Appendix 1: Equations

Equation 1. Respondent's weighting coefficient

1a. In analyses estimating effects over all survey acreage, all respondents are included in the analyses, regardless of whether they reported an estimate. The respondent's share of total survey acreage serves as the respondent's weighting coefficient, w , and is given by the equation

$$w = \frac{r}{h},$$

where r is the number of acres managed by each respondent included in the analysis, and h is the sum total of r, which is the total number of acres included in the survey.

1b. In analyses on acreage where a pest was reported present, only respondents who reported the pest as present on their acreage are included in the weighting scheme. Therefore, a respondent's share of total respondent acreage per pest species serves as the respondent's weighting coefficient, w_o, which is given by the equation

$$w_o = \frac{r}{h},$$

where r is the number of acres managed by each respondent included in the analysis, and h is the sum total of r.

1c. For analyses on acreage where a pest was treated or pesticide applied, only respondents who reported treating for a given pest or with a given pesticide on all or part of their acreage are included in the weighting scheme. Therefore, share of total respondent acreage per pest species serves as the respondent's weighting coefficient in the "per treated acre" analyses, w_t, which is given by the equation

$$w_t = \frac{r}{h},$$

where r is the number of acres managed by each respondent included in the analysis, and h is the sum total of r.

Equation 2. Surveywide average maximum attainable yield and average actual yield, per acre

The average maximum attainable yield, $\overline{m}$, is expressed as a weighted arithmetic mean, and given by the equation

$$\overline{m} = \frac{\sum_{i=1}^{n} w_i b_i}{\sum_{i=1}^{n} w_i},$$

which expands to

$$\overline{m} = \frac{w_1 b_1 + b_2 m_2 + \ldots + w_n b_n}{w_1 + w_2 + \ldots + w_n},$$

where b is the respondent's maximum attainable yield estimate for a single pest species, per acre, and w is the respondent's weighting coefficient. Because this calculation applies the average over the entire survey area, every respondent's estimate and weighting coefficient are included in the calculation. The denominator for this calculation is the sum of all respondents' weighting coefficients, which is 1. **The formula for actual yield is identical to the one above.**

Equation 3. Surveywide average price received per pound of mint oil distillate

The average price received per pound of mint oil distillate is calculated using the arithmetic mean formula,

$$\overline{o} = \frac{\sum_{i=1}^{n} o_i}{n},$$

which expands to

$$\overline{o} = \frac{o_1 + o_2 + \ldots + o_i}{n},$$

where o is the respondent's estimate price received per pound of mint oil distillate in US dollars, and n is the number of observations.

Equation 4. Surveywide yield reduction per impact category

Yield reduction due to a general impact category, $\overline{g}$, is expressed as a weighted arithmetic mean, and given by the equation

$$\overline{g} = \frac{\sum_{i=1}^{n} w_i c_i}{\sum_{i=1}^{n} w_i},$$

which expands to

$$\overline{g} = \frac{w_1 c_1 + w_2 c_2 + \ldots + w_n c_n}{w_1 + w_2 + \ldots + w_n},$$

where c is the respondent's yield reduction estimate per impact category, per acre, and w is the respondent's weighting coefficient. Because this calculation applies the average over the entire survey area, every respondent's estimate and weighting coefficient are included in the calculation (therefore, the number of observations in this calculation is equal to the total number of respondents, which in this case is n = 9). The denominator for this calculation is the sum of all respondents' weighting coefficients, which is 1.

Equation 5. Transformation from estimates on acreage where the pest was present to estimates over all reported acreage

5a. The yield reduction estimates on acreage where a pest is reported present are transformed to estimate yield loss across all reported acreage, x, using the following equation,

$$x = \frac{l \times a}{r},$$

where l is the respondent's raw estimate on acreage where the pest was present, a is the number of acres infested by a single pest species on the respondent's land, and r is the number of acres managed by the respondent.

5b. The application estimates on acreage where a pest is reported present are transformed in order to estimate applications across all reported acreage, b, using the following equation,

$$b = \frac{l \times e}{r},$$

where l is the respondent's raw estimate, e is the number of acres treated for a single pest species on the respondent's land, and r is the number of acres managed by the respondent.

