ASSESSMENT OF THE HEALTH AND ECOLOGICAL RISKS CAUSED BY FUNGICIDES IN CHRYSANTHEMUM CULTIVATION BY ENVIRONMENTAL IMPACT QUOTIENT

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Article history
Received: October 20th, 2022
Received in revised form: January 11th, 2023 | Accepted: February 1st, 2023
Available online: March 30th, 2023

Abstract

This study uses the Environmental Impact Quotient (EIQ) to assess the health and ecological risks caused by fungicides used in chrysanthemum cultivation upstream of Xuan Huong Lake, Da Lat city. Survey results reveal that 134 farmers use 21 fungicides with 18 active ingredients on a total area of 35.2 hectares. In all, 18 fungicides with an EIQ at the level of "unlikely to be hazardous" (EIQ < 25) are used on about 95% of the acreage, and 3 fungicides with an EIQ of "slightly hazardous" (25 < EIQ < 50) are used on the rest of the area. The Field Use EIQ of fungicide was rated very low in only 8.2% of the survey area and moderate in 48%. Areas with high and very high ratings account for 3% and 41%, respectively. Using fungicides according to the instructions can reduce the Field Use EIQ values in cultivated areas by 38% and return areas with high and moderate ratings to a low rating. Therefore, it is necessary to instruct farmers on the safe use of fungicides and to recommend those with low EIQ values for chrysanthemum cultivation.

Keywords: Chrysanthemum; EIQ; Fungicide.

DOI: https://doi.org/10.37569/DalatUniversity.13.2.1079(2023)

Article type: (peer-reviewed) Full-length research article

1. INTRODUCTION

The use of pesticides can bring many benefits, so they have gradually become the most frequently used means of pest control or management. Pesticides can be effective in terms of investment costs, with high performance due to their structural, toxicological, and functional diversity (Pimentel, 1997). Using pesticides reduces crop damage by 40% (Richardson, 1998). The use of pesticides began in 2500 BC, but only became common worldwide in the 19th century (Morley et al., 1991). As in other countries, the use of pesticides in Vietnam has increased by about 3–5 times over the past 25 years (Cassou et al., 2017).

The city of Da Lat is a famous vegetable and flower farming area in Vietnam. According to 2018 statistics, the total agricultural land area of Da Lat city is 13,640.04 hectares. Vegetables, flowers, tea, and coffee are common crops cultivated in Da Lat city. Flowers are a valuable commodity, grown over an area of 8,300.4 ha (Cục Thống kê tỉnh Lâm Đồng, 2018). Agricultural activities in Da Lat city are concentrated along large lake basins. The upstream area of Xuan Huong Lake belongs to the Cam Ly stream system and is an area with well-developed agricultural activities, especially flower cultivation (Uỷ ban nhân dân tỉnh Lâm Đồng, 2008). Farmers in Da Lat city cultivate flowers mainly in greenhouses, with an increasing area of cultivated land using pesticides, accounting for about 80%–90% of the total cultivated area. Fungicides account for 68%–82% of the total pesticides used, insecticides for 13%–16%, and herbicides for 3%–12% (Department of Natural Resources and Environment of Lam Dong Province, CENCOTECH - Dalat University, 2015).

Using too much pesticide in agriculture creates many consequences for public health and environmental pollution (Pimentel, 1997). The two main reasons are that more than 90% of the pesticides go to environmental destinations other than the target pests (Pimentel et al., 1991) and that all pesticides have toxicity that harms some forms of life (OHP, 2020) and ultimately affects humans in a variety of ways. Once pesticides enter the environment, they harm humans, livestock, and the environment (Ohkawa et al., 2007). Pesticide users, consumers, and policymakers recognize pesticide risks to human health and the environment. Many measures have been introduced in pest management and pesticide use to reduce the harm from pesticide products. Scientists from Cornell University (USA) developed the Environmental Impact Quotient (EIQ) in 1992 (Kovach et al., 1992) to quantify the risks of pesticides to humans and the environment.

