – A Statistical Method to Evaluate the Proportionality Principle: Residues vs. Application Rate

[Prepared by US EPA, Office of Pesticide Programs, 20 November 2012]

Contents

Introduction

Rational of fundamental statistical model for Proportionality principle

Statistical Methods

Results

Conclusions

Table 1: structure of the data in the analysis

Table 2: summary results of analyses

Table 3: Dip Commodity

Table 4: Direct Commodity

Table 5: Post harvest

Table 6: Seed Treatment

Table 7: Soil

Table 8: Foliar – Crop = Rice

Table 9: Foliar – Crop = Maize

Table 10a: Foliar – Crops with 10 < number of trials < 50

Table 10b: Foliar – Crops with 10 < number of trials < 50 for
trials with same spray volume

Table 11a: Foliar – Crops with number of trials < 10

Table 11b: Foliar – Crops with number of trials < 10 for
trials with same spray volume

Table 12: Foliar – trials with different spray volume

Table 13: Frequency of trials by Formulation Type:

Table 14: Frequency of trials by Country

Table 15: Frequency of trials by Active Ingredient

Table 16: Frequency of trials by crop

Introduction

Maximum residue limits (MRLs) of pesticide residue in food commodity are needed to regulate pesticide use and are calculated using residue data collected from supervised field trials using good agricultural practice (GAP). In order to generate robust MRLs, it is always preferable to have residue data from a larger rather than a smaller number of field trials. A larger number of field trials produce more reliable MRLs that more nearly – and reliably – approximate the high end of the residue distribution. In order to obtain a large number of field trials for use in estimating tolerances, current practice under certain conditions permits using residues from field trials which are $\pm 25\%$ of the target application rate. The residues from the $\pm 25\%$ field trials, however, are not necessarily routinely adjusted upward or downward for the exaggerated application rate, and this necessarily leads to a biased estimate of the MRL. Allowing such deviating application rates without adjustment of the resulting residues typically relies on the fact that actual field practices may have this much uncertainty in the rate.

The desire to appropriately incorporate residues from a wider range of application rates (more than $\pm 25\%$) in field trials into the MRLs calculation has led to a proposal of the proportionality principle which states that, within limits, residues resulting from field trials conducted at exaggerated rates can be adjusted proportionally to the a 1x application. This proposal has led to the need to evaluate the proportionality principle in order for it to see wider, more acceptable use.

MacLachlan and Hamilton (2011) were one of the first groups to investigate the proportionality concept by regressing $\ln(C_2) = a + b \times \ln(C_1)$, where (C_1, C_2) are residues from side-by-side field trials at application rates (R_1, R_2) and $R_2 > R_1$. For their test case, they used the side-by-side residue trial data reported by the Joint FAO/WHO Meeting on Pesticide Residues (JMPR). In order the proportionality concept to be valid as applied here, the slope b must be equal 1 and the intercept a must be equal to $\ln(R_2/R_1)$. MacLachlan and Hamilton also looked into the ratios $(C_2/C_1)/(R_2/R_1)$ which – if the proportionality is valid – would be equal to 1. Stewart and LaPorte later followed MacLachlan and Hamilton's approach using additional side-by-side crop residue data provided by the Chinese and Japanese governments as well as data provided by BASF, Bayer CropScience, Dow AgroSciences, DuPont, and Syngenta to evaluate the concept of proportionality (*Relationship between Application Rate of Pesticides and Their Residue Levels in Treated Commodities: Further Investigation of the Proportionality Principle*, 2012).

The approach used by MacLachlan and Hamilton and later followed by Stewart and LaPorte has been reviewed and received a number of comments. One specific comment is that the authors have not provided any formal statistical testing of the intercept and slope (i.e., the confidence interval for the estimates of intercept a and slope b); and repeated measures (resulting from multiple application rates) were not addressed, etc. These comments are also applicable to their investigation into the $(C_2/C_1)/(R_2/R_1)$ ratio.

While there is nothing intrinsically incorrect in the approach proposed by MacLachlan and Hamilton and later followed by Stewart and LaPorte, criticism centered around the inability of the method to produce confidence intervals around their ratio estimates. Recognizing the issue, US EPA/OPP perform what we believed to be a more appropriate statistical analysis, using the same data that Stewart-LaPorte had used in their analysis to examine proportionality. This is presented below. The current analysis will be able to incorporate residues of all application rates and all replicates into a single analysis while correctly and appropriately handling the correlation between these data. Furthermore, we believe that it will be easy to evaluate the proportionality concept by examining only one single statistic, slope b (described in next section) and its confidence interval and not require the simultaneous evaluation of a slope and an intercept as in the MacLachlan and Hamilton approach used by Stewart and LaPorte.

Rationale of fundamental statistical model for proportionality principle

Assume residue of a crop follows a lognormal distribution. Let y be the residue of a trial with application rate x . Below is the linear regression equation of $\ln(y)$ vs. $\ln(x)$:

$$\ln(y) = a + b * \ln(x), \quad (1)$$

where a is the intercept and b is the slope. Exponentiate both sides of equation (1), we have:

$$\begin{aligned} e^{\ln(y)} &= e^{a+b*\ln(x)} \\ y &= e^a e^{b*\ln(x)} \\ y &= e^a * x^b \end{aligned} \quad (2)$$

If $b = 1$, equation (2) becomes:

$$y = e^a * x \quad (3)$$

From equation (3), we see that y has a proportional relationship with x .

Therefore, a proportionality relationship between residues vs. application rate is true if the slope “ b ” = 1 in equation (1), and it does not depend on the intercept “ a ” since that is a constant.

An analysis showing slope b in equation (1) is not different from one will lead to a conclusion that the proportionality concept is valid.

Statistical Methods

To examine the relationship between residues and application rate, we only used residue data from side-by-side field trials. The residue data consisted of multiple crops, and each crop might have multiple trials from different countries. Each trial had residues resulting from different application rates, and might have residues at different PHIs as well as multiple replicates (multiple samples from the same trial at the same application rate and PHI). Since different pesticides, different application types, different formulation types, different crops, different trials may have used different application rates, we normalized the application rates of each trials by dividing the application rates (within each trials) by the lowest application rate of the trial. There were many different active ingredients (pesticides), different formulations, and different application types (seed treatment, soil, foliar, etc.) included in the data.

By the nature of random effects, different trials might have different intercepts a and different slopes b . Furthermore, residues from the same trial are likely correlated. Recognizing these characteristics, it is appropriate to use mixed-effects models to examine the relationship as in equation (1) between residues and application rate. The mixed-effects models allow each trial to have its own intercept and slope and correctly take into account the correlation of the data³. The type of pesticide formulation was included into the models as a covariate. Country, Crop, Active Ingredient (AI), and Trial were categorized as a set of

³ Given the short time available for the analysis, the model that assumes all trials have different intercepts but the same common slope has not been examined. However, the use of a common slope model (which might be suggested if a likelihood ratio test showed no statistically improvement over using a random slope model) does not mean that all trials have the same slope. Regardless of whether the common slope model and random slope model are statistically different, the estimated common slope and the estimated average slope are theoretically equivalent (only the confidence interval of estimated common slope is narrower than that of estimated average slope, which is already narrow due to large number of trials in the analysis).

random effects. Residues at different application rates of the same trial and replicates (residues of the same trial, same application rate, and same PHI) were considered as repeated measures (longitudinal data).

Since we focus on the relationship between residues vs. application rate at the same PHI of side-by-side trials (i.e., the importance of relationship “*residue vs. application rate*” at each PHI for trial with multiple PHIs is the same as for the PHI of trials with single PHI), we treated each PHI from trials with multiple PHIs as a different trial with single PHI⁴.

Data handling

To reduce the number of categories of application types that had only small number of records, additional regrouping was done as following:

- Dip Commodity
- Directed Commodity (a directed post-harvest application)
- Seed treatment (including: seed treatment, seed treatment commodity, and seed treatment dry)
- Post harvest (including: foliar and post harvest, post harvest, and post harvest dip)
- Soil (including: soil, broadcast soil, soil (1st):foliar, and soil/foliar)
- Foliar (including: foliar, broadcast foliar, and foliar (post-emergence))

Results

Separate analyses were done for the data of each application type: dip commodity (6 trials), directed commodity (19 trials), postharvest (17 trials), seed treatment (36 trials), soil application (97 trials), and foliar application (751 trials) which included rice (161 trials), maize (56 trials). Based on the distribution of number of trials (i.e., records) per crop, 7 separate analyses were performed for foliar application as follow: 1) rice crop; 2) maize crop; 3) all crops that had more than 10 trials (excluding rice and maize); 4) all crops that had more than 10 trials that used the same spray volume within each trial; 5) all crops that had less than 10 trials; 6) all crops that had less than 10 trials that had same spray volume within each trial; and 7) all foliar trials that used different spray volumes within each trial. The reason behind three of the analyses – 4), 6), and 7) – was that about 11% of the foliar trials used different spray volumes (as opposed on different spray concentrations) to achieve different application rates. These three additional analyses would allow us to examine whether the multiple-spray-volume practice altered the “*residue vs. rate*” relationship (e.g., through foliar run-off)

- Table 1 presents the data structure that was used in the analyses.
- Table 2 summarizes the results of slope analyses of different application types.

⁴ One may let the PHIs nest into the trial; however, by doing that, the importance of “*residue vs. rate*” relationship at each PHI from multiple-PHI trials is less than the relationship at the PHI of single PHI trials, which is not what was wanted. Furthermore, by treating PHIs as different trials, we could reduce one nesting level in the model and avoid computational difficulties and to allow us to check whether the relationship held at different PHIs.

- Tables 3 – 9, 10a, 10b, 11a, 11b, and 12 present the results of individual analysis by application type.
- Tables 13 – 16 present the frequency of trials by formulation type, country, AI, and crops.

As shown in Table 2, only rice and maize, which were the two major crops in the foliar application trials, had slopes that were not significantly different from 1. The slope for rice was 0.98 (95% CI = 0.89, 1.07); and the slope for maize was 0.80 (95% CI = 0.59, 1.01). Slopes of 1 indicate proportionality: that is, an increase of a given percentage in the application rates results in that same percentage increase in the residue levels (e.g., doubling the application rate would double the residue).

The estimated slopes of other application types and crops (various combinations of crops) were significantly less than 1 (i.e. 95% CIs did not include 1) (see Table 2). For example, the slopes for “dip commodity” (n=6), directed commodity (n=19), postharvest treatment (n=17), and seed treatment (n=36) applications ranged from between 0.6 and 0.8. In other words, if there were a 100% increase in the application rates for these applications (a doubling), it would result only about 50% to 75% increase in the residue (percent increase = $2^b - 1$). On the other hand, the estimated slope for soil application was 0.88 and for foliar application (excluding rice and maize) were between 0.8 and 0.88. This means a 100% increase (i.e., doubling) in the application rate for soil application would result in an increase in the residue of 84% and for foliar treatment (excluding rice and maize) somewhere between 74% and 84%.

In addition to presenting the slopes, Table 2 also presents the impact of applying the proportionality principle to a 1.25x rate, by contrasting this with the residues that would be assumed with no adjustment (current practice) to the residues. By applying the proportionality principle to adjust the residues from 1.25X to 1X for foliar application, the estimated residues are generally under-estimated by less than 5% (i.e., percent over/under estimated = $\frac{x^b - x}{x}$, where x is the factor of application rate). However, without any adjustment, the residues at 1.25X are generally 20-25% higher than the residues at 1X for foliar application. Similarly, the resulted residues are over-estimated by less than 5% if using proportionality principle to convert residues at 0.75X to 1X for foliar application. Without adjustment, the residues at 0.75X are generally about 20-25% less than residues at 1X (not shown in Table 2).

In some case, the exaggerated application rate was achieved by applying a greater volume of liquid, for example, as opposed to the same volume with a higher concentration. To the extent that the extra volume may run-off or otherwise be unavailable to the plant, this may affect the determination of proportionality. Thus, we also investigated the effect of whether spraying a different volume to achieve different application rates (as opposed to the same volume with a higher concentration) would alter the relationship the residue vs. application rate. The analyses were conducted on those trials that modified application amounts by modifying either the volume or concentration vs. those conducted which modified the amount of pesticide applied by only changing the concentration generally produced similar slopes (0.8 vs. 0.8 for crops that had less than 10 trials; and 0.87 vs. 0.88 for crops with more than 50 trials). The estimated slope of trials with different spray volume = 0.82 was in line with that of analysis including all trials. Thus, we conclude that the changing the amount of pesticide applied by either modifying the concentration or modifying the spray volume was not, in these trials, a significant factor.

