Modelling the Effect of Pyrethroid Use Intensity on Mite Population Density in Walnuts

Yu Zhan[1], Siqi Fan[1], Minghua Zhang[1], and Frank Zalom[2]
[1]Department of Land, Air, and Water Resources, [2]Department of Entomology and Nematology,
University of California, Davis, CA 95616, USA

1 Introduction

- ➢ While the biological link between pyrethroid use and mite outbreaks has been widely studied, the presumption that this leads to increased miticide use is not as well-documented, and the relationship may well be region- and crop-specific.
- ➢ This study derives a mathematical model which is designed to quantify the effect of pyrethroid use intensity on mite population density based on regional and long-term pesticide use data.

European Red Mite

Twospotted Spider Mite

Walnut Blister Mite

Fig. 1 Walnuts and the main mites

2 Materials and Methods

- ➢ **Study crop, area, and period**: Walnuts, California, 1995 – 2009
- ➢ **Data**: Annual pyrethroid and miticide use intensities obtained from the Pesticide Use Report (PUR) maintained by the California Department of Pesticide Regulation (CDPR)
- ➢ **Exploratory analysis**: Scatter plot and LOESS (Local Linear Regression)
- ➢ **Mathematical model**

It was assumed that pyrethroid uses increased subsequent mite population densities, with a density-dependent growth rate. Therefore, the change of *MI* in response to the change of the pyrethroid use intensity (*PI*) has the following form.

$$\frac{dMI}{dPI} = g + h \cdot MI \qquad (1)$$

PI: the pyrethroid annual use intensity;
MI: the miticide annual use intensity indicating mite population intensity;
g: the initial change rate of ***MI*** to ***PI***;
h: the intrinsic change rate or the exponential change rate per ***MI***

The integral solution to Eq. (1) is as follows:

$$MI = -\frac{g}{h} + b \cdot e^{h \cdot PI} \qquad (2)$$

b: determined by a boundary condition.

- ➢ **Model Parameterization**

The raw dataset, with a low signal-to-noise ratio, was preprocessed before being fitted by Eq. (2).

1. A sub-range of *PI* was selected based on the *LOESS* result and the data variation and density.
2. The sub-range of *PI* was equally divided into intervals, and then the centroid of all pairs of *(PI, MI)* was calculated as the regression input.
3. The root-mean-square error (*RMSE*) was calculated to measure the goodness-of-fit of the model, where a lower value indicates a better fit.

$$RMSE = \sqrt{\frac{\{\sum_{i=1}^{n}[f(PI_i) - MI_i]^2\}}{n}} \qquad (3)$$

f(): parameterized Eq. (2);
PI$_i$: annual pyrethroid use intensity for interval ***i***;
MI$_i$: average annual miticide use intensity for interval ***i***;
n: number of intervals

3 Results and Discussion

- ➢ **LOESS**
  - The smooth line clearly shows that *MI* increased along with *PI*, until *PI* reached a threshold (≈ 0.05 kg/ha), where *MI* reached its maximum (≈ 1.5 kg/ha) and leveled off thereafter.
  - The smooth line remains relatively steady when varying the *LOESS* parameters, indicating that the local regression result is robust.