Chrysanthemums are one of the major crops cultivated year-round in the area upstream of Xuan Huong Lake Chi cục Bảo vệ thực vật tỉnh Lâm Đồng, 2013). Favorable farming conditions also lead to the development of chrysanthemum pests, including thrips, red spiders, leaf borers, aphids, worms, nematodes, and especially fungi that cause rust, root collar, gray mold, yellow wilt disease, and powdery mildew (Sở nông nghiệp và phát triển nông thôn tỉnh Lâm Đồng, 2012). These pests harm crop yields and quality and reduce farmers' profits. Given the wide pathogenic range of fungal strains, the use of fungicides in chrysanthemum cultivation is inevitable. However, there has been no research or official publications to date on indicators of environmental health risks brought about by agricultural activities in Da Lat city, especially the risks posed by pesticides. Therefore, this study uses EIQ values to assess the health and ecological risks caused by the use of fungicides in chrysanthemum cultivation upstream of Xuan Huong Lake, Da Lat city. The research results will contribute to an initial database for making recommendations to minimize the health and ecological impacts of pesticides.

2. METHODS

2.1. Data collection methods

2.1.1. Primary data collection

The main method to collect primary data was a field survey with a sample size determined by Equation (1) (Yamane, 1967):

$$n = \left(\frac{z^2 \,.\, \mathrm{p}.\,(1-\mathrm{p}).\,\mathrm{N}}{z^2 \,.\, \mathrm{p}.\,(1-\mathrm{p}) + \mathrm{N}.\,e^2}\right) \tag{1}$$

where:

- n = cultivated area to be surveyed (ha);
- N = total area of chrysanthemum cultivation in the survey area, 64 ha (Chi cục Bảo vệ thực vật tỉnh Lâm Đồng, 2013);
- e = allowable error, taken as ±10%;
- z = 1.96 corresponding to a 95% confidence interval;
- p = overall ratio, taken as 0.95 for the survey results to be statistically significant.

Based on Equation (1), surveys were conducted from June 2021 to June 2022 of 134 households cultivating chrysanthemums on 35.2 hectares upstream of Xuan Huong Lake. The surveys collected information on (1) arable land, (2) types of plant pests and diseases, (3) fungicides and dosages used to prevent and destroy plant pests and diseases, (4) the times of spraying, and (5) the total number of spraying times for the whole season.

2.1.2. Secondary data collection

Secondary data were collected from documents on the chrysanthemum growing area upstream of Xuan Huong Lake (Chi cục Bảo vệ thực vật tỉnh Lâm Đồng, 2013) and detailed information on pesticides posted on the manufacturers' websites (Agriviet, 2022; Syngenta, 2022; Việt Nam Nông nghiệp sạch, 2022). Toxicity information on active fungicidal ingredients was taken from the New York State Integrated Pest Management Program website of Cornell University (Eshenaur et al., 2020).

2.2. Calculating the Environmental Impact Quotient

Two values, EIQ and Field Use EIQ, are used to assess the environmental impact of pesticides. The EIQ value is calculated for a specific active ingredient and reflects the potential toxicity of the pesticide. The Field Use EIQ indicates the potential environmental impact of a prescribed dose of a specific pesticide formulation. The Field Use EIQ reflects the possible level of risk on cropland when farmers spray.

The EIQ value of a specific active ingredient is the average of three environmental impact (EI) factors: EI farm workers, EI consumers, and EI ecology. The maximum possible EIQ score is 210 and the minimum score is 6.7 (FAO, 2008a).