The analysis here chiefly uses slopes to evaluate the validity of the proportionality assumption, with a slope of 1 indicating that residues scale proportionately to application rate. The paper by MacLachlan and Hamilton (Pest Manag Sci 2011; 67:609-615) – and by extension the work by Stewart and Laporte – use a ratio (or, better described, a ratio of ratios) to describe this relationship, with a ratio of 1 (and an intercept equal to the log of the ration of application rates) indicating proportionality. One can convert the slopes that we estimated in Table 2 into ratios $\frac{C_2/C_1}{R_2/R_1}$ that can be compared to the Stewart/Laporte analyses by

using the following formula $\frac{C_2/C_1}{R_2/R_1} = \frac{(R_2/R_1)^b}{R_2/R_1}$. As we can see, $\frac{C_2/C_1}{R_2/R_1}$ is a function of R_2/R_1 , and it is not a constant when $b \neq 1$. In Table 2, we calculated the estimated ratio $\frac{C_2/C_1}{R_2/R_1}$ for $R_2/R_1 = 1.5$ and 2. Since majority of data in Stewart-Laporte analysis had a ratio $R_2/R_1=2$, the estimated ratios computed from slope of mixed-effects models for a ratio $R_2/R_1=2$ compare well with the ratios that calculated by Stewart-LaPorte. For example, the ratios computed from slope vs. Stewart-LaPorte ratios are 0.92 vs. 0.90 for soil treatment; 0.87 vs. 0.83 for seed treatment; and 0.80 vs. 0.80 for post-harvest, and 0.87 to 0.99 vs. 0.93 for foliar. The similarity of these results is encouraging, and suggests that the two methods – the hierarchical (multilevel) mixed model used here and the ratio method used by Stewart/Laporte from the work of MacLachlan and Hamilton produce similar conclusions with respect to the relationship between application rate and resulting residues. Specifically: that while strict proportionality which would be demonstrated by a ratio of 1 is ruled, out, the observed values for the soil and foliar application methods are reasonable close to 1 suggesting that there is reasonable near to a proportionate relationship between application rate and resulting residues. For other application types the deviations from strict proportionality were larger. Regression diagnostics were performed to detect any systematic difference in the relationship between residue and application rate among the formulation types. There was no clear evidence indicating that any of available formulation types would have the relationship different from others. We do not here present the resulting tables from the diagnostics given a short time frame for this work, but it appears that formulation type is not a factor that affects proportionality. We have not checked whether any systematic differences were caused by different PHIs.

Conclusion

Our analysis found a significant relationship between the *residue vs. application rate*. As the application rate increases, the resulting residue increases. Foliar applications to rice had an exact linear proportional relationship between *application rate and residue* (100% increases in application rate would increase 100% in residue), while other crops with foliar application still had a very significant relationship with slopes between 0.8 and 0.88 (the estimated residues from 2X to 1X are under-estimated about 10% if using the proportionality principle). Similarly, soil applications and seed treatments also had a A slope of 0.88 and 0.79, respectively. This linear effects model analysis confirms the bias noted in the simulations (appendix 2) and in the second review of residue data.

There appears to be less evidence for a proportionate relationship between *application rate and residue* for other application types. Although the numbers of trials was comparatively smaller and thus estimates are less precise, a 100% increase in application rate would result in 60% to 80% increase in the residue for dip commodity, directed commodity, and post-harvest applications.

While the slope is not exactly 1, it is reasonable close to 1. Our calculations suggest that by assuming proportionality when it is not precisely true will result in many cases in only minor over-or under-estimations of residues which are typically less than the maximal errors introduced by using the $\pm 25\%$ rule for combining field trials. We suggest that the closeness of the factor to 1 suggests further investigation for its potential utility (best use) in adjusting residues from higher to lower (or vice versa) application rates than the proposed range and its wider adoption for uses currently excluded.

Finally, we note that the estimated ratios calculated from the slope derived from our mixed-model analysis closely agrees with the ratios calculated from the raw data (by Stewart-LaPorte).

Table 1: structure of the data in the analysis

Data structure	Quantity
Row	5355
Trial	926
Crop	92
Active Ingredient	80
Formulation Type	14
Application Type	6
Country	36
PHIs per trial	1 to 7
Replicates per PHI	1 to 4

Table 2: summary results of analyses

Application Type	# Rows	# Trials	Slope (95% CI)	$\frac{C_2/C_1}{R_2/R_1}$ (95% CI)		Stewart - LaPorte $\frac{C_2/C_1}{R_2/R_1}$	% under/over estimated residue (*) using slope = 1		
				$R_2/R_1 = 1.5$	$R_2/R_1 = 2$		$R_2/R_1 = 1.25$ (**) adjusted vs. non- adjusted	$R_2/R_1 = 0.5$ (***)	$R_2/R_1 = 2$ (***)
DIP COMMODITY	66	6	0.63 (0.41, 0.86)	0.86 (0.79, 0.94)	0.77 (0.66, 0.91)	NA	-7.9% vs. 15.1%	29.2%	-22.6%
DIRECTED COMMODITY	223	19	0.73 (0.59, 0.87)	0.90 (0.85, 0.95)	0.83 (0.75, 0.92)	NA	-5.8% vs. 17.7%	20.6%	-17.1%
POSTHARVEST	105	17	0.67 (0.47, 0.88)	0.88 (0.81, 0.95)	0.80 (0.69, 0.92)	0.80	-7.1% vs. 16.1%	25.7	-20.4%
SEED TREATMENT	283	36	0.79 (0.66, 0.93)	0.92 (0.87, 0.97)	0.87 (0.79, 0.95)	0.83	-4.6% vs. 19.3%	15.7%	-13.5%
SOIL TREATMENT	618	97	0.88 (0.78, 0.98)	0.95 (0.92, 0.99)	0.92 (0.86, 0.99)	0.90	-2.6% vs. 21%	8.7%	-8%
FOLIAR	4060	751				0.93			
Rice	1286	161	0.98 (0.89, 1.07)	0.99 (0.96, 1.03)	0.99 (0.92, 1.05)		-0.4% vs. 24.4%	1.4%	-1.4%
Maize	360	56	0.80 (0.59, 1.01)	0.92 (0.85, 1.00)	0.87 (0.75, 1.00)		-4.4% vs. 19.5%	14.9%	-12.9%
Crops, 10 < # trials < 50	1307	371	0.80 (0.73, 0.86)	0.92 (0.90, 0.94)	0.87 (0.83, 0.91)		-4.4% vs. 19.5%	14.9%	-12.9%
Crops, 10 < # trials < 50 (same spray volume)			0.80 (0.73, 0.87)	0.92 (0.90, 0.95)	0.87 (0.83, 0.91)		-4.4% vs. 19.5%	14.9%	-12.9%
Crops, # trials ≤ 10	1107	163	0.87 (0.80, 0.93)	0.95 (0.92, 0.97)	0.91 (0.87, 0.95)		-2.9% vs. 21.4%	9.4%	-8.6%
Crops, # trials ≤ 10 (same spray volume)			0.88 (0.81, 0.94)	0.95 (0.93, 0.98)	0.92 (0.88, 0.96)		-2.6% vs. 21.7%	8.7%	-8.0%
Multi Spray Volume	497	82	0.82 (0.70, 0.94)	0.93 (0.88, 0.98)	0.88 (0.81, 0.96)		-3.9% vs. 20.1%	13.3%	-11.7%

Total	5355	926							
-------	------	-----	--	--	--	--	--	--	--

(*): % under/over estimated using slope=1 is $\frac{x^b-x}{x}$.

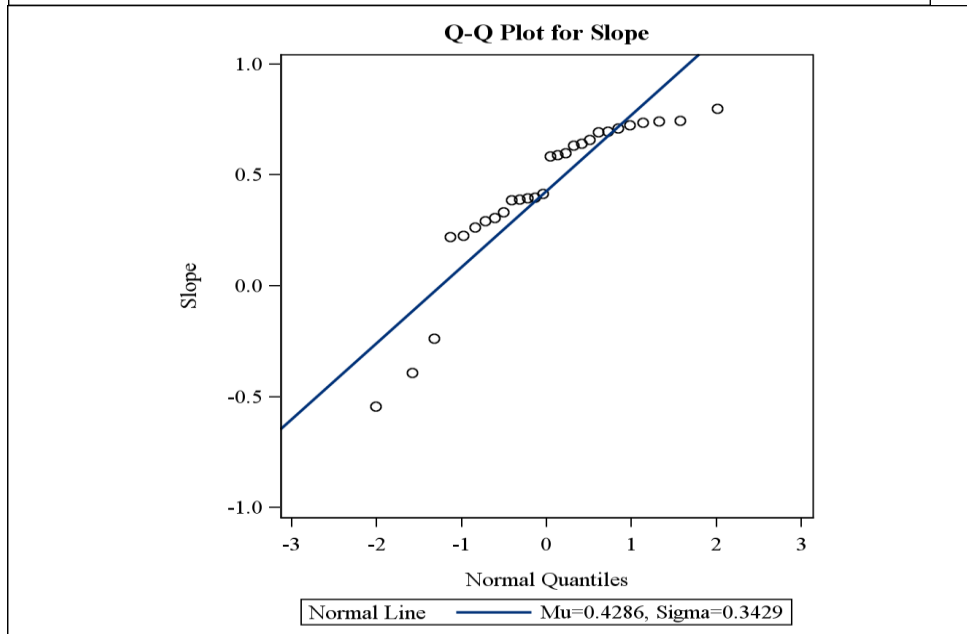
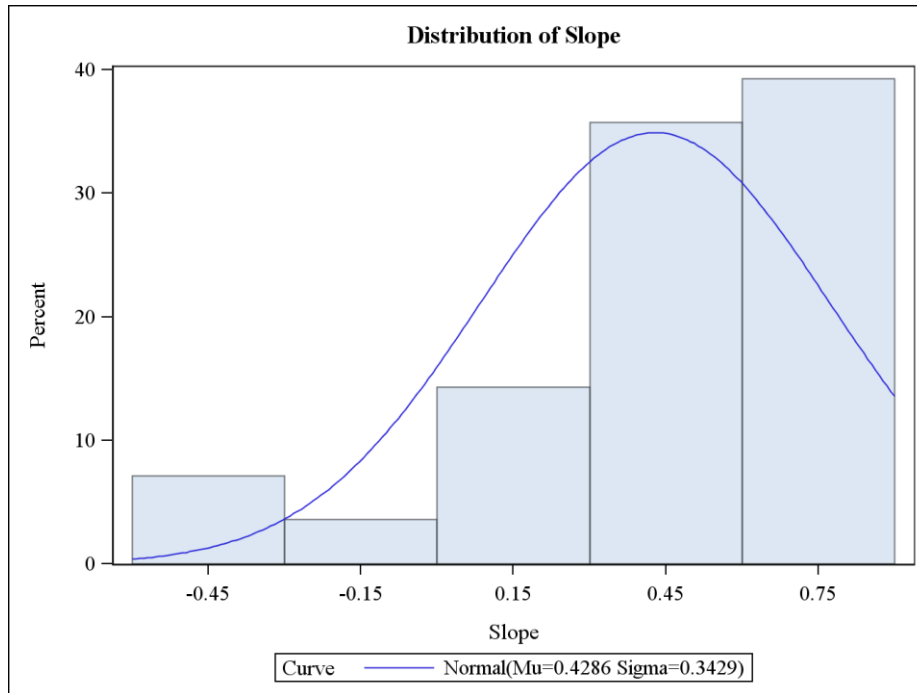
(**): The percent on the left is the percent of under/over-estimated in the residue if proportionality principle is used. The percent on the right is the percent of over/under valued if no adjustment has been made to the residue when lumping a residue at 1.25X back to 1X.

(***): percent of over/under-estimated in the residues when using proportionality principle to adjust residues at 0.5X or 2X to the application rate 1X.