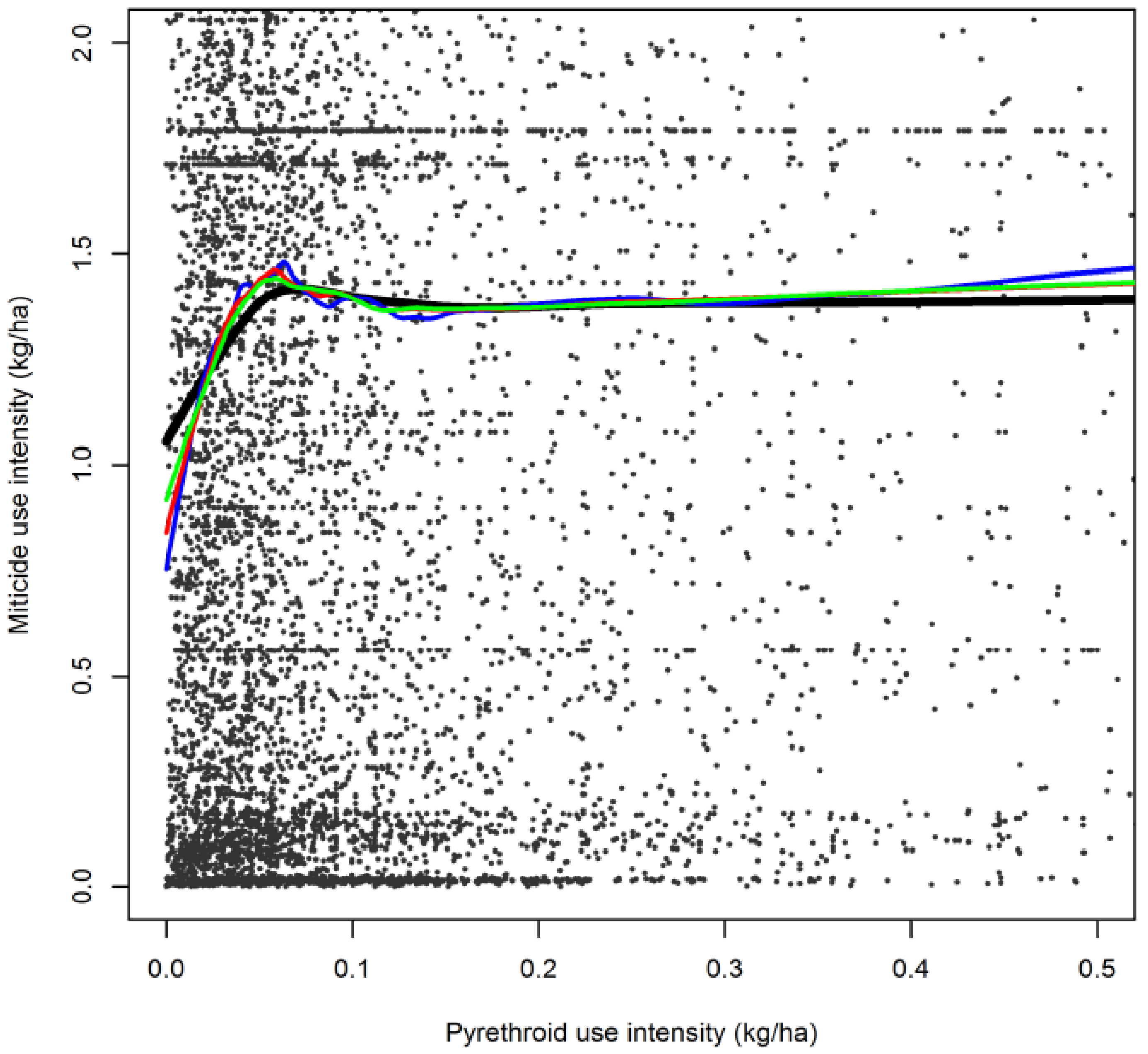

Fig. 2. Scatter plot of the pyrethroid and miticide use intensity, with smooth lines fitted by LOESS (local regression) at different spans (Blue – 0.25; red – 0.375; green – 0.5; and black – 2/3).

- ➢ **Model Parameterization**

The sub-range of *PI* between 0 and 0.1kg/ha was chosen based on the following parameters:

- *MI* increased and reached an equilibrium state within this sub-range;
- After 0.1kg/ha of *PI,* the standard error of mean increased greatly while the data density dramatically decreased

