Engineering in Agriculture, Environment and Food xxx (2016) 1–13

Contents lists available at ScienceDirect

Engineering in Agriculture, Environment and Food

journal homepage: http://www.sciencedirect.com/eaef

A modeling approach to study the pesticide dynamics to reduce pesticide residues in Japanese green tea

Ibnu Susanto Joyosemito*, Akihiro Tokai

Osaka University, Graduate School of Engineering, Division of Sustainable Energy and Environmental Engineering, 2-1 Yamadaoka, Suita, Osaka, 565-0871, Japan

ARTICLE INFO

Article history:
Received 22 August 2015
Received in revised form
7 April 2016
Accepted 15 April 2016
Available online xxx

Keywords:
Food safety
Maximum residue limits
Good agricultural practices
Dynamic exposure model
Japanese green tea

ABSTRACT

In this study, a modeling approach is used to clarify and estimate the exposure pathways of pesticides on tea plantations using a case study of Shizuoka Prefecture, Japan, and an improvement to the Japanese good agricultural practice (GAP) is proposed. We develop a dynamic compartment model to project the fate and transport of a pesticide after application in accordance with the Japanese GAP. Two pesticides, Azoxystrobin and Clothianidin, were analyzed using the model for a given set of circumstances. The results indicate that the implementation of a fixed preharvest interval time, which is a crucial provision in the GAP, is not appropriate. The reason for this is that the dissipation rates of pesticides in tea leaves vary with the timing of the pesticide application and are influenced by factors specific to the plantation area. The dissipation rates are 1.5–3.9 days for Azoxystrobin and 3.8–9.5 days for Clothianidin. This study also clarifies that incorporating plantation-area-specific factors, such as temperature, in the GAP guidelines are essential to ensure that pesticide residues are lower than the desired level. Furthermore, to produce good-quality and safe green tea, the GAP should provide detailed and precise guidelines for the timing of pesticide application and formulation of the dosage treatment. These guidelines should be determined by considering specific provisions for the harvest times of fresh tea leaves.

1. Introduction

Concerns about food safety are increasing globally. One major concern is the use of pesticides on crops. The maximum residue limit (MRL) is a value that is set to ensure the use of a pesticide such that consumer health will not be harmed. The MRL value defines the maximum concentration of pesticide residue legally permitted in food or feed commodities and is applied through the good agriculture practice (GAP) guidelines (Bates, 2002) (MacLachlan and Hamilton, 2010). GAP was established to satisfy several objectives; one of which is to ensure the safety and quality of products in the food chain (FAO, 2008).

A food commodity for which pesticide residues are of particular concern is tea. As tea is a popular beverage worldwide, there is a possibility that many people are exposed to pesticide residues through drinking tea. As awareness of this issue is increasing, many countries are taking action by setting their own tentative limits for pesticide residues in tea, or by adopting the default MRL values set by international organizations such as the Codex Alimentarius Commission (CAC), or by establishing more stringent MRL based on their own studies (Jaggi et al., 2001) (Huang et al., 2007). Conversely, MRLs are also major constraints for tea-exporting countries in marketing their tea, especially for exporters from the least-developed countries (Gurusubramanian et al., 2008) (FAO, 2014).

Tea, particularly green tea, is a common beverage in Japan and has also been part of food culture among people for centuries. Although Japan is an exporter of green tea, its products cannot be shipped to certain European countries. This is because some pesticide residues are higher than the MRL standards set by CAC and European Union (EU). Therefore, more attention to the management of tea plantations by application of GAP is needed. The challenge for tea plantation management is identifying methods to produce good and safe fresh tea leaves, while using pesticides intensively to reduce yield losses and plant toppling caused by pests and diseases (e.g., plant-parasitic nematodes, insect pests, and pathogenic fungi). With the use of pesticides, an appropriate

* Corresponding author.
E-mail address: ibnususanto@em.see.eng.osaka-u.ac.jp (I.S. Joyosemito).

http://dx.doi.org/10.1016/j.eaef.2016.04.002
1881-8366/

Please cite this article in press as: Joyosemito, I.S., Tokai, A., A modeling approach to study the pesticide dynamics to reduce pesticide residues in Japanese green tea, Engineering in Agriculture, Environment and Food (2016), http://dx.doi.org/10.1016/j.eaef.2016.04.002

implementation of GAP in tea plantations plays an important role in decreasing chemical contamination in green tea. Hence, it is crucial to study the MRL values and application of GAP in tea plantation areas in order to reduce the constraints in exporting to other countries.

Supervised field trials are conducted to quantify and determine the pesticide residue and MRL values for tea. To summarize, experiments are conducted in tea plantation areas according to GAP, pesticides are applied based on the dosage forms, and tea samples plucked after an appropriate time interval (i.e., the pre-harvest interval; PHI) are analyzed in laboratory tests. Finally, all trial data that are considered to be valid are considered for setting of MRL (FAO, 2005) (Seenivasan and Muraleedharan, 2009) (EFSA, 2012). However, these steps are time-consuming and costly. Using models that represent some important aspects of the real system, it may be possible to improve our understanding of how to manage the application of GAP to meet the expected pesticide residue levels such that the MRL values can satisfy CAC and EU standards.

The aim of this study is to develop a modeling approach to clarify and estimate the exposure pathways of pesticides on a tea plantation using a case study in Shizuoka, Japan, and finally to propose an improvement to the Japanese GAP.