1. Dip Commodity

Table 3: Slope analysis for crops with application type = dip commodity

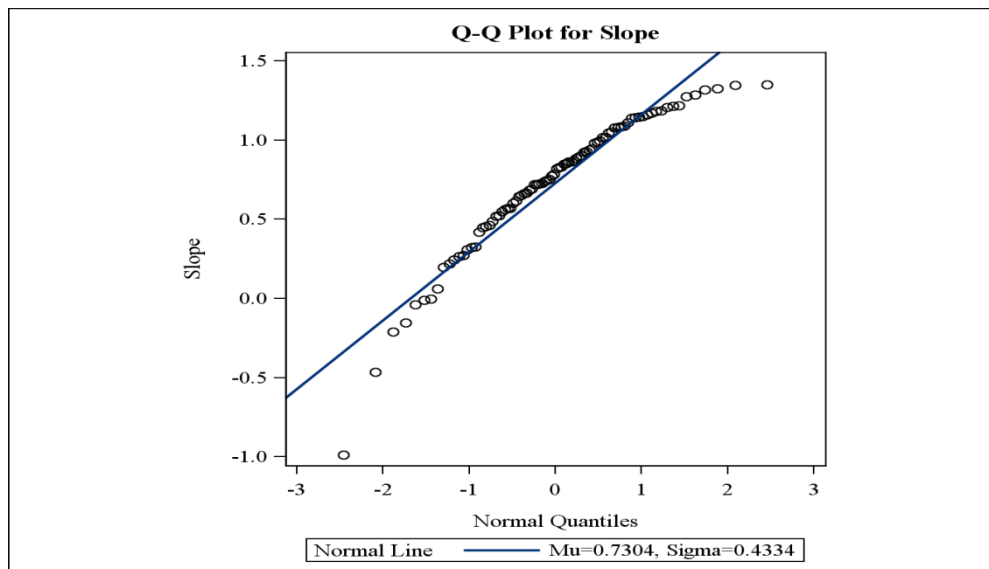
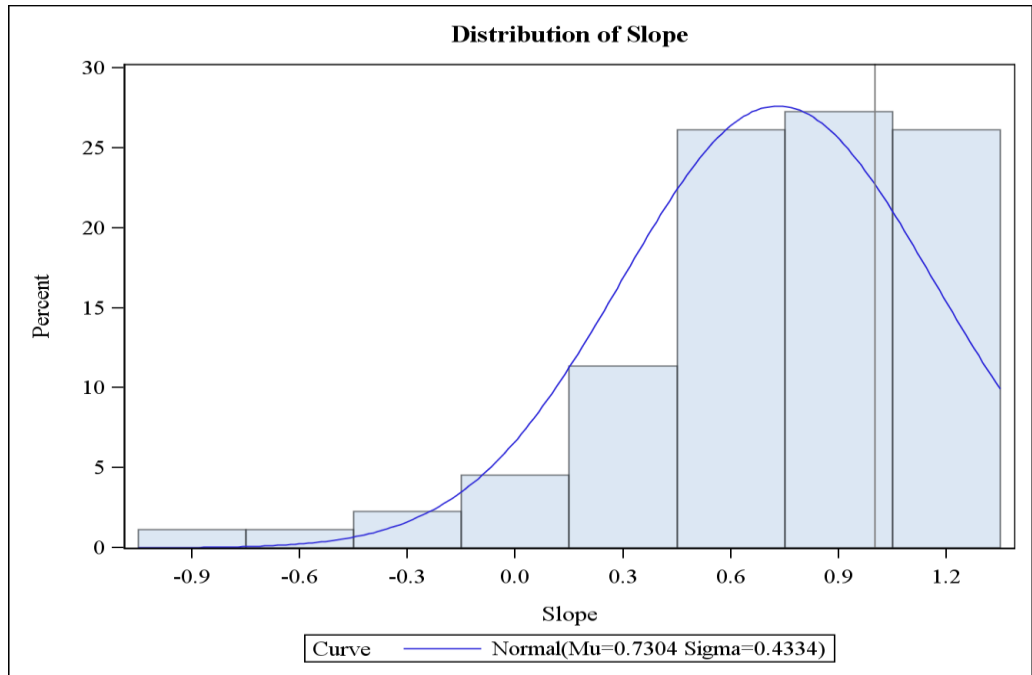
Solution for Fixed Effects					
Effect	Estimate	Standard Error	Pr > t	Lower	Upper
log(rate)	0.6317	0.1095	<.0001	0.4070	0.8565



2. Directed Commodity

Table 4: Slope analysis for crops with application type = directed commodity

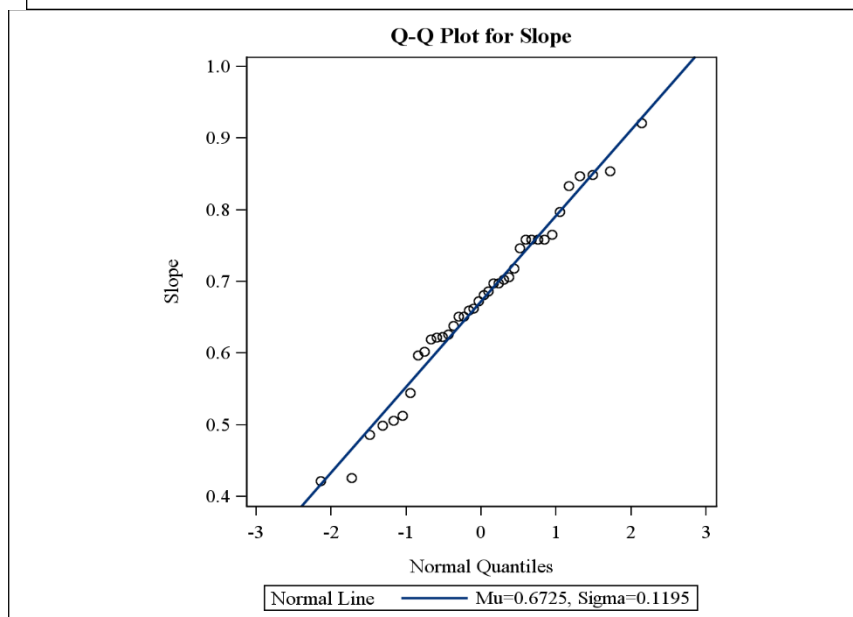
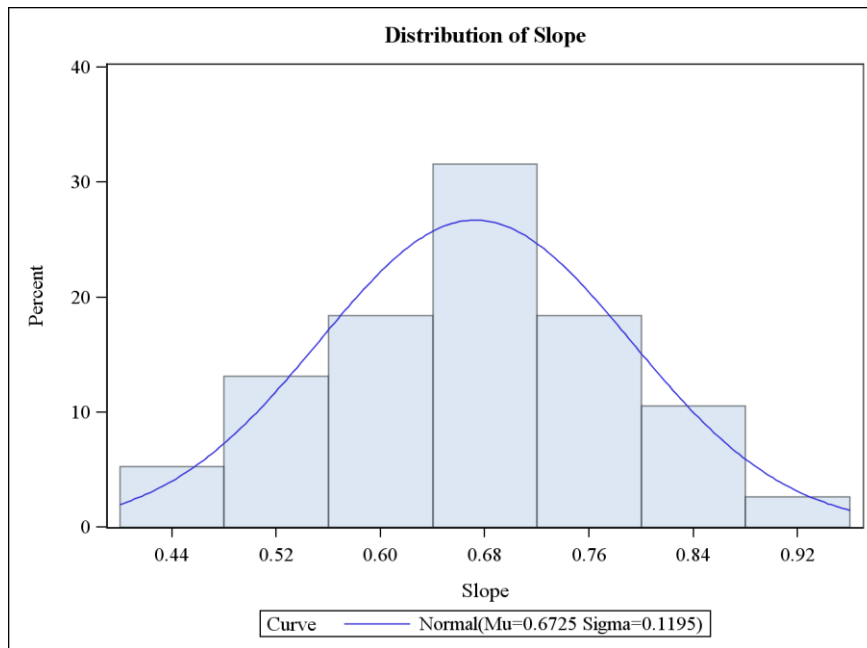
Solution for Fixed Effects						
Effect	Formulation	Estimate	Standard Error	Pr > t	Lower	Upper
Formulation Type	EC	-2.1880	0.2918	<.0001	-2.7751	-1.6009
	WP	-1.3688	0.6441	0.0389	-2.6645	-0.0731
log(rate)		0.7304	0.07149	<.0001	0.5883	0.8725



3. Post Harvest

Table 5: Slope analysis for crops with application type = postharvest

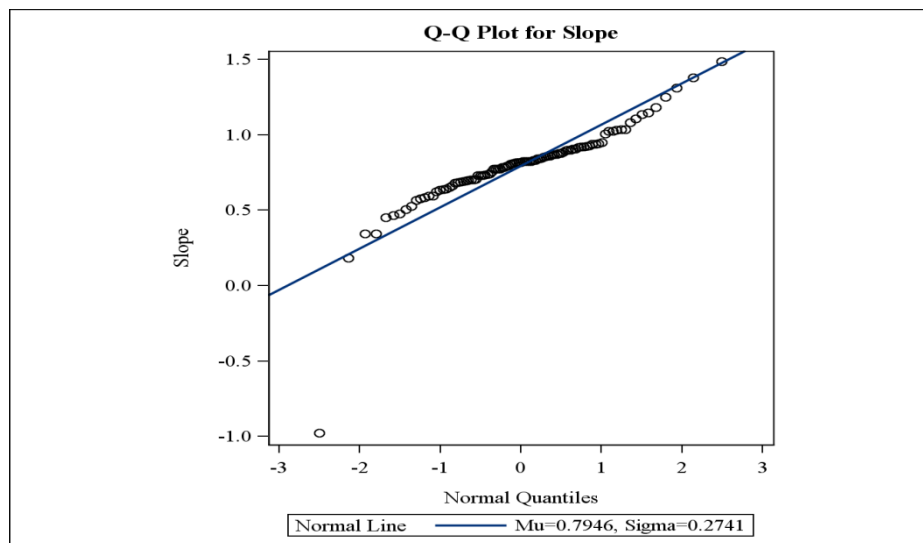
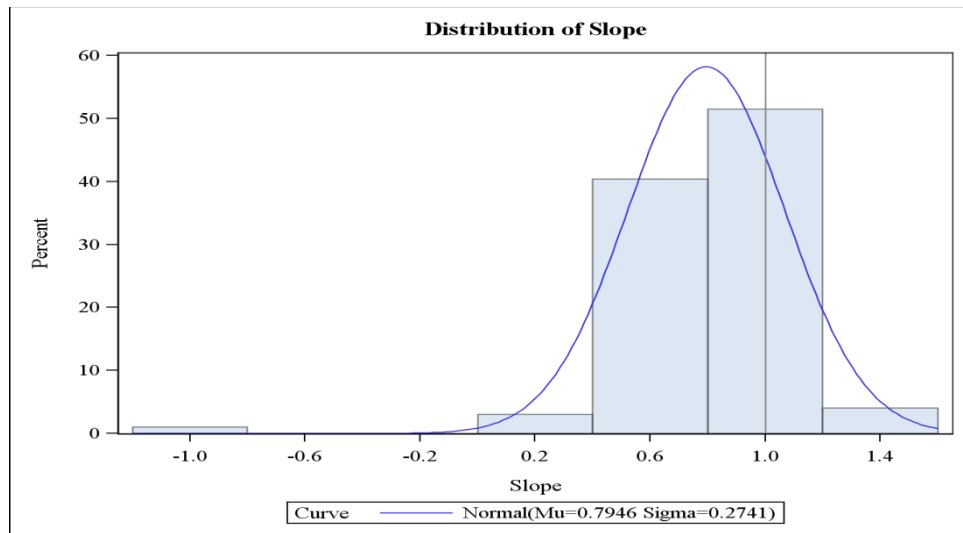
Solution for Fixed Effects						
Effect	Formulation	Estimate	Standard Error	Pr > t	Lower	Upper
Formulation Type	DP	-2.4260	1.3812	0.0896	-5.2510	0.3989
	EC	0.2556	0.2388	0.2934	-0.2328	0.7440
	SC	-2.0381	0.6934	0.0064	-3.4564	-0.6199
log(rate)		0.6725	0.1000	<.0001	0.4698	0.8751