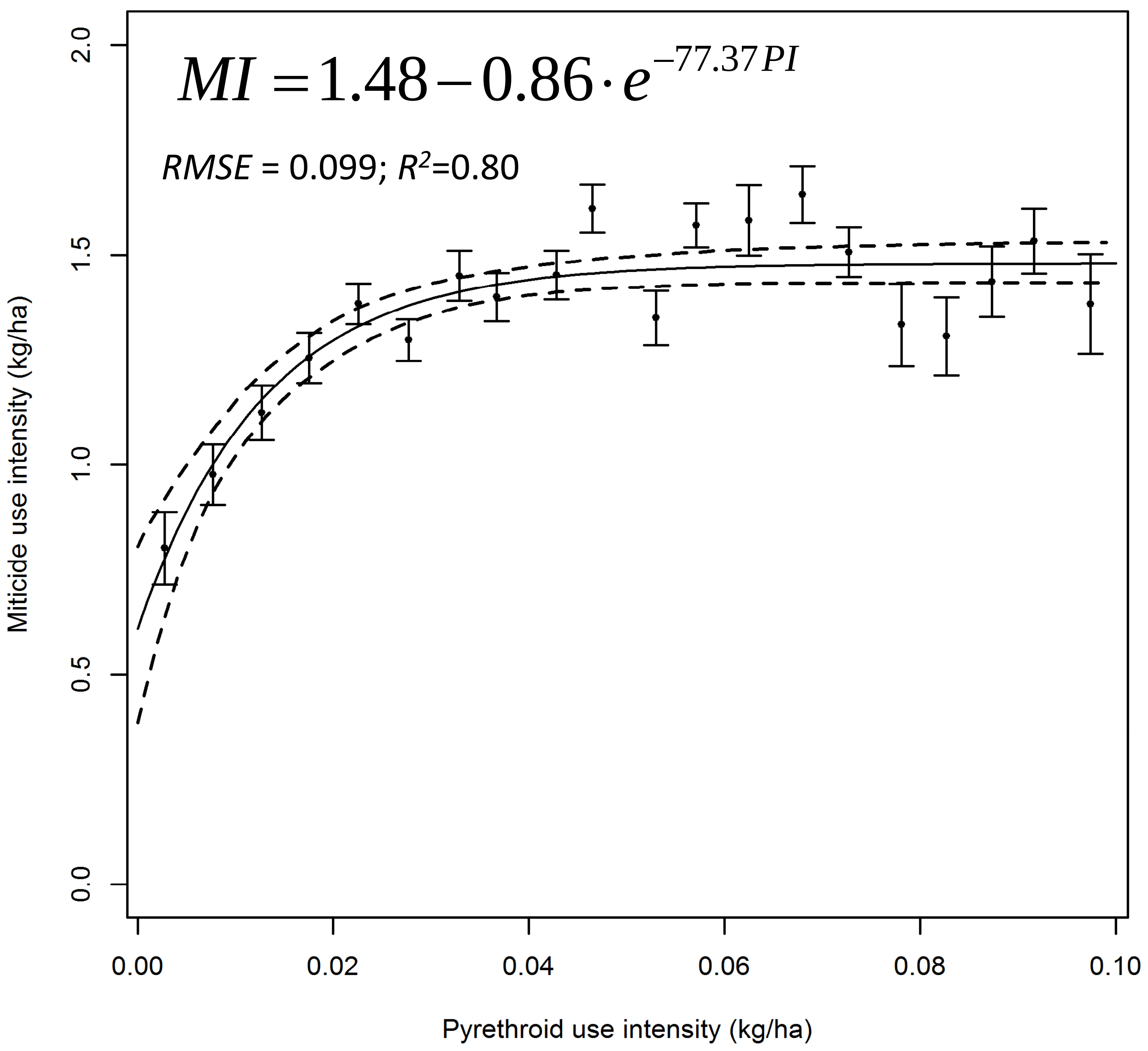

Fig. 3. The parameterized model (solid line) with the 95% confidence interval (dashed lines), and the data points (with standard errors) for the parameterization.

- ➢ **Three-Range Scheme**

The relationship between *PI* and *MI* can be classified into three ranges based on the change rate of *MI* to *PI* (Fig. 4).

- 91.33% of miticide applications (18.45 t/year) occurred in range 1; 7.34% (1.48 t/year) in range 2; and only less than 2% (0.27 t/year) in range 3.
- Since a large portion of applications are in range 1, a small increase of pyrethroid use in each application can result in a considerable increase of miticide use.