2. Method and modeling process

2.1. Model construction

Model development in this study uses the compartmental mass-balance concept (Trapp and Matthies, 1998). We adopt and simplify the United States Environmental Protection Agency (USEPA) conceptual model of pesticide effects on terrestrial organisms (USEPA, 2011). Fig. 1 depicts the structural relationships between the elements that may relevant to and sufficient for the representation of the real system being studied. The model is divided into sub-models of tea plant developmental stages and pesticide fate and transport. The conceptual models are subsequently formalized in the quantitative model. We mainly refer to the studies of Trapp and Matties (1995), Fantke and Juraske (2013), Fantke et al. (2014a) for the formulation of the pesticide fate and transport sub-model. The model of this study is implemented in Analytica Software: further details about the software are provided in Lumina Decision Systems (2015). The descriptions and mathematical models corresponding to the structural relationships (Fig. 1) are discussed in the following sections (the indices and symbols of the mathematical equations are listed in Table 1).

2.1.1. Sub-model of tea plant developmental stages

The amount of applied pesticide is assumed relative to the tea plant growth stage, the main developmental stages of tea plants in Japan are as follows.

- Tea seedlings are usually transplanted to the plantation area when they are two years old. Furthermore, branch formation (by pruning) begins in the second year after the fixed planting of the tea seedlings in the plantation area. Pruning is conducted to curb the height of the main trunk and promote the growth of lateral branches (ITOEN, 2015). Thus, the total time required for a new seedling to become an immature tea plant is approximately four years.
- From fixed planting of the tea seedlings in the plantation area, four to eight years are required for the plants to reach maturity and become suitable for commercial exploitation (ITOEN, 2015). Although it is possible to harvest the tea leaves from the fourth year, harvesting in the fifth year will provide a more stable yield and better quality (WGTA, 2015). Thus, an immature tea plant requires three years (five years minus the two-year seedling stage) to become a mature plant.

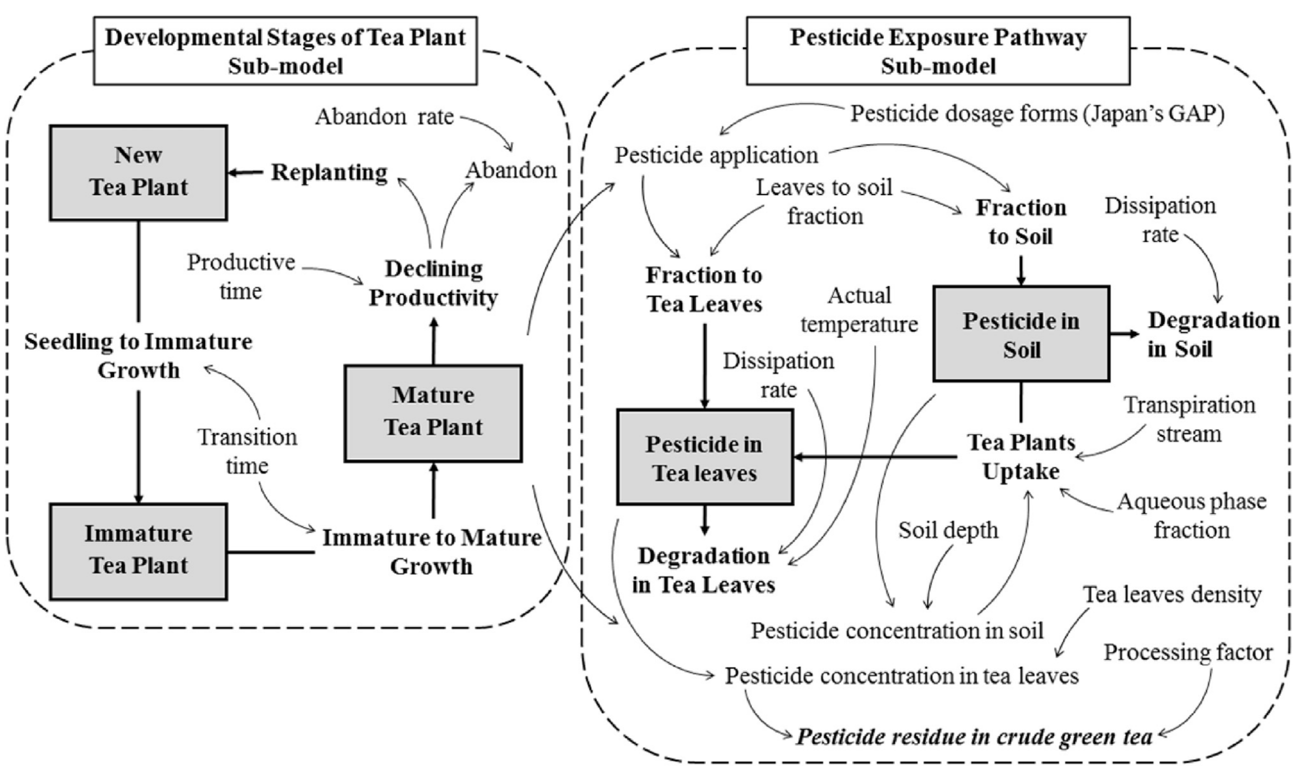

Fig. 1. The model of this study.

Please cite this article in press as: Joyosemito, I.S., Tokai, A., A modeling approach to study the pesticide dynamics to reduce pesticide residues in Japanese green tea, Engineering in Agriculture, Environment and Food (2016), http://dx.doi.org/10.1016/j.eaef.2016.04.002