The impact of fungicide on producers, consumers, and the environment is assessed on the basis of quantitative values of the potential risks of the active chemical ingredients (Kovach et al., 1992). The EIQ value is determined from the quantitative values of the potential risks of each type of active ingredient in Table 1 using Equation (2) (FAO, 2008b). The environmental impact factors representing the potential risk of each type of active ingredient are based on research by scientists at Cornell University (Eshenaur et al., 2020) and include EI Sprayer, EI Picker, EI Consumer Exposure Potential, EI Ground Water Leaching, EI Fish, EI Bird, EI Honey Bee, and EI Natural Enemies.

$$\text{EIQ value of active ingredient} = \frac{\text{EI Farm Worker} + \text{EI Consumer} + \text{EI Ecology}}{3} \quad (2)$$

where:

- EI Farm Worker = EI Sprayer + EI Picker;
- EI Consumer = EI Consumer Exposure Potential + EI Ground Water Leaching;
- EI Ecology = EI Fish + EI Bird + EI Honey Bee + EI Natural Enemies.

Each type of fungicide includes different active ingredients. Therefore, the EIQ value of each fungicide is determined as in Equation (3):

EIQ value of fungicide = EIQ value of the first active ingredient × % active ingredient + EIQ value of the second active ingredient × % active ingredient + … + EIQ value of the *ith* active ingredient × % active ingredient. (3)

The EIQ value of each pesticide serves as a basis for calculating the Field Use EIQ of the fungicide according to Equation (4) (FAO, 2008a).

Field Use EIQ = EIQ of fungicide × dosage rate (kg/ha/season or L/ha/season) (4)

where: Dosage Rate: Dose (usually in liters or kilograms of formulated product) of a specific chemical applied per hectare or acre over one season. The total dosage rate (kg/ha/season or L/ha/season) = number of spray applications per season × amount of fungicide in one application.

2.3. Evaluation of EIQ

The EIQ results are evaluated based on the index scale in Figure 1 (Ibrahim, 2016).

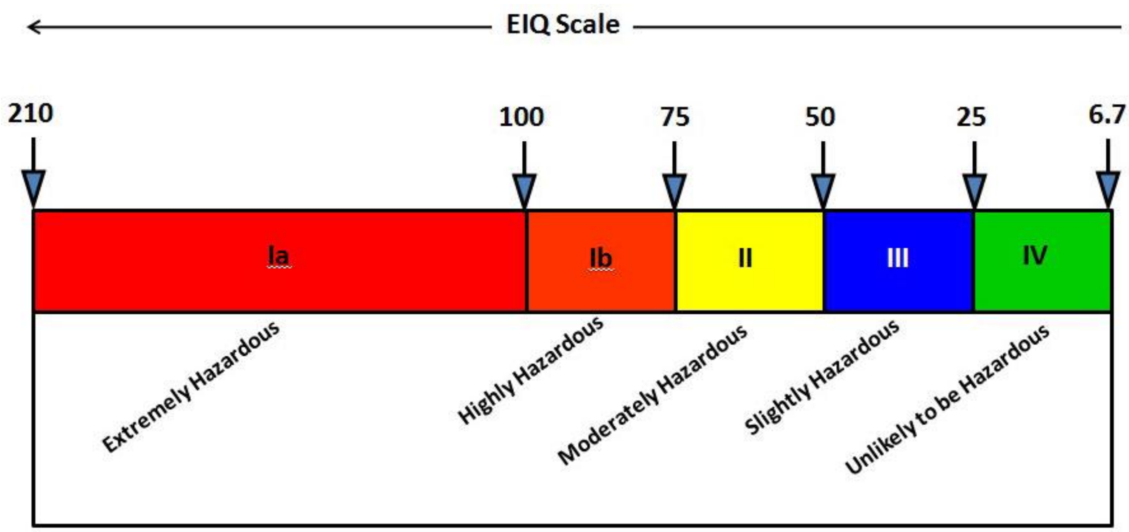

Figure 1. EIQ value scale

Source: Ibrahim (2016).

The scale includes five levels of pesticide risks to humans and ecosystems: unlikely to be hazardous (6.7 < EIQ <25), slightly hazardous (25 < EIQ < 50), moderately hazardous (50 < EIQ < 75), highly hazardous (75 < EIQ < 100), and extremely hazardous (100 < EIQ < 210).

The Field Use EIQ is evaluated based on the EIQ Field Use Rating (EIQFUR) (Kovach et al., 1992; Grant, 2020) shown in Figure 2.