5c. The cost per treated acre estimate is transformed in order to derive the per-acre cost of a single pesticide application across all acres reported on by a respondent. Transformed applications, f, is expressed by the equation

$$f = \frac{l \times e}{r},$$

where l is the respondent's raw estimate, e is the number of acres treated for a single pest species on the respondent's land, and r is the number of acres managed by the respondent.

Equation 6. Weighted average single-species yield reduction, on acreage where pest was present

Per-acre yield reduction due to a single pest species, $\overline{p}$, is expressed as a weighted arithmetic mean, and is given by the equation

$$\overline{p} = \frac{\sum_{i=1}^{n} w_{oi} p_i}{\sum_{i=1}^{n} w_{oi}},$$

which expands to

$$\overline{p} = \frac{w_{o1}p_1 + w_{o2}p_2 + \ldots + w_{on}p_n}{w_{o1} + w_{o2} + \ldots + w_{on}},$$

where p is the respondent's yield reduction estimate for a single pest species on acreage where the pest was reported present, and w_o is the respondent's weighting coefficient. This calculation applies only to respondents who reported an infestation on all or part of the acreage. Therefore, the weighting coefficient is each respondent's share of the total infested acreage reported for a given pest species. (The number of observations in this calculation is equal to the total number of respondents who reported the presence of a specific pest on their acreage, which varies among pest species.) The denominator for this calculation is the sum of all included respondents' weighting coefficients, which is 1.

Equation 7. Weighted average single-species yield reduction, across all surveyed acreage

Surveywide per-acre yield reduction due to a single pest species, $\overline{y}$, is expressed as a weighted arithmetic mean, and is given by the equation

$$\overline{y} = \frac{\sum_{i=1}^{n} w_i x_i}{\sum_{i=1}^{n} w_i},$$

which expands to

$$\overline{y} = \frac{w_1x_1 + w_2x_2 + \ldots + w_nx_n}{w_1 + w_2 + \ldots + w_n},$$

where x is the respondent's transformed yield reduction estimate for a single pest species (see Equation 6a), per acre, and w is the respondent's weighting coefficient. Because this calculation averages across all acres surveyed, each respondent's estimate and weighting coefficient are included in the calculation. If a respondent did not report yield reduction for a pest species, they were assigned an estimate of zero. (The number of observations is equal to the total number of respondents, which in this case is n = 9.). The denominator for this calculation is the sum of all respondents' weighting coefficients, which is 1.

Equation 8. Average single application cost per pest species, on acreage where the pest was reported

The single-species chemical and nonchemical control costs estimates are calculated using the arithmetic mean formula,

$$\overline{s} = \frac{\sum_{i=1}^{n} s_i}{n},$$

which expands to

$$\overline{s} = \frac{s_1 + s_2 + \ldots + s_i}{n},$$

where s is the respondent's estimate for a single pesticide application (including application cost) per pest species in U.S. dollars, and n is the number of observations per pest species. (The number of observations in this calculation is equal to the total number of respondents who reported the presence of a specific pest on their acreage, which varies among pest species.) In the nonchemical treatment calculations, s is the respondent's cost estimate per single treatment activity, in dollars. (In this case, the number of observations is equal to the number of respondents who reported administering a nonchemical treatment on their acreage.)

To calculate the financial impact of a pest category — whether weeds, invertebrates or pathogens— we sum the average costs for each pest species or treatment method within a pest category.

Equation 9. Average applications per pest species, on acreage where the pest was reported as present or treated

9a. Average applications per acre, per pest species, on acreage where treatment occurred, $\overline{a}$, is expressed as a weighted arithmetic mean, and given by the equation

$$\overline{a} = \frac{\sum_{i=1}^{n} w_{ti} a_i}{\sum_{i=1}^{n} w_{ti}},$$

which expands to

$$\overline{a} = \frac{w_{t1} a_1 + w_{t2} a_2 + \ldots + w_{tn} a_n}{w_{t1} + w_{t2} + \ldots + w_{tn}},$$

where a is the respondent's estimate for number of applications performed for management of a single pest species, per treated acre, and w_t is the respondent's weighting coefficient (see Equation 1b). This calculation applies only to respondents who reported a given pest species as present on all or part of their acreage. The weighting coefficient is each respondent's share of the total treated acreage reported for a given pest species.