4. Seed Treatment

Table 6: Slope analysis for crops with application type = seed treatment

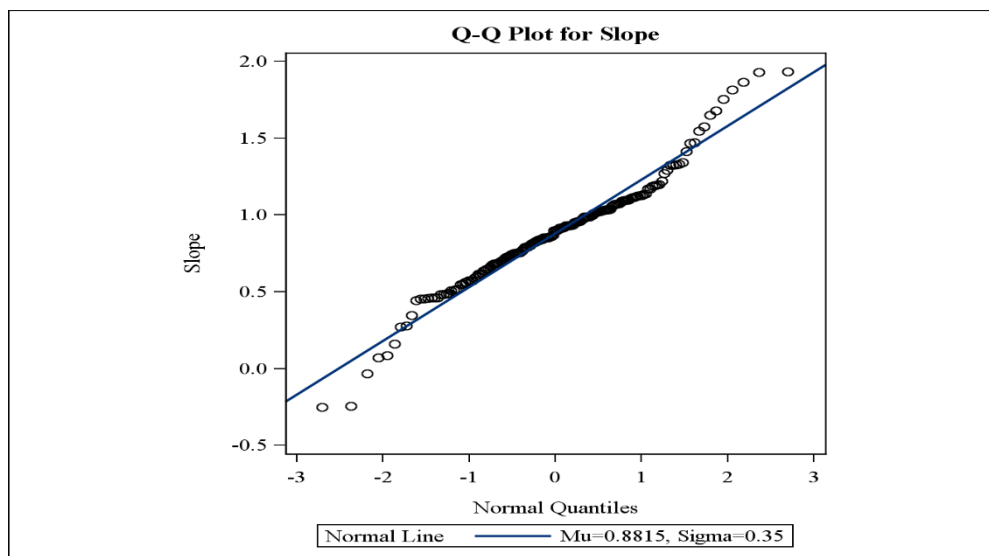
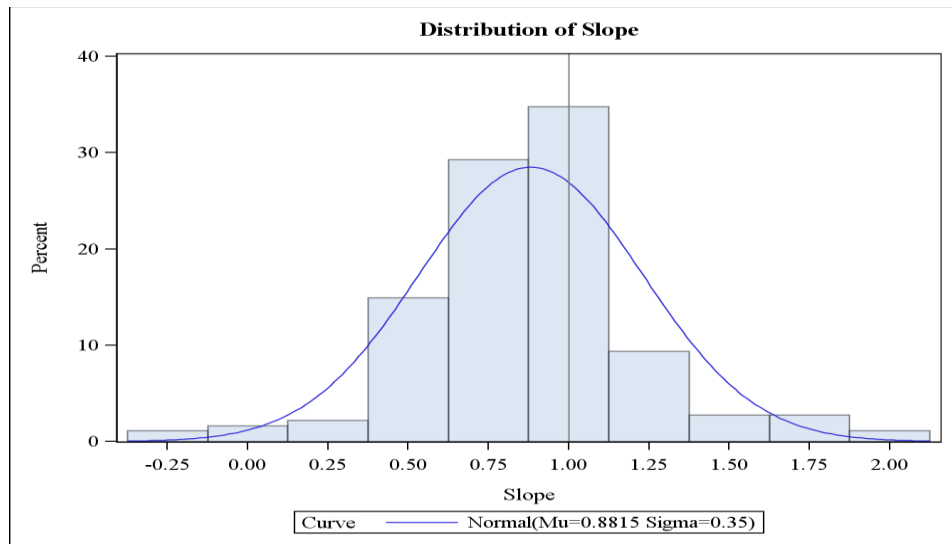
Solution for Fixed Effects						
Effect	Formulation	Estimate	Standard Error	Pr > t	Lower	Upper
Formulation Type	DS	-2.4867	2.1555	0.2519	-6.7723	1.7990
	EC	1.5349	1.6321	0.3496	-1.7101	4.7799
	FS	-1.9071	1.0718	0.0787	-4.0380	0.2239
	SC	-4.1142	1.3922	0.0040	-6.8823	-1.3461
	WP	-2.5199	2.3431	0.2852	-7.1786	2.1389
	WS	-3.2319	1.5762	0.0434	-6.3658	-0.09796
log(rate)		0.7946	0.06937	<.0001	0.6569	0.9323



5. Soil

Table 7: Slope analysis for crops with application type = soil

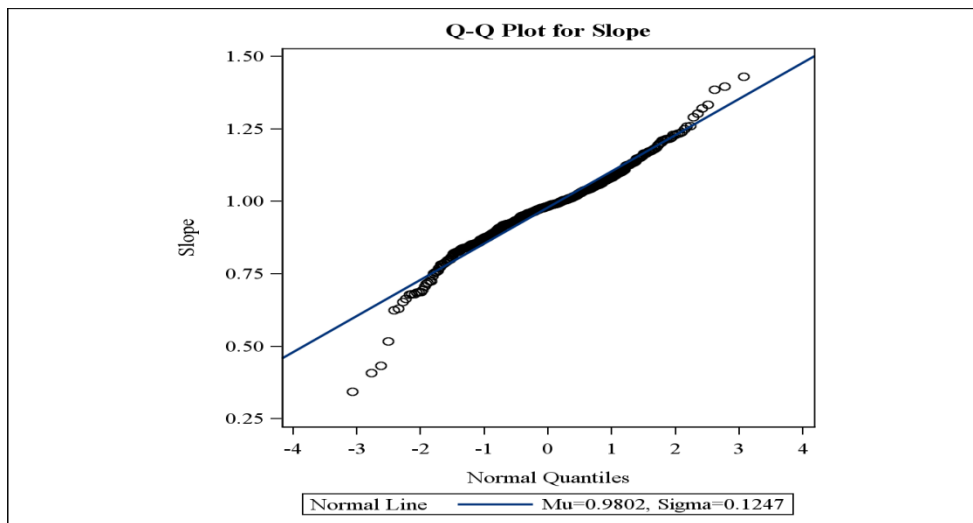
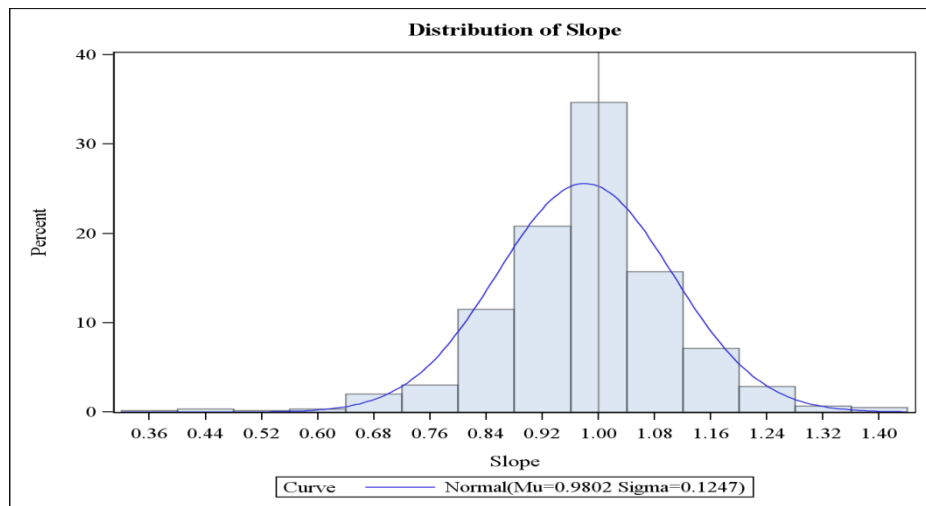
Solution for Fixed Effects						
Effect	Formulation	Estimate	Standard Error	Pr > t	Lower	Upper
Formulation Type	EC	-1.4538	0.9603	0.1313	-3.3450	0.4374
	FS	-0.4864	1.1594	0.6752	-2.7697	1.7968
	SC	0.6001	1.1329	0.5968	-1.6309	2.8310
	SL	-1.0099	0.6925	0.1460	-2.3737	0.3538
	WG	-1.0924	0.8285	0.1885	-2.7240	0.5393
	WP	-1.4846	0.7438	0.0470	-2.9495	-0.0198
log(rate)		0.8815	0.05011	<.0001	0.7827	0.9804



6. Foliar: Crop = Rice

Table 8: Slope analysis for Rice crop with application type = foliar

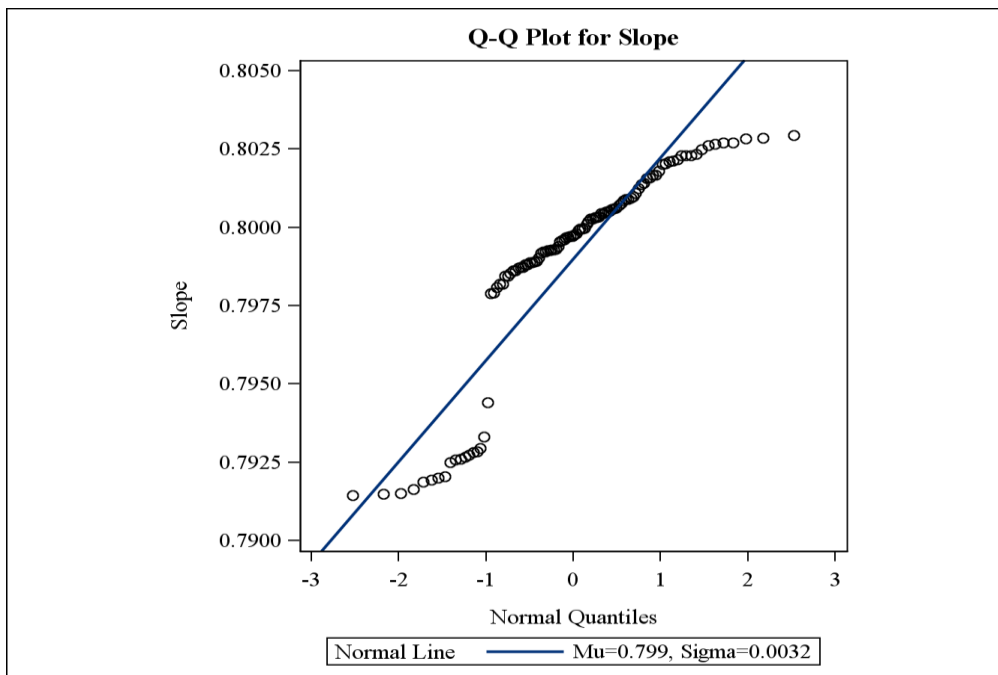
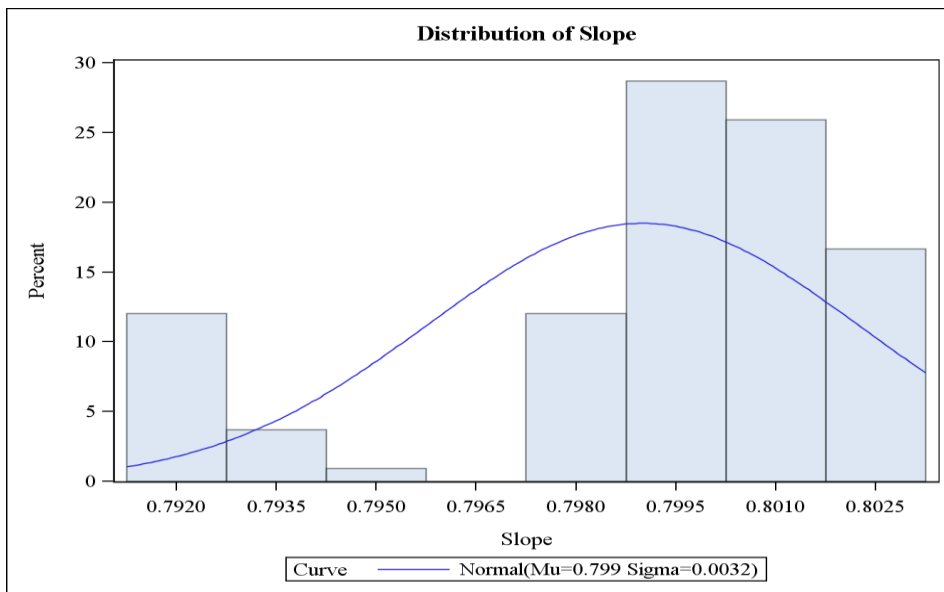
Solution for Fixed Effects						
Effect	Formulation	Estimate	Standard Error	Pr > t	Lower	Upper
Formulation Type	EC	-2.0024	0.5133	0.0002	-3.0204	-0.9844
	EW	-1.5037	0.6855	0.0305	-2.8630	-0.1444
	GR	-2.9458	1.3146	0.0272	-5.5527	-0.3389
	OD	-1.8936	1.0379	0.0710	-3.9517	0.1646
	SC	-2.0488	0.5824	0.0006	-3.2037	-0.8939
	SL	-1.8223	0.8408	0.0325	-3.4897	-0.1550
	WG	-2.7942	0.8614	0.0016	-4.5024	-1.0859
	WP	-1.2738	0.6270	0.0448	-2.5172	-0.03038
log(rate)		0.9802	0.04764	<.0001	0.8867	1.0738