<25	<50	50-100	>100	>150
Very low	Low	Moderate	High	Very high

Figure 2. EIQ Field Use Rating

Source: Kovach et al. (1992).

3. RESULTS

3.1. Use of fungicides in chrysanthemum cultivation

The survey results showed that fungicides were used in 100% of the chrysanthemum cultivation area during the growth and development of the plants. Fungal diseases were controlled by applying 21 fungicides with 18 different active ingredients (Table 1).

Table 1. Fungicides and active ingredients used in chrysanthemum cultivation

Area (m^2)	Name of fungicide	Active ingredient 1	Active ingredient 2
8,700	Amistar Top 325SC	Azoxystrobin	Difenoconazole
46,200	Anvil 5SC	Hexaconazole	
15,350	Azo-Elong 350SC	Azoxystrobin	
27,800	Cadillac 80 WP	Mancozeb	
8,000	Champion 57.6 DP	Copper hydroxide	
32,750	Daconil 500SC	Chlorothalonil	
29,300	Dithane M-45 80WP Xanh	Mancozeb	
82,200	DuPont Aproach 250SC	Picoxystrobin	
10,500	Isacop 65.2WG	Copper hydroxide	
10,500	Mataxyl 500WP	Metalaxyl	
16,800	Monceren 250SC	Pencycuron	
10,500	Nativo 750WG	Trifloxystrobin	Tebuconazole
9,350	Razocide 720WP	Mancozeb	Cymoxanil
40,500	Revus Opti 440SC	Mandipropamid	Chlorothalonil
2,500	Ridomil Gold 68WG	Metalaxyl	Mancozeb
1,500	Selecron 500EC	Profenofos	
72,900	Sporekill 120SL	Didecyldimethyl ammonium chloride	
37,500	Tepro-Super 300EC	Tebuconazole	Propiconazole
15,250	Tisabe 550SC	Hexaconazole	Chlorothalonil
35,500	Viroval 50WP	Iprodione	
47,000	Xantocin 40WP	Bronopol	

Note: 20.8 ha are sprayed with more than one fungicide.

The most commonly used fungicides are DuPont Aproach 250SC and Sporekill 120SL, with applications on 8.2 ha and nearly 7.3 ha, respectively. Both fungicides contain only one active ingredient (Table 1). Fungicides having two active ingredients, such as Ridomil Gold 68WG, Amistar Top 325SC, and Razocide 720WP, are used less often, with less than 1.0 ha for each.

Conditions of high humidity, low temperature (17^{o}C–24^{o}C), and excess water favor fungus growth on a large scale (Sở nông nghiệp và phát triển nông thôn tỉnh Lâm Đồng, 2012). Therefore, the prevention and control of fungi are carried out continuously throughout the chrysanthemum cultivation process.

The prevention and control of fungi by farmers begins at the end of the first growing season, ten days after planting (Thuan et al., 2020). The farmers continuously spray with an average frequency of once every three days during the growing and mid-crop periods. Some farmers spray fungicides once or twice at the end of the growing season. The rapid growth of plants in the growth and mid-crop stages leads to large cover and reduced surface evaporation (Thuan et al., 2020), which creates favorable conditions for fungal growth and damage, so farmers spray a lot of fungicides during these stages.

Although different fungicides are used, the total number of spray applications by the surveyed households is almost the same, ranging from 21 to 23 times and averaging about 22 times per season (Table 2).

