The influence of crop type on the exposure of nursery workers to pesticides

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Abstract. Several factors may influence the exposure of nursery workers to pesticides during their work. This study investigates the influence of crop type on potential exposure and associated health risks among ten nursery workers from ten different nurseries in Johor, Malaysia. Personal interviews and questionnaire surveys were used to collect various information from the selected nursery workers in August and September 2023, together with the collection of pesticide labels. The collected data were input parameters in the appropriate exposure model to quantify their daily exposure and then assessed against the regulatory limit. Overall, individuals treated 1-13 different plant species on 2-9 spray days with 1-4 products containing 1-3 active substances. Ornamental nursery workers had the highest estimated daily exposures (30 applications; mean: 0.05 mg kg-bw^{-1} day^{-1}), followed by flowers (11 applications; mean: 0.02 mg kg-bw^{-1} day^{-1}) and fruits (6 applications; mean: 0.01 mg kg-bw^{-1} day^{-1}). Thirty applications exceeded the respective regulatory limits (ornamentals>flowers>fruits: 20>9>1), indicating a possible health risk. While the use of highly hazardous active substances and inappropriate protective measures were the significant risk factors, pesticide applications were primarily influenced by the crop type, which requires crop species-specific assessment among nursery workers.

1 Introduction

Commercial nurseries often grow different plants throughout the year, constantly needing to maintain a healthy crop using pesticides [1]. Nevertheless, the lack of crop uniformity (species, sizes, shapes, growth patterns and harvest schedules) means that routine pesticide treatments are needed to meet the market demand for aesthetics [2]. For example, ornamental nurseries typically consist of many plants in a small space (i.e., containers), where significant water inputs, fertiliser and pesticides are often used [3]. Over time, smart nursery spraying

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has evolved to ensure precision spraying [4], but this may be different in small-scale nurseries in developing countries such as Malaysia.

Pesticides are a diverse range of chemical and organic mixtures that can cause adverse health effects by interfering with biological molecules, tissues and organs, resulting in acute or chronic diseases [5]. Several health problems have been associated with agricultural workers, including respiratory issues, endocrine disruption, haematological changes, neurotoxicity, infertility, and certain cancers (e.g., bladder, prostate, and lip cancer) [6]. This is particularly relevant for workers producing, transporting, mixing/loading and spraying pesticide products [7].

Pesticides can be transferred directly or indirectly from sources to workers' bodies via three main exposure pathways: (i) emission through direct release from sources (e.g., splashes and spills), (ii) deposition of pesticide vapours and mists (<100 μm) from the air onto the workers' bodies, and (iii) transfer of pesticides through contact with contaminated surfaces (e.g., work tools and equipment) [8]. This means that occupational exposure to pesticides is a common problem during mixing/loading and spraying, with the two main routes of exposure generally agreed to be dermal and inhalation [9].

Following a previously conducted study on nursery workers [10], this study further investigates the influence of different crop types on nursery workers' exposure to pesticides applied over two months in August and September 2023. Contextual information was collected from ten nursery workers using personal interviews and questionnaires in Johor, Malaysia. The data were used to determine the pesticide use pattern and quantify exposure levels using the established Agricultural Operator Exposure Model (AOEM). The exposure estimates were compared with the respective Agricultural Operator Exposure Level (AOEL) for individual active substances. A ratio greater than 1.0 indicates a potential health risk. This study provides valuable preliminary insights into the influence of crop type on the exposure of nursery workers to applied pesticides.

2 Materials and Methods

This study collected information and pesticide application data from ten nursery workers (the principal pesticide applicators denoted as NS01, NS02, etc.) from ten nurseries in Johor Bharu, Malaysia. The data were collected using personal interviews and questionnaire surveys, and the workers volunteered to participate. The pesticide use data were cleaned against the pesticide labels collected from the selected nurseries and used as key input parameters in the Agricultural Operator Exposure Model (AOEM) [11].

The AOEM model's algorithms for predicting the median daily exposure during tank mixing/loading (ML) and high crop hand-held application (HCHH AP) were used to predict the total daily exposure of individuals to single pesticide active substances. This aligns with Wong et al. [9], which also explains the use of default values in exposure modelling. During tank mixing/loading activities, the potential hand exposure algorithm was used to estimate hand exposure for those not wearing gloves and those wearing cotton gloves, given the latter's ability to absorb pesticides. Likewise, cotton masks were not adjusted for the absorbent material.