7. Foliar: Crop = Maize

Table 9: Slope analysis for Maize crop with application type = foliar

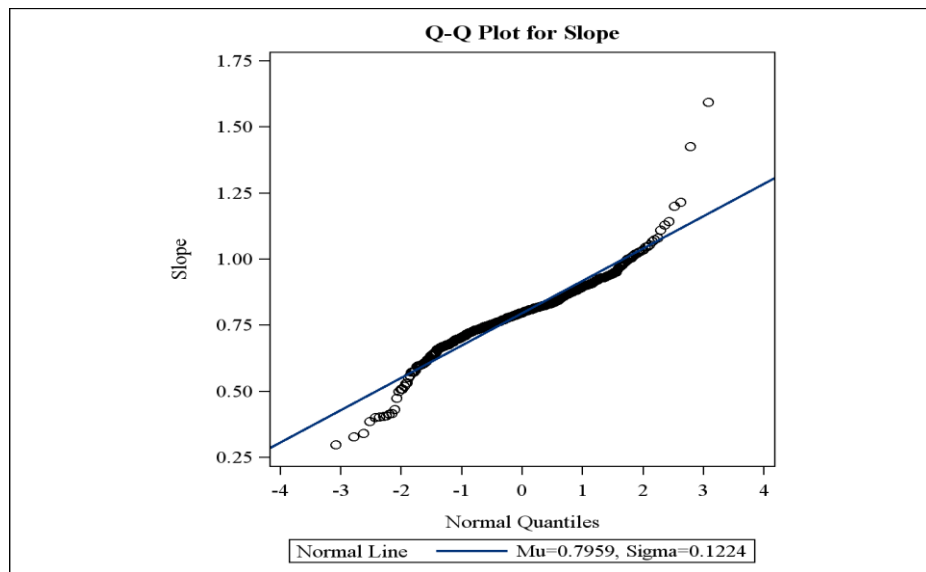
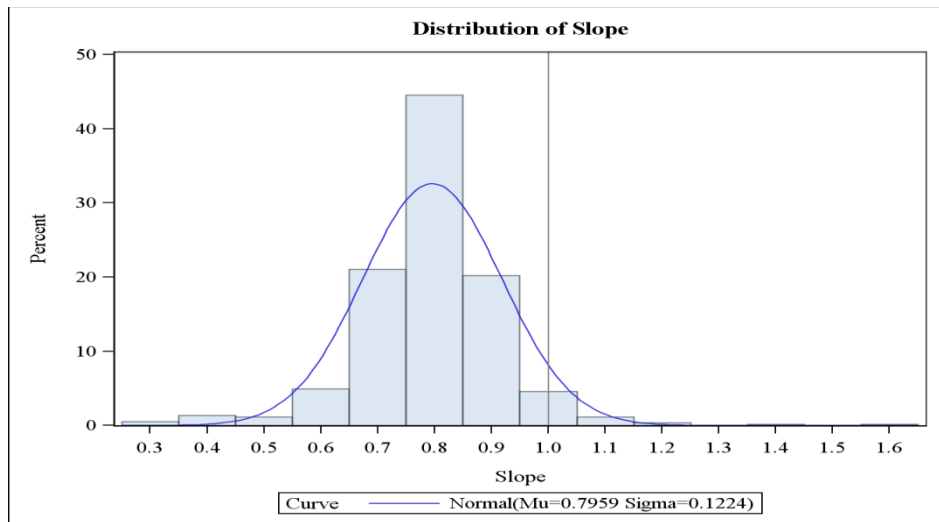
Solution for Fixed Effects						
Effect	Formulation	Estimate	Standard Error	Pr > t	Lower	Upper
Formulation Type	SC	-3.9913	1.0153	0.0001	-5.9980	-1.9845
	SL	-1.0635	0.3127	0.0009	-1.6816	-0.4454
log(rate)		0.7990	0.1049	<.0001	0.5911	1.0069



8. Foliar: crops with number of trials greater than 10 and less than 50

Table 10a: Slope analysis for crops with application type = foliar and had more than 10 trials/crop

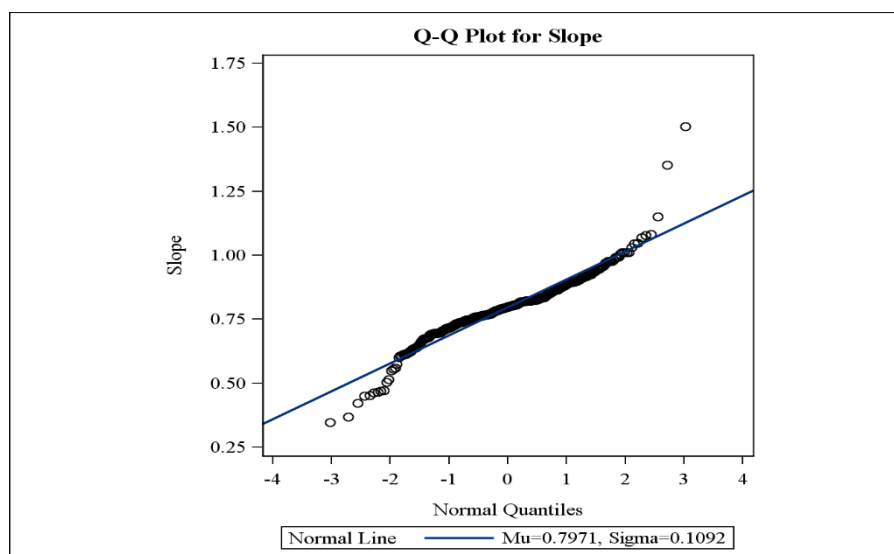
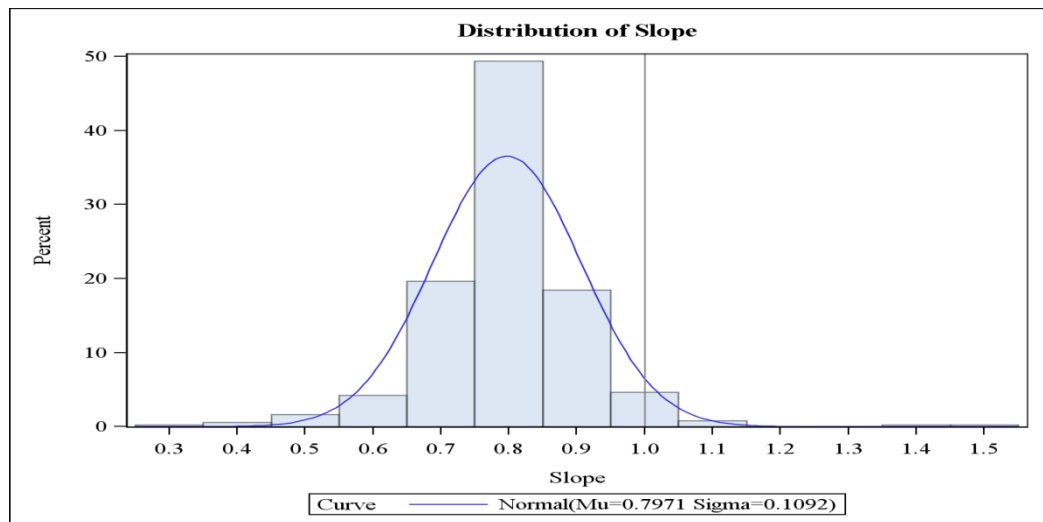
Solution for Fixed Effects						
Effect	Formulation	Estimate	Standard Error	Pr > t	Lower	Upper
Formulation Type	EC	-1.6747	0.3413	<.0001	-2.3527	-0.9966
	EW	-0.9401	0.9226	0.3110	-2.7732	0.8931
	SC	-2.0178	0.3373	<.0001	-2.6880	-1.3476
	SL	-1.8232	0.4068	<.0001	-2.6315	-1.0149
	WG	-2.7703	0.4810	<.0001	-3.7260	-1.8146
	WP	-1.2488	0.3836	0.0016	-2.0111	-0.4865
log(rate)		0.7959	0.03211	<.0001	0.7328	0.8589



9. Foliar: crops with number of trials greater than 10 and less than 50 (same spray volume)

Table 10b: Slope analysis for crops with application type = foliar and had more than 10 trials/crop (same spray volume)

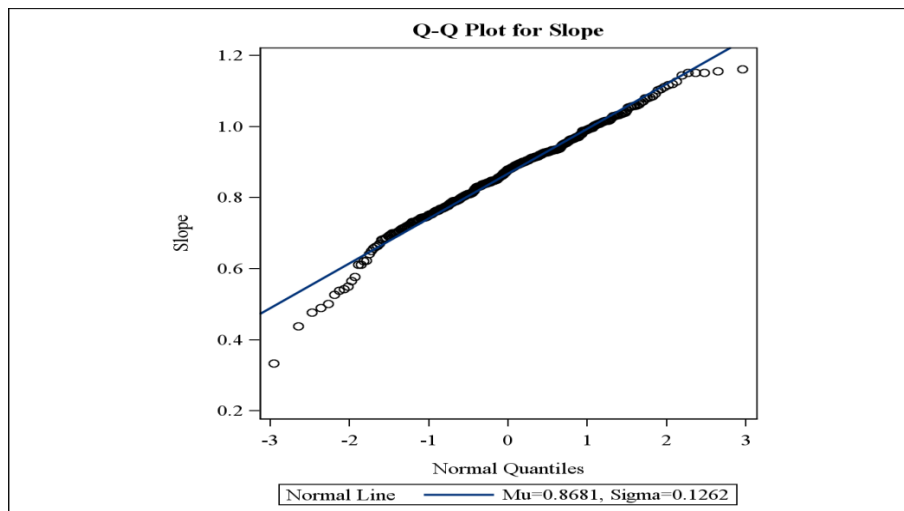
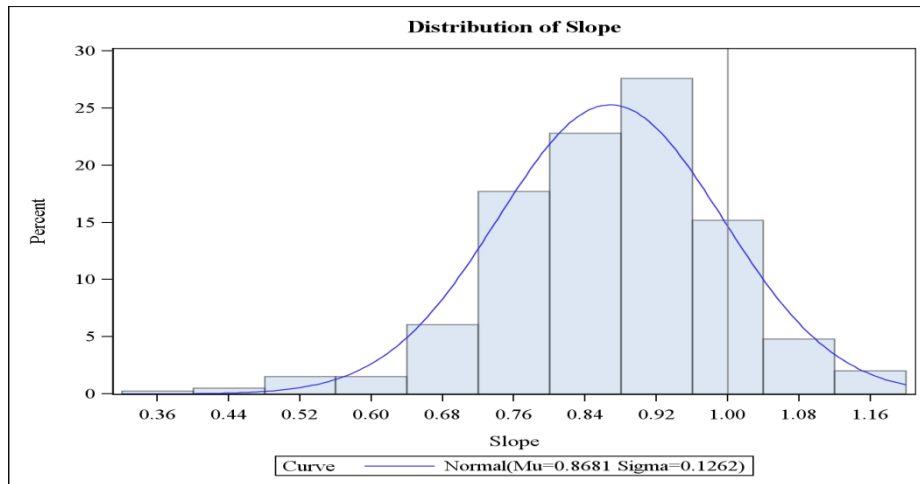
Solution for Fixed Effects						
Effect	Formulation	Estimate	Standard Error	Pr > t	Lower	Upper
Formulation Type	EC	-1.4613	0.4491	0.0016	-2.3544	-0.5681
	EW	-0.7501	0.9443	0.4293	-2.6279	1.1278
	SC	-1.7208	0.4494	0.0002	-2.6144	-0.8271
	SL	-1.6348	0.5039	0.0017	-2.6369	-0.6327
	WG	-2.6059	0.5786	<.0001	-3.7565	-1.4552
	WP	-1.0518	0.4872	0.0337	-2.0206	-0.08288
log(rate)		0.7971	0.03539	<.0001	0.7276	0.8667



10. Foliar: crops with number of trials less than 10

Table 11a: Slope analysis for crops with application type = foliar and had less than 10 trials/crop