9b. Average applications per acre, per pesticide active ingredient, for control of a single pest species, $\overline{k}$, is expressed as a weighted arithmetic mean, and given by the equation

$$\overline{k} = \frac{\sum_{i=1}^{n} w_{ti} k_i}{\sum_{i=1}^{n} w_{ti}},$$

which expands to

$$\overline{k} = \frac{w_{t1}k_1 + w_{t2}k_2 + \ldots + w_{tn}k_n}{w_1 + w_2 + \ldots + w_n},$$

where k is the respondent's estimate for number of applications performed for management per pesticide active ingredient on acreage where the pesticide was applied, and w_t is the respondent's weighting coefficient (see Equation 1b). This calculation applies only to respondents who reported the use of a given pesticide on all or part of the acreage. Therefore, the weighting coefficient is each respondent's share of the total treated acreage reported for a given pesticide.

In both of these calculations, the number of observations is equal to the total number of respondents who reported the treatment of a specific pest on their acreage, which varies among pest species.

Equation 10. Weighted average number of applications per pest species, across all surveyed acreage

Weighted average number of applications for control of a single pest species across all surveyed acreage, $\overline{b}$, is expressed as a weighted arithmetic mean, and given by the equation

$$\overline{b} = \frac{\sum_{i=1}^{n} w_i m_i}{\sum_{i=1}^{n} w_i},$$

which expands to

$$\overline{b} = \frac{w_1 m_1 + w_2 m_2 + \ldots + w_n m_n}{w_1 + w_2 + \ldots + w_n},$$

where m is the respondent's transformed estimate (see Equation 6b) for number of applications performed for management of a single pest species, per acre, and w is the respondent's weighting coefficient. Because this calculation averages across all surveyed acres, each respondent's estimate and weighting coefficient are included in the calculation. If a respondent did not report an application for a specific pest or pesticide, they were assigned an estimate of zero. (The number of observations is equal to the total number of respondents, which in this case is n = 9.) The denominator for this calculation is the sum of all respondents' weighting coefficients, which is 1.

Equation 11. Weighted average single-species yield reduction value, across all surveyed acreage

To calculate the weighted average single-species yield reduction value across all surveyed acreage, the weighted average yield loss per pest species is multiplied by the surveywide maximum attainable yield estimate and the surveywide average price received per pound estimate to calculate, $\overline{z}$, the monetary value of yield lost (in U.S. dollars) attributed to a single pest species. This is given by the equation,

$$\overline{z} = \overline{y} \cdot \overline{o} \cdot \overline{m},$$

where $\overline{y}$ is the transformed weighted average yield reduction estimate for a single pest species (Equation 8), $\overline{m}$ is the surveywide weighted maximum attainable yield estimate (Equation 2), and $\overline{o}$ is the surveywide average price received per pound of mint oil distillate.

Equation 12. Weighted average single-species yield reduction value, on acreage where the pest was reported present

To calculate the weighted average single-species yield reduction value on acreage where a pest was reported present, we multiplied the weighted average yield reduction per pest species by the surveywide average maximum attainable yield estimate, and the survey-wide average price received per pound estimate to calculate, $\overline{q}$, the monetary value of yield lost (in U.S. dollars) attributed to a single pest species. This is given by the equation,

$$\overline{q} = \bar{p} \cdot \bar{o} \cdot \overline{m},$$

where $\bar{p}$ is the per-acre weighted average yield reduction estimate for a single pest species on acreage where it was reported as present (Equation 7), $\overline{m}$ is the surveywide maximum attainable yield estimate (Equation 2), and $\bar{o}$ is the surveywide average price received per pound of mint oil distillate.