The estimated daily exposures were then compared with the AOELs for individual substances by the PPDB [12], where a ratio greater than 1.0 indicates a potential health risk. This study defines total daily exposure as the sum of exposure to the same active substance for all crop types treated on the same day. This is because the AOEL is the maximum daily amount of a substance to which the operator can be exposed without experiencing adverse health effects [12].

3 Results and Discussion

Table 1 shows that the ten selected nurseries had between one and thirteen plant species, broadly categorised as flowers, fruits, herbs and ornamentals. Ornamentals were the most common crop type in eight nurseries, followed by flowers in five, fruits in three and herbs in one. Each nursery had a different number of crop species, ranging from one to thirteen, and the total number of spraying days ranged from two to nine. Six nurseries applied the same product to all plant species. Three nurseries applied two different products, and one nursery applied four different products, with an average of one active substance applied. Further analysis is needed to determine whether these pesticides were applied based on their authorisation for use in nurseries, where data are available.

For personal protective equipment (PPE) use during mixing/loading and application activities, six of the ten selected nursery workers wore cotton gloves, six wore cotton masks, and only four wore long sleeves and long pants (Table 1). Typically, the use of PPE can be influenced by several factors, including demographic characteristics, farm structure factors and environmental factors, while education and training programmes can affect behavioural and psychosocial factors in terms of individual awareness and attitudes when handling pesticides [13]. While recommending the use of PPE is the last resort for marketing authorisation, especially for some hazardous products, its effectiveness under actual conditions of use may be overestimated [14].

Table 1. Summary of the characteristics of the ten selected nurseries and the respective agricultural practices for the principal operators during work.

Nursery ID	Crop type	No. of plant species	No. of spraying day	No. of pesticide product	No. of active substance	Gloves (cotton)	Long sleeves & long pants	Masks (cotton)
NS01	flowers	4	4	1 (same product)	1	Yes	No	No
	fruits	2	2					
	ornamentals	2	4					
NS02	flowers	2	2	1 (same product)	1	Yes	Yes	Yes
	ornamentals	1	2					
NS03	fruits	3	5	1	1	No	No	No
NS04	ornamentals	10	4	2	1	No	No	Yes
NS05	flowers	5	7	1	1	Yes	No	Yes
	ornamentals	6	7	1				
NS06	ornamentals	13	2	1	2	Yes	Yes	Yes

NS07	ornamentals	2	9	4	5	No	No	No
NS08	flowers	4	9	1	n/a	Yes	Yes	Yes
	ornamentals	3	8	1				
NS09	flowers	6	3	1 (same product)	2	Yes	Yes	Yes
	herbs	2	3					
	ornamentals	9	3					
NS10	fruits	2	4	1	1	No	No	No
Mean	-	**4**	**5**	**1**	**1**	-	-	-

Table 2 shows the different types of pesticide active substances from different substance groups used by at least one of the ten selected nursery workers. Insecticides were the most frequently used products across all crop types. Herbicide use was limited to NS07 (ornamentals) and NS08 (flowers and ornamentals), while molluscicide use was confined to NS03 (fruits). Liquid formulations were the most commonly used in nine nurseries, with only two nurseries each using granular and wettable powder formulations. The AOEM inherent assumption is that exposure to liquid formulations is intermediate compared to the relatively higher exposure to wettable powders and the relatively low exposure to granular formulations [11].

Of the 14 active substances, organophosphate groups contributed the highest number of substances (4 compounds), followed by neonicotinoids and pyrethroids (2 compounds each). According to Nguyen et al. [1], organophosphates are often used to control insect pests, while pre-emergent herbicide mixtures, hand weeding and non-selective herbicides are used to control weeds. Based on the WHO recommended toxicity classification, there were six active substances categorised in class II (moderately toxic compounds), three active substances in class III (slightly toxic compounds) and five active substances in class IV (less toxic compounds), with AOEL values ranging from 0.00063 to 0.1 mg $kg\text{-}bw^{-1}$ day^{-1}. According to a review by El-Nahhal and El-Nahhal [15] on 60 pesticides involved in cardiotoxicity, more than half were in classes II and III, with 30 and 13 pesticides, respectively.