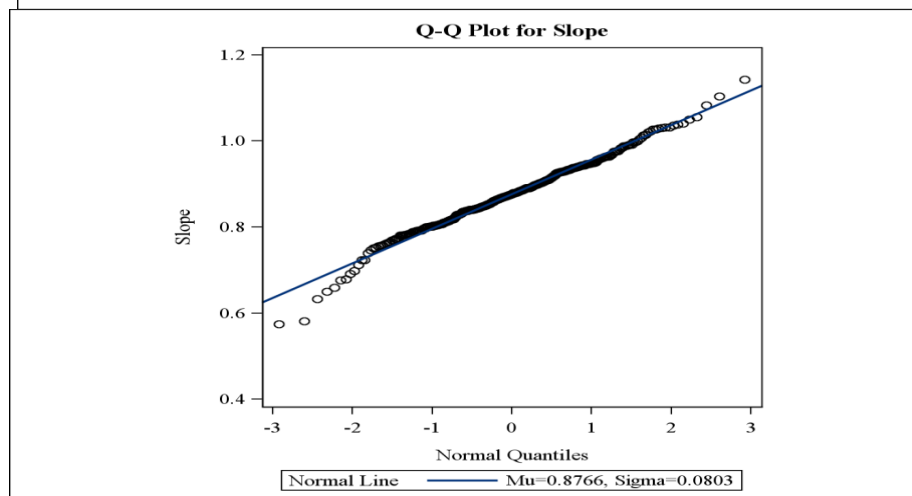
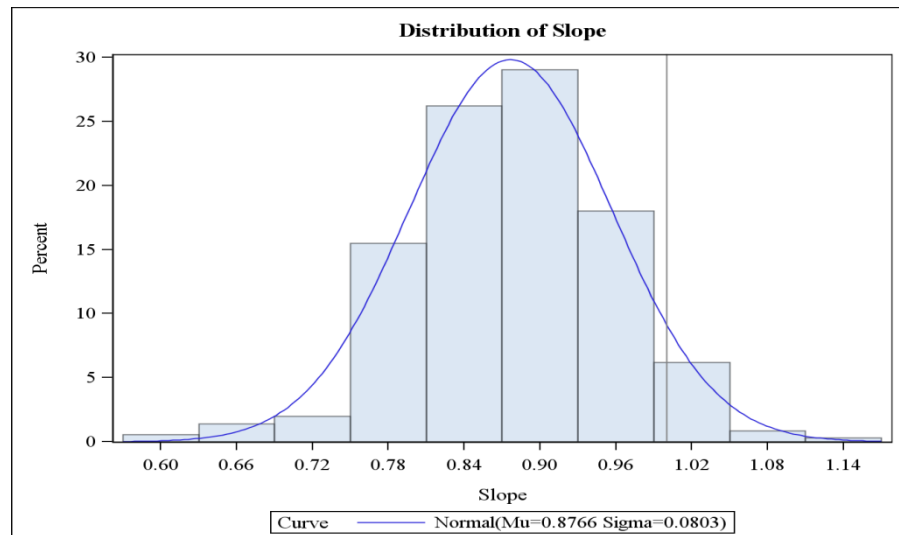
Solution for Fixed Effects						
Effect	Formulation	Estimate	Standard Error	Pr > t	Lower	Upper
Formulation Type	CS	-1.2754	1.2457	0.3067	-3.7264	1.1755
	DP	-3.5681	0.9625	0.0002	-5.4618	-1.6743
	EC	-1.8344	0.4299	<.0001	-2.6802	-0.9885
	GR	-6.9224	1.0695	<.0001	-9.0266	-4.8182
	Liquid	-2.2544	0.8615	0.0093	-3.9493	-0.5595
	SC	-1.6561	0.5436	0.0025	-2.7255	-0.5866
	SL	-2.0550	0.5148	<.0001	-3.0678	-1.0422
	WG	-2.4851	0.7413	0.0009	-3.9436	-1.0266
	WP	-0.5941	0.6089	0.3300	-1.7921	0.6039
log(rate)		0.8681	0.03228	<.0001	0.8047	0.9316



11. Foliar: crops with number of trials less than 10 (same spray volume)

Table 11b: Slope analysis for crops with application type = foliar and had less than 10 trials/crop

Solution for Fixed Effects						
Effect	Formulation	Estimate	Stand. Error	Pr > t	Lower	Upper
Formulation Type	CS	-1.1804	0.8597	0.1711	-2.8747	0.5138
	DP	-3.3765	0.9966	0.0008	-5.3406	-1.4124
	EC	-1.7661	0.4437	<.0001	-2.6406	-0.8916
	GR	-6.8789	1.1159	<.0001	-9.0781	-4.6796
	Liquid	-2.1113	0.8912	0.0187	-3.8676	-0.3550
	SC	-1.4421	0.6005	0.0171	-2.6255	-0.2588
	SL	-1.9253	0.5680	0.0008	-3.0447	-0.8059
	WG	-2.3803	0.7688	0.0022	-3.8955	-0.8651
log(rate)		0.8766	0.03165	<.0001	0.8143	0.9388



12. Foliar – multiple spray volume

Table 12: Slope analysis for crops with application type = foliar and had less than 10 trials/crop

Solution for Fixed Effects						
Effect	Formulation	Estimate	Standard Error	Pr > t	Lower	Upper
Formulation Type	EC	-2.4103	0.5323	<.0001	-3.4628	-1.3578
	OD	-1.5623	0.9245	0.0933	-3.3904	0.2658
	SC	-3.6855	0.5497	<.0001	-4.7726	-2.5984
	SL	-0.8749	0.5225	0.0963	-1.9082	0.1583
	WG	-1.9435	0.7996	0.0164	-3.5246	-0.3623
log(rate)		0.8192	0.06279	<.0001	0.6953	0.9431

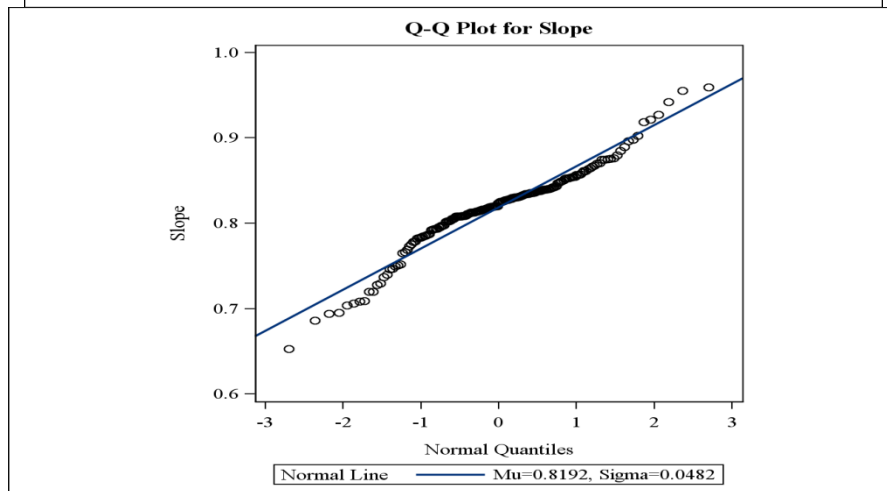
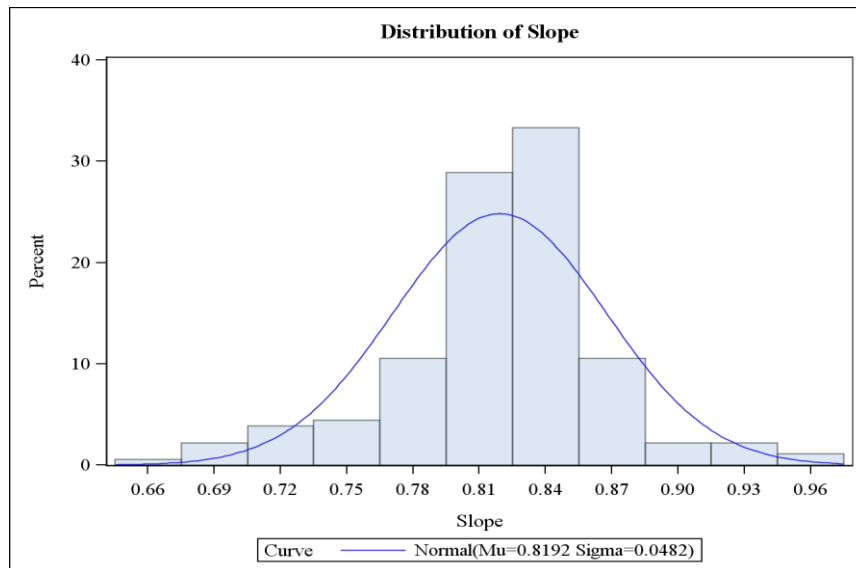


Table 13: Frequency of trials by Formulation Type:

Formulation Type	Frequency
CS	1
DP	2
DS	1
EC	256
EW	52
FS	31
GR	4
Liquid	4
OD	4
SC	213
SL	173
WG	69
WP	114
WS	2

Table 14: Frequency of trials by Country

COUNTRY	Frequency
ARGENTINA	3
AUSTRALIA	122
BELGIUM	5
BRAZIL	291
BULGARIA	2
CANADA	3
CERIALE	1
CHINA	80
COSTA RICA	6
DENMARK	10
DUNS TEW OXFORD	2
FINLAND	1
FRANCE	30
GERMANY	21
GREAT TEW OXFORD	1
GREECE	30
HOLLAND	7
HUNGARY	3
INDONESIA	1
ITALY	31
MALAYSIA	3
MAROCCO	1
MEXICO	2
NETHERLANDS	2
NEW ZEALAND	2
PHILIPPINES	7
POLAND	2

COUNTRY	Frequency
SOUTH AFRICA	22
SPAIN	39
SURINAM	1
SWEDEN	1
SWITZERLAND	1
THESSALONIKI	2
UK	54
USA	136
ZAPPONETA	1

Table 15: Frequency of trials by Active Ingredient

AI	Frequency
517 01	1
517 22	2
590	12
693	2
720	1
ACETAMIPRID	6
AZOXYSTROBIN	6
BETA-CYFLUTHRIN	29
BITERTANOL	2
BYF 14182	12
CHLORIMURON ETHYL	3
CHLORMEQUAT CHLORIDE	5
CHLORPYRIFOS	6
CYCLANILIDE	6
CYFLUTHRIN	28
CYPROCONAZOLE	11
DAS1	1
DAS10	10
DAS11	1
DAS12	6
DAS13	34
DAS14	4
DAS15	2
DAS2	13
DAS3	4
DAS4	1
DAS5	15
DAS7	8
DAS9	87
DELTAMETHRIN	7
DIFENOCONAZOLE	6
ENDOSULFAN	4
EPOXICONAZOLE	4
ETHEPHON	24
ETHIPROLE	1

AI	Frequency
ETHOXYSTROBIL	1
FAMOXADONE	23
FENOXANIL	6
FENOXAPROP-ETHYL	2
FENOXAPROP-P-ETHYL	9
FENPYROXIMATE	3
FLUAZIFOP	35
FLUOPICOLIDE	24
FOSETYL	17
FOSETYL-AL	5
GLUFOSINATE-AMMONIUM	89
Glyphosate-trimesium	15
HEXACONAZOLE	6
IMIDACLOPRID	75
IPRODIONE	1
Iprovalicarb	3
ISOPROCARB	4
ISOXAFLUTOLE	15
MEFENPYR-DIETHYL	25
METHIOCARB	1
NNI-0001	12
OXADIAZON	8
OXYDEMETON-METHYL	2
PENCYCURON	2
PROCHLORAZ	6
PROFENOFOS	4
PROPAMOCARB	6
PROPAMOCARB HYDROCHLORIDE	7
PROPICONAZOLE	9
PROPINEB	23
PROTHIOCONAZOLE	4
RIMSULFURON	3
SPIRODICLOFEN	5
SPIROMESIFEN	10
TEBUCONAZOLE	49
TEFLUBENZURON	1
THIACLOPRID	4
THIDIAZURON	2
THIODICARB	3
TRIADIMENOL	6
TRIAZOPHOS	8
TRIBUFOS	1
TRICYCLAZOLE	3
TRIFLOXYSTROBIN	14
TRIFLUMURON	11

Table 16: Frequency of trials by crop

Crop	COUNT
ALFALFA	1
AVOCADO	1
BROAD BEAN	1
CELERY	1
CITRUS FRUITS	1
CLOVER	1
FIELD PEA	1
FLAX	1
GRASSLAND (PASTURE)	1
KAKI	1
KIDNEY BEAN	1
LENTIL	1
MUSTARD	1
OLIVE	1
ONION	1
PASSION FRUIT	1
PEACH	1
RASPBERRIES, RED, BLACK	1
RUTABAGA	1
SPINACH	1
SUNFLOWER	1
SWEDE	1
TABLE-GRAPES	1
TEA	1
BLACKBERRIES	2
CACAO BEANS	2
CHERRY, SOUR	2
GARDEN PEA	2
GUAVA	2
LUPIN	2
MELONS, EXCEPT WATERMELON	2
OATS	2
RAPE SEED	2
RYE	2
SMALL FRUIT/BERRIES	2
SUGAR CANE	2
SUMMER SQUASH	2
CARROT	3
CAULIFLOWER	3
CHICORY, LEAVES	3
EGG PLANT	3
HOPS	3
LEEK	3
LETTUCE	3
LUCERNE	3

Crop	COUNT
OILSEED RAPE	3
RAPE	3
TURNIP	3
CURRENT, RED	4
MEADOW GRASS	5
CANTELOUPE	6
CORN	6
PINEAPPLE	6
FIG	7
MANDARIN	7
PEA	7
TOBACCO	7
CABBAGE	8
SORGHUM	8
BEET	9
DRY HAY	10
SNAP BEAN (YOUNG PODS)	13
STRAWBERRY	13
APPLE	14
CUCUMBER	15
PEPPERS	15
CHERRY TOMATO	17
COFFEE	17
ORANGE	17
SOYBEAN	18
BEAN	19
WHEAT	19
MELON	21
GRAPES	23
POTATO	23
COTTON	34
TOMATOES	40
BARLEY	43
MAIZE	56
RICE	161

APPENDIX 4

Possible Impact of the Proportionality Approach on MRL Setting

[Frank Laporte, 22 Nov. 2012, as revised by USEPA, April 2013]

As a general rule, MRLs are set based on residue data from supervised trials conducted at the critical GAP rate $\pm 25\%$. However, assuming proportionality between application rates and residue levels in treated commodities at harvest, it may be possible to also consider the results of supervised trials conducted at rates below or above $\pm 25\%$ of the critical GAP rate, provided the observed residue levels are corrected for the application rate ("scaled") before use for MRL calculation. This could possibly broaden the statistical basis for MRL calculation and hence improve the accuracy of the MRLs.