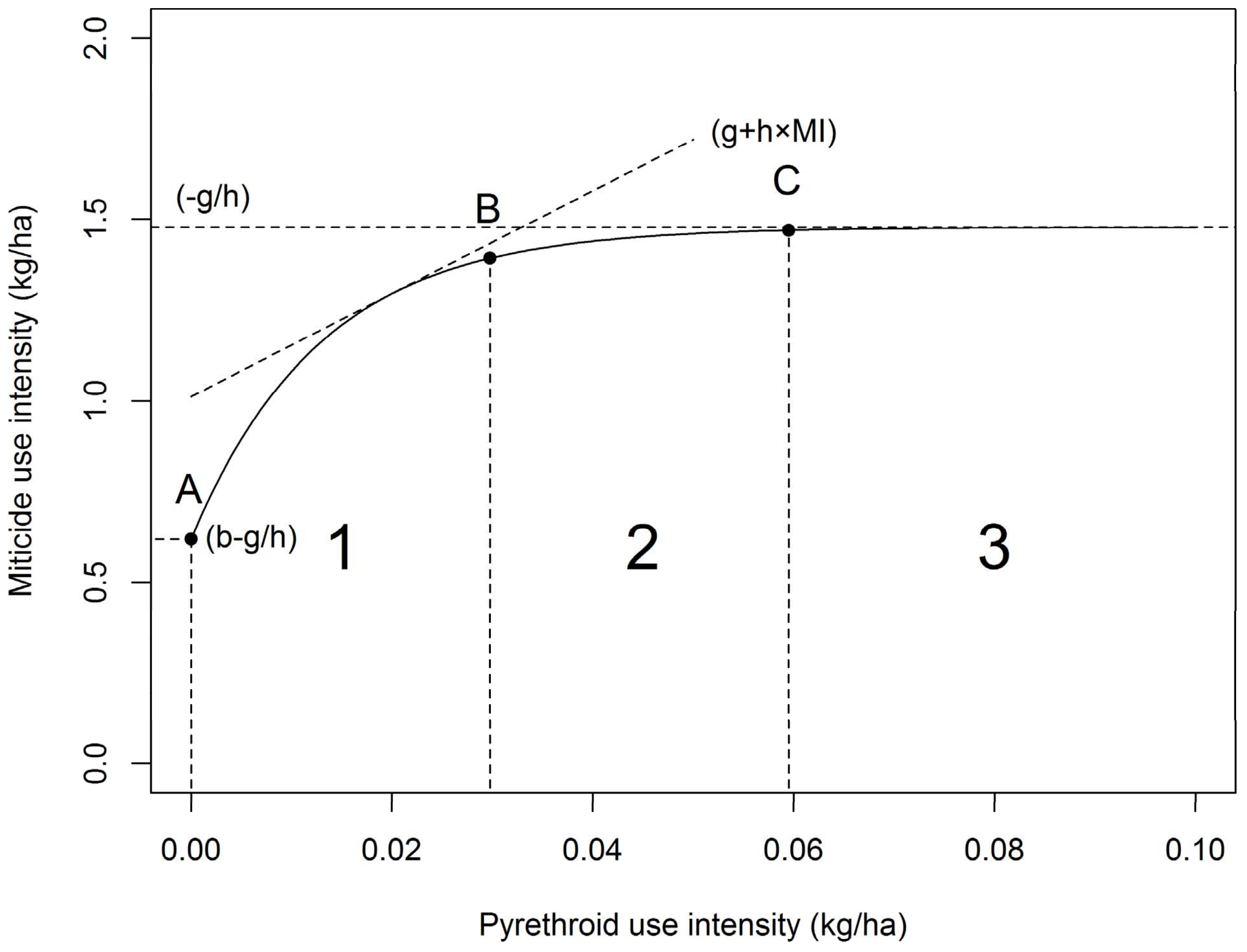

Fig. 4. The three-range scheme. In range 1 (rapidly-increasing), *MI* increases quickly by |90%*b*| while *PI* increases by ln(0.1)/*h*. In range 2 (slowly-increasing), *MI* increases by |9.9%*b*| while *PI* increases by ln(0.1)/*h*. In range 3 (equilibrium), *MI* approaches equilibrium even though *PI* continues to increase. See Eq. (2) for the variable descriptions.

4 Conclusions

1) Results confirm that more miticide is used, presumably to prevent or control mite resurgence, when pyrethroids are applied.

2) These results are particularly interesting as they do not rely on predictions of miticide use based on laboratory or experimental field studies, but rather on actual pesticide use data that intrinsically account for additional effects such as environmental conditions, grower behavior, and pesticide regulations.

3) A three-range scheme is presented to quantify pesticide applications based on the change rate of *MI* to *PI*. Specific for California walnuts, the *PI* range of 0-0.03 kg/ha is identified as the range where *MI* increases very rapidly with *PI* increases.

4) The cost implications of greater pyrethroid use include not only amplified production costs for growers, but also societal costs associated with economic and human or environmental health.

Reference

Zhan, Y., Fan, S., Zhang, M., Zalom, F. (in review). Modelling the effect of pyrethroid use intensity on mite population density for walnuts. Submitted to *Ecological Informatics*.

Contact: Yu Zhan, yzhan@ucdavis.edu