The present study excluded biopesticides (white oil, natural pyrethrin and bacillus thuringiensis) from the exposure modelling due to their relatively low health risk, and no AOEL values were assigned. Ametryn and dimethoate were also excluded because no AOEL values were identified. Generally, chemical control agents are more popular than biological and antimicrobial pesticides due to their rapid action and high reliability [16].

Table 2. List of fourteen active substances and their substance groups, formulation type and toxicity class extracted from the product labels and the respective AOEL values extracted from the PPDB [12].

Nursery ID	Active substance	Substance group	Product formulation	WHO Toxicity Class	AOEL
NS01	cypermethrin	pyrethroid insecticide	liquid	III	0.0025
NS02	malathion	organophosphate insecticide	liquid	III	0.03
NS03	metaldehyde	tetroxocane compound (molluscicide)	granule	IV	0.1
NS04	acetamiprid	neonicotinoid insecticide	liquid	II	0.025
	dimethoate	organophosphate insecticide	wettable powder	II	n/a
NS05	cypermethrin	pyrethroid insecticide	liquid	III	0.0025
	malathion	organophosphate insecticide	liquid	III	0.03
NS06	lambda-cyhalothrin	pyrethroid insecticide	liquid	II	0.00063
	thiamethoxam	neonicotinoid insecticide	liquid	II	0.08
NS07	ametryn	triazine herbicide	liquid	III	n/a
	glyphosate-isopropylammonium[a)]	organophosphate herbicide	liquid	III	0.1
	Chlorpyrifos	organophosphate insecticide	liquid	II	0.001[b)]
	cypermethrin	pyrethroid insecticide	liquid	II	0.0025
	white oil[c)]	insecticide	liquid	IV	n/a
NS08	not shown in labels	herbicide	liquid	n/a	n/a
NS09	canola oil[d)]	Plant-derived substance	liquid	IV	n/a

	natural pyrethrins[d)]	Plant-derived substance (insecticide)	liquid	IV	n/a
NS10	bacillus thuringiensis subsp. Kurstaki[d)]	Micro-organism	liquid	IV	n/a

Note: "n/a" denotes data not available, where alternative sources were referred to: [a)]glyphosate was referred to, [b)] the AOEL value for chlorpyrifos was extracted from the EFSA (2014), [c)]compound found in the Malaysian Pesticide Information (SISMARP) [18], and [d)]compounds found in the Bio-Pesticides Database (BPDB) [19].

Over the two-month study period, 47 applications were made for the eight active substances with assigned AOELs. The estimated daily exposures ranged from 0.004 to 0.2 mg kg-bw^{-1} day^{-1}, with a mean of 0.04 mg kg-bw^{-1} day^{-1} (Fig. 1). Thirty applications were conducted at the ornamental nurseries with estimated daily exposure estimates ranging from 0.004 to 0.2 mg kg-bw^{-1} day^{-1} (mean: 0.05 mg kg-bw^{-1} day^{-1}). Eleven applications were carried out at the fruit nurseries with exposure estimates ranging from 0.008 to 0.05 mg kg-bw^{-1} day^{-1} (mean: 0.02 mg kg-bw^{-1} day^{-1}). Six applications were completed at ornamental nurseries with exposure estimates ranging from 0.006 to 0.02 mg kg-bw^{-1} day^{-1} (mean: 0.01 mg kg-bw^{-1} day^{-1}).

Further analysis suggests that the relatively higher exposures on individual spraying days were due to the larger areas treated (3 – 4 hectares) and, therefore, the amount applied, with relatively higher dermal exposures than inhalation exposures, as studies generally agree [9]. Notably, each crop type consisted of different plant species (e.g., orchid, rambutan tree, bonsai, basil), which undoubtedly influences pesticide use and, thus, pesticide exposure.