However, the evaluation of side-by-side trials conducted at different application rates suggests that the residue levels are not strictly proportional but only nearly proportional to the application rates. A further simulation was conducted in order to assess the impact on MRLs from applying the proportionality principle when the relationship "residue vs. application rate" is not perfectly proportional. As shown in figure 2B, with a slope $b = 0.8$ obtained from the mixed linear effect model and the application rate of the scaled residue ranging from $0.33X - 4.2X$ the GAP rate, the relative amount of over-estimated or under-estimation amount in the scaled residues would be less than 25% from the true value. The objective of this simulation is to evaluate the MRLs calculated from scaled residues (which are under/over-estimated) and compare these to the residues of GAP trials at application $1X$.

For the residues of GAP field trials (application rate = $1X$; thus, no scaling was needed), we randomly generated a distribution of residue values from a log-normal distribution. To obtain scaled residues (resulted from applying proportionality principle to non-GAP field trials, at application rates $\neq 1X$), we multiplied under-estimating/over-estimating factors to the residues at $1X$. For example, to create a scaled residue with 25% under-estimation, we multiplied 0.75 by a randomly generated residue at $1X$.

The impact of applying proportionality on the MRLs was evaluated when the scaled residues are under/over-estimated by 25%, 20%, 15%, and 10%. We used the lognormal distributions with geometric mean = 1 and CV = 0.7, 1.0, and 1.3 to represent the distributions of residues at $1X$ (using different geometric mean values may slightly have different simulation results due to the OECD rules of rounding MRL values; however, the conclusions would not change). The simulation included 1000 datasets (1000 MRLs) per scenario. Below are the scenarios that MRLs were evaluated:

- Scenario 1: calculation based on **4** random residues from the critical GAP rate field trials
- Scenario 2: calculation based on **8** random residues from the critical GAP rate field trials
- Scenario 3: calculation based on **16** random residues from the critical GAP rate field trials
- Scenario 4: calculation based on **4** random residues from the critical GAP rate field trials and **4** scaled residues from non-critical GAP field trials
- Scenario 5: calculation based on **8** random residues from the critical GAP rate field trials and **8** scaled residues from non-critical GAP field trials
- Scenario 6: calculation based on **8** scaled residues from non-critical GAP field trials

The primary criterion to evaluate and compare the MRLs between scenarios is the proportion of MRLs \geq the true 95th percentile (typically, we aim to have 95% of the estimated MRLs \geq the 95th percentile). The secondary criterion is the how close (or “tight”) the distribution of MRLs is to the true 95th percentile.

Conclusions:

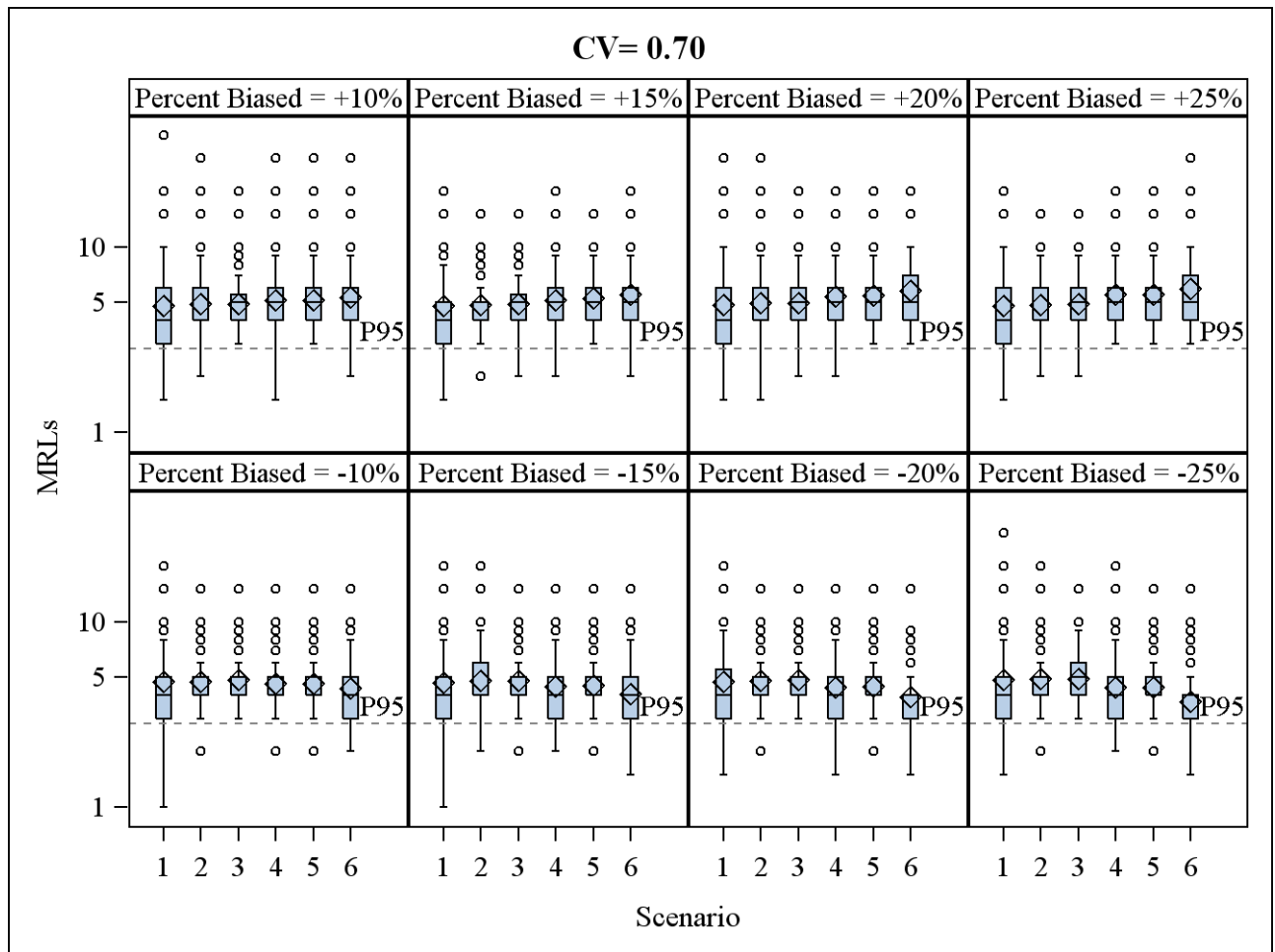
- Adding more scaled residues (to increase sample size) generally results better MRL estimates (scenario 4 vs. scenario 1, and scenario 5 vs. scenario 2).
- As the proportion of scaled residues increases, the MRL estimates become slightly worse (scenario 4 vs. scenario 2, and scenario 5 vs. scenario 3), but the MRL estimates are NOT substantially worse if the entire dataset consists of scaled residues, except in the extreme scenario in which the entire dataset were all scaled residues and were 25% under- or over-estimated (scenario 6 vs. scenario 2). However, this extreme scenario as done in the simulation with all scaled residues being under-or over-estimated by 25% does not apply if proportionality is limited to application rates between 4.2 \times to 0.33 \times label rate, respectively. With this range, the percent biased in the scaled residue will be within $\pm 25\%$. The 25% biased case gave acceptable results in the simulation, so using a full adjusted set of data (100%) is acceptable between 4.2x to 0.33x label rate.
- Another important factor worth mentioning is that the estimated slope from the linear mixed-effects model analysis was underestimated for the same reasons for which the ratio (C2/C1)/(R2/R1) was underestimated (refer to Appendix 1 and paragraph III.16).. For that reason, the actual amount of under/over-estimation in the scaled residues may be less than the values that were used in the simulation, and the MRL estimates calculated from using scaled residues may be better than what we see in the simulation results.

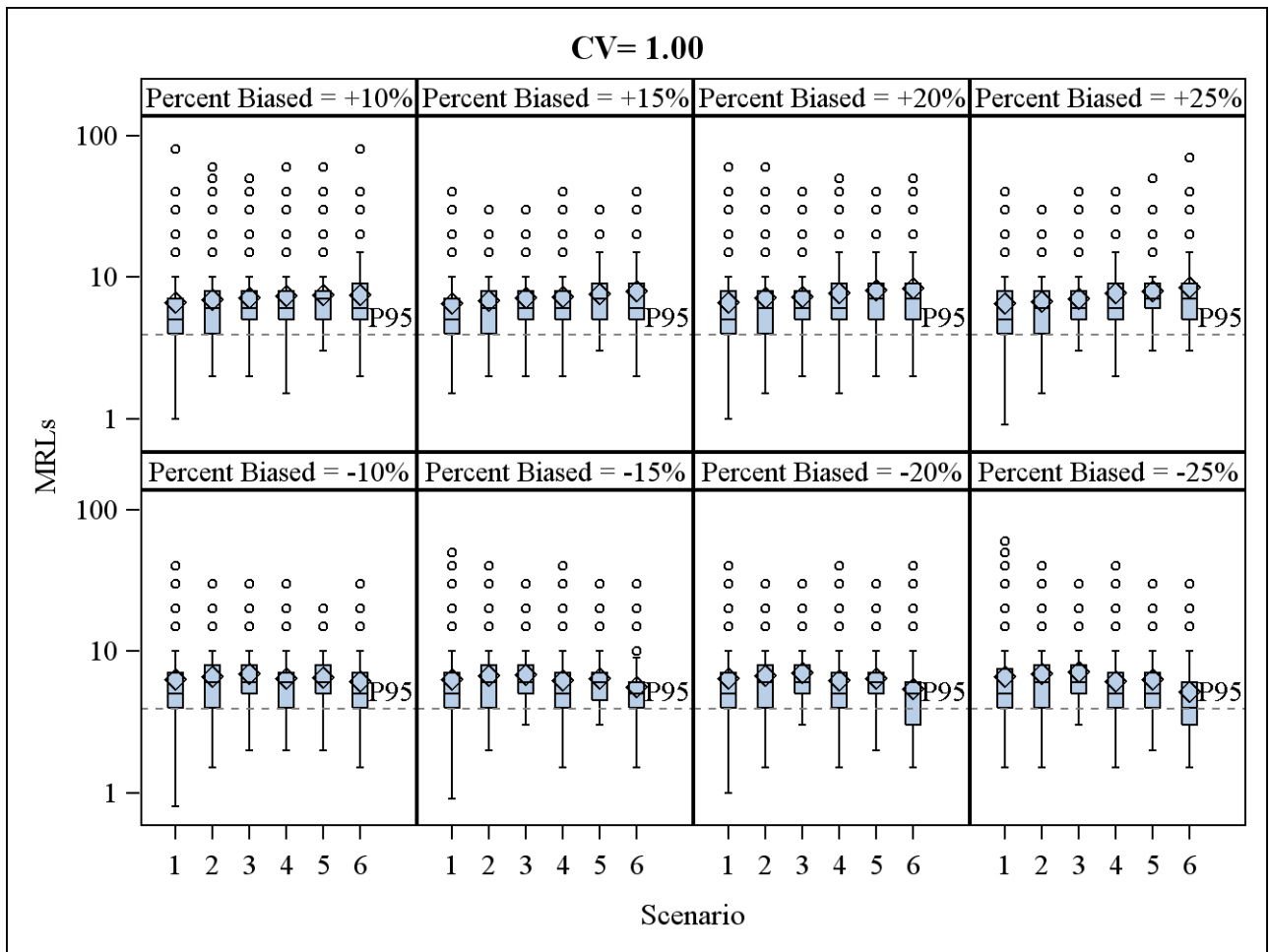
Therefore, increasing sample size by applying the proportionality principle on trials in which the application rate ranges from 0.33X to 4.2X the target rate results in better MRL estimates than would result if only the 1X (target) rate was considered even when the estimated slope is as low as 0.8.