Table 2. Frequency and dosage of fungicides used in chrysanthemum cultivation

Fungicide	Number of spray applications per season	Units	Spraying according to experience	Spraying according to instructions
Amistar Top 325SC	21	L/ha	0.979	0.4
Anvil 5SC	22	kg/ha	0.521	0.9
Azo-Elong 350SC	22	L/ha	0.500	0.3
Cadillac 80 WP	22	kg/ha	1.942	2.5
Champion 57.6 DP	22	kg/ha	0.720	1.75
Daconil 500SC	22	L/ha	0.866	0.75
Dithane M-45 80WP Xanh	22	kg/ha	2.275	2.63
DuPont Aproach 250SC	21	L/ha	0.779	0.6
Isacop 65.2WG	21	kg/ha	2.500	2.863
Mataxyl 500WP	21	kg/ha	0.500	0.25
Monceren 250SC	21	L/ha	0.671	0.8
Nativo 750WG	21	kg/ha	0.180	0.2
Razocide 720WP	21	kg/ha	2.400	0.8
Revus Opti 440SC	21	L/ha	0.800	2.25
Ridomil Gold 68WG	21	kg/ha	3.300	3
Selecron 500EC	22	L/ha	0.600	0.5
Sporekill 120SL	22	L/ha	0.498	0.208
Tepro-Super 300EC	21	kg/ha	0.388	0.4
Tisabe 550SC	23	L/ha	0.840	0.788
Viroval 50WP	23	kg/ha	0.927	0.6
Xantocin 40WP	21	kg/ha	0.510	0.22

In terms of fungicide dosage, Table 2 shows that Razocide 720WP was sprayed with 3.0 times the amount specified in the instructions, followed by Amistar Top 325SC with 2.4 times. However, because the area used for these two fungicides is relatively small, remedies may be easier to implement. The most worrisome aspect is that Sporekill 120SL was used in up to 21% of the area (Table 1) and in amounts 2.4 times the dose specified in the manual. Similarly, DuPont Aproach 250SC was used in more than 23%

of the total survey area and at doses 1.3 times the recommended level. In general, Tables 1 and 2 show that more than 50% of the chrysanthemum cultivation area received fungicide doses of 1.1 to 3.0 times the recommended dose.

Nine of the 21 fungicides are used at doses lower than the instructions on the package. Typically, the fungicide Revus Opti 440SC is used at doses 2.8 times lower than the recommended dosage, followed by Anvil 5SC at 1.7 times lower than the recommended dosage. Both are used on more than 4 hectares of arable land. Champion 57.6 DP is used on less than 1 hectare, and the dosage is about 2.4 times lower than that specified in the guidelines.

Farmers used 18 active ingredients to control fungi in the survey area. Chlorothalonil, picoxystrobin, didecyldimethylammonium chloride, and Mancozeb were each applied on areas of 6.9 to 8.9 ha (Table 3).

Table 3. Area of applied fungicidal active ingredients on chrysanthemum flowers

No	Active ingredient	Area (m^2)	No	Active ingredient	Area (m^2)
1	Azoxystrobin	24,050	10	Mancozeb	68,950
2	Bronopol	47,000	11	Mandipropamid	40,500
3	Chlorothalonil	88,500	12	Metalaxyl	13,000
4	Copper hydroxide	18,500	13	Pencycuron	16,800
5	Cymoxanil	9,350	14	Picoxystrobin	82,200
6	Didecyldimethylammonium chloride	72,900	15	Profenofos	1,500
7	Difenoconazole	8,700	16	Propiconazole	37,500
8	Hexaconazole	61,450	17	Tebuconazole	48,000
9	Iprodione	35,500	18	Trifloxystrobin	10,500

3.2. The EIQ of fungicides

3.2.1. Active ingredient EIQ values

Environmental impact factors EI Sprayer, EI Picker, EI Consumer Exposure Potential, EI Ground Water Leaching, EI Fish, EI Bird, EI Honey Bee, and EI Natural Enemies provided by Cornell University (Eshenaur et al., 2020) are given in Table 4.

The EIQ value of each active ingredient is found from Equation (2) and the data in Table 4. The values, given in Table 5, range from 10.67 (didecyldimethylammonium chloride) to 59.53 (profenofos). Eight of the 18 active ingredients were used at levels “unlikely to be hazardous” (EIQ < 25), nine active ingredients were used in the “slightly hazardous” range (25 < EIQ < 50), and one active ingredient was used at the “moderately hazardous” level (50 < EIQ < 75). The use of active ingredients at the slightly and moderately hazardous levels is a concern because these active ingredients were used in more than 50% of the cultivated area (Table 2).