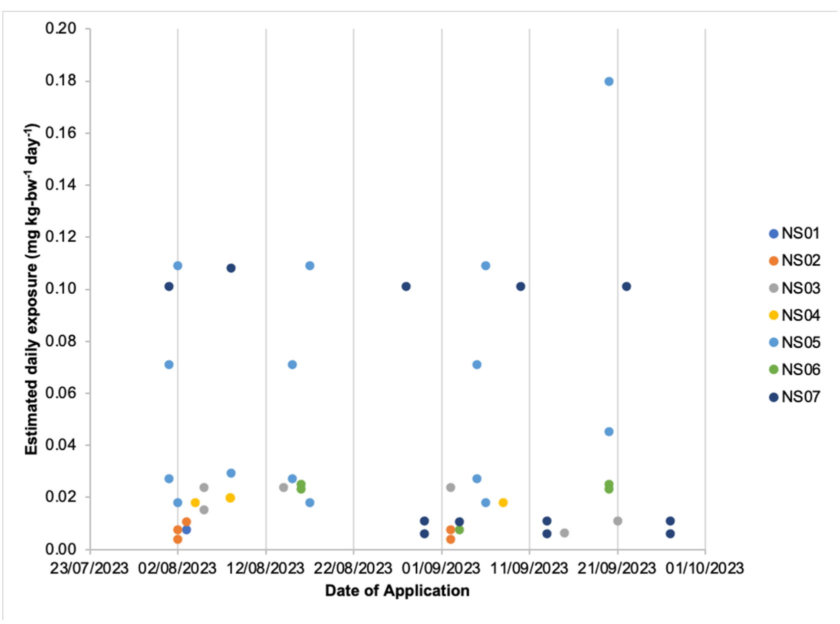

Fig. 1. Estimated daily exposure to eight selected active substances used by seven nursery workers during the two-month study period.

Thirty of the 47 applications of single active substances had a ratio of estimated exposure exceeding the respective AOELs, indicating a possible health risk. Ornamentals had the highest number of applications that had exposure estimates exceeding the respective AOELs (20 applications), followed by flowers and fruits (9 and 1 applications, respectively). The ratios were relatively higher for lambda-cyhalothrin (NS06; ornamentals), followed by cypermethrin (NS05; flowers) and chlorpyrifos (NS07; ornamentals), mainly due to their relatively higher toxicities (AOELs: 0.00063 – 0.0025 mg kg-bw^{-1} day^{-1}) (Fig. 3). Notably, chlorpyrifos is not currently registered for use in the Malaysian Pesticide Information System [18].

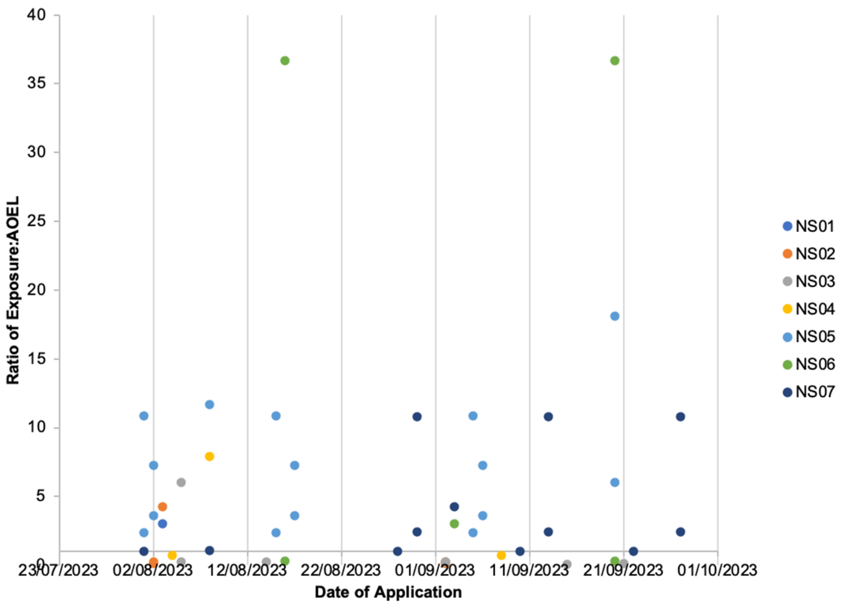

Fig. 2. Ratio of estimated exposure: AOEL for individual active substances applied by seven nursery workers during the two-month study period.

4 Conclusion

The present study shows that crop type influences pesticide use in nurseries, resulting in relatively higher estimated risks for ornamental nursery workers than for flower and fruit nursery workers. Therefore, future studies may consider the influence of crop species when assessing pesticide risk among nursery workers. Other important risk factors include the use of hazardous pesticide products and the use of appropriate PPE to reduce pesticide exposure. Study findings can be used to target efforts to reduce pesticide exposure and risk among nursery workers.

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