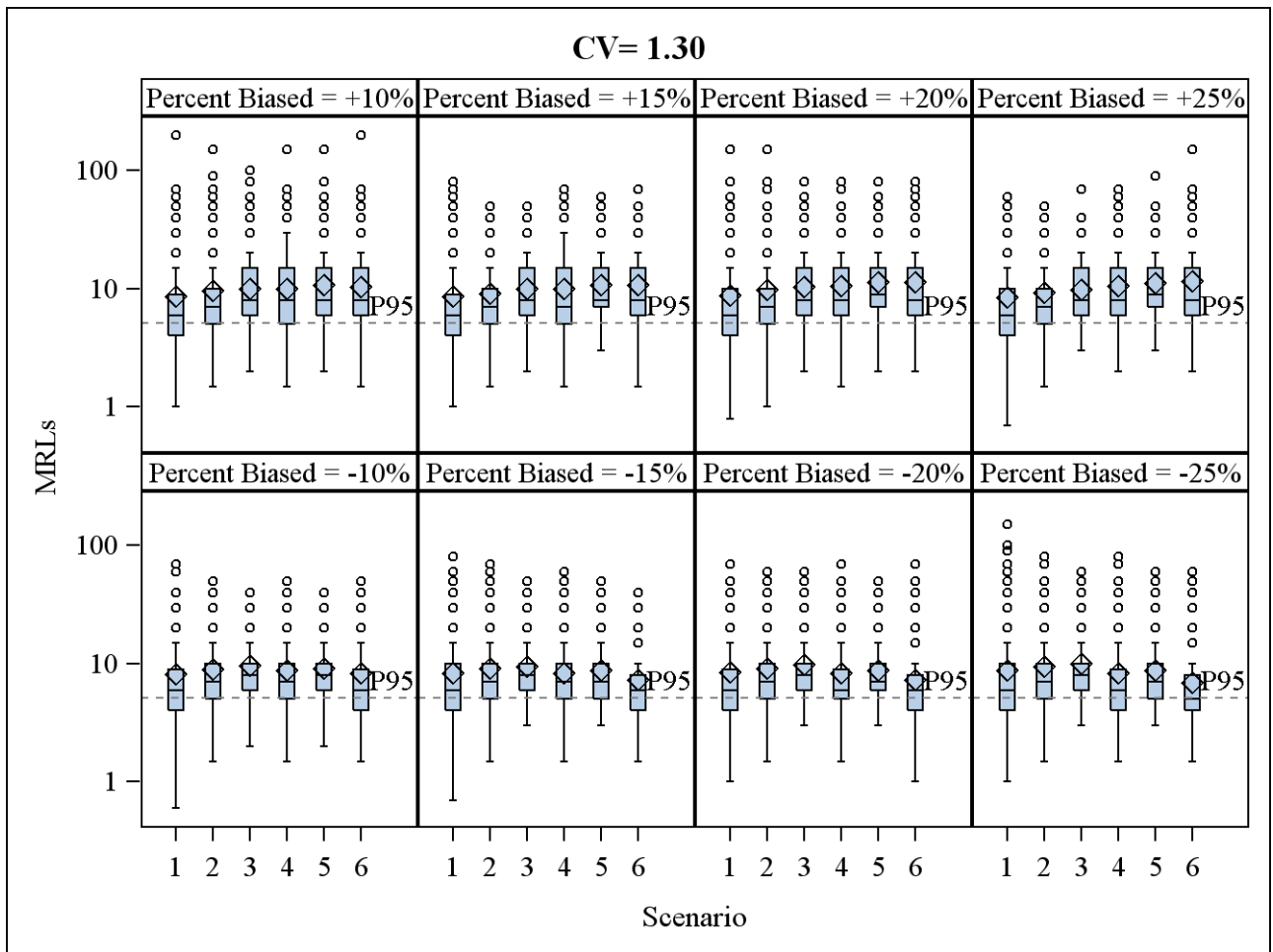
Simulation Results

CV	Percent biased in Scaled Residue	Proportion of MRL \geq 95 th percentile					
		Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
		4 GAP residues	8 GAP residues	16 GAP residues	4 GAP residues + 4 scaled residues	8 GAP residues + 8 scaled residues	8 scaled residues
0.7	- 25%	0.954	0.993	1.000	0.972	0.997	0.891
	-20%	0.938	0.987	1.000	0.974	0.996	0.928
	-15%	0.955	0.991	0.999	0.990	0.999	0.950
	- 10%	0.952	0.993	1.000	0.986	0.998	0.977
	10%	0.953	0.991	1.000	0.994	1.000	0.997
	15%	0.947	0.995	0.999	0.998	1.000	0.996
	20%	0.951	0.991	0.998	0.996	1.000	1.000
	25%	0.941	0.993	0.999	1.000	1.000	1.000
1.0	- 25%	0.790	0.902	0.975	0.826	0.940	0.712

CV	Percent biased in Scaled Residue	Proportion of MRL \geq 95 th percentile					
		Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
		4 GAP residues	8 GAP residues	16 GAP residues	4 GAP residues + 4 scaled residues	8 GAP residues + 8 scaled residues	8 scaled residues
	-20%	0.765	0.891	0.968	0.828	0.931	0.749
	-15%	0.772	0.887	0.965	0.837	0.946	0.786
	- 10%	0.769	0.880	0.961	0.876	0.947	0.830
	10%	0.789	0.892	0.978	0.926	0.986	0.933
	15%	0.791	0.917	0.978	0.922	0.987	0.930
	20%	0.787	0.899	0.970	0.944	0.987	0.953
	25%	0.771	0.889	0.972	0.949	0.985	0.968
1.3	- 25%	0.544	0.677	0.833	0.591	0.735	0.482
	-20%	0.552	0.688	0.829	0.618	0.756	0.533
	-15%	0.526	0.668	0.798	0.631	0.738	0.546
	- 10%	0.555	0.674	0.832	0.666	0.804	0.613
	10%	0.562	0.682	0.827	0.731	0.862	0.759
	15%	0.567	0.696	0.841	0.724	0.873	0.762
	20%	0.575	0.706	0.821	0.769	0.881	0.780
	25%	0.558	0.690	0.825	0.766	0.893	0.808







SAS code:

```

=====
* Programmer: James Nguyen *
*
* Project: Proportionality *
*
* Purpose: Perform Simulation to evaluate the impact on MRLs *
* when applying proportionality principle in fact *
* that the relationship between residue vs. *
* application rate is not precisely proportional *
*
* Data Source: *
* - simulation *
*
* Descriptions: *
* - generate data from lognormal, given GM (=1) and *
* CV (= 0.7, 1.0, and 1.3) *
* - under/over-estimated percent = -25%, -10%, 10%, 25% *
* - calculate MRL for each dataset of each scenario *
* - created box-plot MRL for each scenario *
* - caculated proportion of MRL > 95%-tile *
*
* Date Started: 4/09/2013 *
*
=====

```

```

Option FormDlim = "=" NoDate NoNumber;
ods nopitle;

```

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 Simulation(NSim=,GM=, CV=, ListRate =, seed=);

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

    %let nRate = 1;
    %let Rate&nRate = %nrquote(%scan(&ListRate,&nRate,%str( )));
    %Do %while (&&Rate&nRate ^=);
        %let nRate = %eval(&nRate+1);
        %let Rate&nRate = %nrquote(%scan(&ListRate,&nRate,%str( )));
    %end;
    %let nRate = %eval(&nRate - 1);

Data P95;
    P95 = exp(&MY + 1.645*&SY);
    call symput('P95',P95);
run;

Data Simmer;
    %do i = 1 %to &nRate;
        Rate = &&Rate&i;
        do Sim = 1 to &NSim;
            do N = 1 to 16;

                *==> create set of 16 residues at GAP;
                res = exp(&MY + &SY*rannor(&seed));

                *==> create a new set of residues:
                - first 8 data points are at GAP (no scaling is made)
                - last 8 data points are under/over estimated (not GAP)
                - the amount under/over-estimated = 1 - Rate;
                ares = res*((N<=8) + (N>8)*Rate);

                output;
            end;
        end;
    %end;
run;

Proc SQL;
    create table Scenario1 as
        select Rate, Sim, count(*) as N, avg(Res) as MeanV,

```

```

        max(res) as MaxV, std(res) as SD,
        max(calculated MaxV, calculated MeanV*3,
        calculated MeanV + calculated SD*4) as MRL
    from Simmer
    where N <= 4
    group by Rate, Sim;

create table Scenario2 as
    select Rate, Sim, count(*) as N, avg(Res) as MeanV,
        max(res) as MaxV, std(res) as SD,
        max(calculated MaxV, calculated MeanV*3,
        calculated MeanV + calculated SD*4) as MRL
    from Simmer
    where N <= 8
    group by Rate, Sim;

create table Scenario3 as
    select Rate, Sim, count(*) as N, avg(res) as MeanV,
        max(res) as MaxV, std(res) as SD,
        max(calculated MaxV, calculated MeanV*3,
        calculated MeanV + calculated SD*4) as MRL
    from Simmer
    group by Rate, Sim;

create table Scenario4 as
    select Rate, Sim, count(*) as N, avg(aRes) as MeanV,
        max(ares) as MaxV, std(ares) as SD,
        max(calculated MaxV, calculated MeanV*3,
        calculated MeanV + calculated SD*4) as MRL
    from Simmer
    where N <= 4 or N >= 13
    group by Rate, Sim;

create table Scenario5 as
    select Rate, Sim, count(*) as N, avg(aRes) as MeanV,
        max(ares) as MaxV, std(ares) as SD,
        max(calculated MaxV, calculated MeanV*3,
        calculated MeanV + calculated SD*4) as MRL
    from Simmer
    group by Rate, Sim;

create table Scenario6 as
    select Rate, Sim, count(*) as N, avg(aRes) as MeanV,
        max(ares) as MaxV, std(ares) as SD,
        max(calculated MaxV, calculated MeanV*3,
        calculated MeanV + calculated SD*4) as MRL
    from Simmer
    where N > 8
    group by Rate, Sim;
quit;
```

```

Data AllScenarios;
  set Scenario1(in=s1) Scenario2(in=s2) Scenario3(in=s3)
    Scenario4(in=s4) Scenario5(in=s5) Scenario6(in=s6);
  P95 = &P95;
  if s1 then Scenario = 1;
  if s2 then Scenario = 2;
  if s3 then Scenario = 3;
  if s4 then Scenario = 4;
  if s5 then Scenario = 5;
  if s6 then Scenario = 6;

  *==> 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;

  Pass = (P95 <= MRL);
run;

Proc SQL;
  create table PassRate as
  select Rate, Scenario, avg(Pass) as Pass
  from AllScenarios
  group by Rate, Scenario;
quit;

proc transpose data= PassRate prefix= Scenario
  out= PassRate(drop=_name_);
  by Rate;
  ID Scenario;
  var Pass;
run;

Data PassRate;
  set PassRate;
  Rate = Rate-1;
run;

ods listing;
title "CV= &CV";
Proc print data = PassRate noobs;
  format Rate percent6.2;
run;

Data AllScenarios;
  set AllScenarios;
  if Rate = 0.75 then Percent_Biased = "-25%";
  if Rate = 0.80 then Percent_Biased = "-20%";
  if Rate = 0.85 then Percent_Biased = "-15%";
  if Rate = 0.90 then Percent_Biased = "-10%";

```

```

    if Rate = 1.25 then Percent_Biased = "+25%";
    if Rate = 1.20 then Percent_Biased = "+20%";
    if Rate = 1.15 then Percent_Biased = "+15%";
    if Rate = 1.10 then Percent_Biased = "+10%";
    label Percent_Biased = "Percent Biased";
run;

ods listing close;
Proc SGPANEL data = AllScenarios;
  PANELBY Rate / rows = 2 columns = 4;
  VBOX MRL/category = Scenario;
  rowaxis type= log label= "MRLs" logbase= 10 logstyle= logexpand;
  colaxis offsetmax = .2 label= 'Scenario';
  reflate &P95/lineattrs =(pattern = 2) label = ('P95');
run;
Proc datasets nolist;
  delete AllScenarios Scenario: Simmer Summary P95;
quit;
%Mend;

%let outpath = C:\Documents and Settings\jnguyen\Desktop\SAS Junks;
option orientation = landscape;
ods rtf file = "&outpath\Proportionality Impact.RTF" bodytitle startpage = no;
%Simulation(NSim=1000,GM=1, CV=0.70, ListRate = 0.75 0.8 0.85 0.9 1.10 1.15 1.20 1.25,
seed=16513);
%Simulation(NSim=1000,GM=1, CV=1.00, ListRate = 0.75 0.8 0.85 0.9 1.10 1.15 1.20 1.25,
seed=16513);
%Simulation(NSim=1000,GM=1, CV=1.30, ListRate = 0.75 0.8 0.85 0.9 1.10 1.15 1.20 1.25,
seed=16513);
ods rtf close;
option orientation = portrait;

```