Table 4. Environmental impact factors for fungicidal active ingredients

Active ingredient	EI Sprayer	EI Picker	EI Consumer Exposure Potential	EI Ground Water Leaching	EI Fish	EI Bird	EI Honey Bee	EI Natural Enemies
Azoxystrobin	5.00	3.10	3.05	3.00	15.00	9.15	9.30	33.17
Bronopol	25.00	5.00	1.00	5.00	15.00	3.00	3.00	5.00
Chlorothalonil	10.00	10.00	8.00	3.00	15.00	12.00	15.00	39.25
Copper hydroxide	15.00	9.30	4.05	5.00	5.00	36.45	9.30	15.50
Cymoxanil	13.50	8.37	16.61	5.00	1.00	6.15	9.30	46.50
Didecyldimethyl-ammonium chloride	15.00	3.00	1.00	1.00	1.00	3.00	3.00	5.00
Difenoconazole	5.00	1.00	9.00	1.00	15.00	9.00	3.00	12.50
Hexaconazole	25.00	5.00	2.00	1.00	1.00	30.00	3.00	5.00
Iprodione	10.00	6.20	6.10	3.00	9.00	9.15	9.30	20.00
Mancozeb	12.50	7.75	5.13	3.00	9.00	6.15	9.30	24.34
Mandipropamid	13.50	8.37	16.61	3.00	9.00	6.15	9.30	15.50
Metalaxyl	5.00	1.00	6.00	3.00	3.00	6.00	3.00	12.50
Pencycuron	5.00	3.10	3.05	1.90	3.20	9.15	9.30	25.42
Picoxystrobin	5.00	1.00	3.00	3.00	15.00	3.00	3.00	8.20
Profenofos	5.00	3.10	2.05	1.00	25.00	18.45	46.50	77.50
Propiconazole	7.50	4.50	18.00	1.00	15.00	12.00	9.00	27.90
Tebuconazole	10.00	10.00	30.00	1.00	15.00	15.00	15.00	25.00
Trifloxystrobin	7.50	4.65	9.23	1.00	5.00	6.15	9.30	46.50

Source: Eshenaur et al. (2020).

Table 5. EIQ values of fungicidal active ingredients on chrysanthemums

Active ingredient	EI Farm Worker	EI Consumer	EI Ecology	EIQ Value
Azoxystrobin	8.10	6.05	66.62	26.92
Bronopol	30.00	6.00	26.00	20.67
Chlorothalonil	20.00	11.00	81.25	37.42
Copper hydroxide	24.30	9.05	66.25	33.20
Cymoxanil	21.87	21.61	62.95	35.48
Didecyldimethylammonium chloride	18.00	2.00	12.00	10.67
Difenoconazole	6.00	10.00	39.50	18.50
Hexaconazole	30.00	3.00	39.00	24.00

Table 5. EIQ values of fungicidal active ingredients on chrysanthemums (cont.)

Active ingredient	EI Farm Worker	EI Consumer	EI Ecology	EIQ Value
Iprodione	16.20	9.10	47.45	24.25
Mancozeb	20.25	8.13	48.79	25.72
Mandipropamid	21.87	19.61	39.95	27.14
Metalaxyl	6.00	9.00	24.50	13.17
Pencycuron	8.10	4.95	47.07	20.04
Picoxystrobin	6.00	6.00	29.20	13.73
Profenofos	8.10	3.05	167.45	59.53
Propiconazole	12.00	19.00	63.90	31.63
Tebuconazole	20.00	31.00	70.00	40.33
Trifloxystrobin	12.15	10.23	66.95	29.78

3.2.2. Field Use EIQ of fungicides on chrysanthemums

The results of fungicide EIQ on chrysanthemums are shown in Table 6. Fungicide EIQ ratings range from “unlikely to be hazardous” to “slightly hazardous” (EIQ < 50). In all, 18 of the 21 fungicides had an EIQ rating in the “unlikely to be hazardous” range, accounting for 95% of the application area. Three fungicides, Azo-Elong 350SC, Nativo 750WG, and Selecron 500EC have EIQ ratings at the “slightly hazardous” level and were applied on about 5% of the total area.

The Field Use EIQ of fungicide ranges from 13 to 1177 when spraying is based on the farmer’s experience and from 23 to 1301 when spraying is performed according to instructions. These values are all much higher than the EIQ values for the fungicide dose per hectare used in a single season (Table 2). Of the 21 fungicides, only Anvil 5SC had a Field Use EIQ lower than the EIQ value for both spraying “according to experience” and “according to instructions.” Because Anvil 5SC was sprayed (based on experience) in doses 1.7 times lower than the guidelines (Table 2), the Field Use EIQ was lower than if the dose specified by the manual had been applied. However, this fungicide was only applied to less than 10% of the area (Table 1).

Table 6. EIQ of fungicides used on chrysanthemums

Name of fungicide	EIQ value of fungicide	Field Use EIQ of fungicide	
		Spraying according to experience	Spraying according to instructions
Amistar Top 325SC	7.01	144	59
Anvil 5SC	1.15	13	23
Azo-Elong 350SC	25.04	275	165
Cadillac 80 WP	20.58	879	1,132

Table 6. EIQ of fungicides used on chrysanthemums (cont.)

Name of fungicide	EIQ value of fungicide	Field Use EIQ of fungicide	
		Spraying according to experience	Spraying according to instructions
Champion 57.6 DP	19.12	303	736
Daconil 500SC	18.71	356	309
Dithane M-45 80WP Xanh	20.58	1,030	1,191
DuPont Aproach 250SC	3.43	56	43
Isacop 65.2WG	21.65	1,136	1,301
Mataxyl 500WP	6.59	69	35
Monceren 250SC	5.01	71	84
Nativo 750WG	27.61	104	116
Razocide 720WP	19.30	973	324
Revus Opti 440SC	13.36	224	631
Ridomil Gold 68WG	16.99	1,177	1,070
Selecron 500EC	25.84	341	284
Sporekill 120SL	8.17	90	37
Tepro-Super 300EC	10.79	88	91
Tisabe 550SC	19.91	385	361
Viroval 50WP	12.13	259	167
Xantocin 40WP	8.27	89	38

Applying a fungicide according to the guidelines reduced the Field Use EIQ by 0.35 to 3.0 times compared to spraying according to experience (Table 6). At the same time, the EIQFUR rating decreased from moderate to low over 38% of the total area (Figure 2 and Table 7).

Table 7. EIQFUR by percentage area of fungicide use on chrysanthemums

EIQFUR	Area (%)	
	Spraying according to experience	Spraying according to instructions
Very low	8	8
Low	0	38
Moderate	48	11
High	3	2
Very high	41	41

4. CONCLUSION

This study determined EIQ values of 21 fungicides used in chrysanthemum cultivation upstream of Xuan Huong Lake, Da Lat city. Most fungicides are composed of one active ingredient at concentrations below the threshold for being harmful to health and the ecosystem. Of the 13 fungicides in the hazardous range, six fungicides were composed of two active ingredients. Using fungicides with many active ingredients can increase the effectiveness of prevention and control of fungi, but the potential harm to health and the environment is also great. Most of the large fungicide EIQ Field Use values occur because of the amount used and the number of spray applications, which vary from 21 to 23 during the growth and development of the chrysanthemums.

Spraying according to the manual guidelines can reduce the Field Use EIQ by 0.35 to 3.0 times compared to spraying based on the farmer’s experience, and can partly minimize the damage to health and the environment caused by the use of fungicides in chrysanthemum cultivation.

The research results show the impact of using chemical ingredients in agricultural cultivation and the need to disseminate EIQ information to the public. The EIQ value should be added to fungicide labels so that the public can decide on the types and amounts of fungicide to use to minimize the impact on health and the environment.

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