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Article

Assessment of Total Risk on Non-Target Organisms in Fungicide Application for Agricultural Sustainability

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Abstract: In Turkey, in 2010, the amount of pesticide (active ingredient; a.i.) used in agriculture was about 23,000 metric tons, of which approximately 32% was fungicides. In 2012, 14 a.i. were used for fungus control in wheat cultivation areas in Adana province, Turkey. These a.i. were: azoxystrobin, carbendazim, difenoconazole, epoxiconazole, fluquinconazole, prochloraz, propiconazole, prothioconazole, pyraclostrobin, spiroxamine, tebuconazole, thiophanate-methyl, triadimenol, and trifloxystrobin. In this study, the potential risk of a.i. on non-target organisms in fungicide application of wheat cultivation was assessed by The Pesticide Occupational and Environmental Risk (POCER) indicators. In this study, the highest human health risk was for fluquinconazole (Exceedence Factor (EF) 1.798 for human health), whereas the fungicide with the highest environmental risk was propiconazole (EF 2.000 for the environment). For non-target organisms, the highest potential risk was determined for propiconazole when applied at 0.1250 kg a.i. ha-1 (EF 2.897). The lowest total risk was for azoxystrobin when applied at 0.0650 kg a.i. ha-1 (EF 0.625).

Keywords: human health; environment; wheat; non-target organism; POCER

1. Introduction

Pesticides are used extensively in agricultural production systems to prevent or reduce losses by pests and/or improve the yield and quality of agricultural crops [1–3]. Fungicides are necessary to control diseases and used to kill fungi and their spores on a wide range of agricultural crops [4,5]. In Turkey, approximately 22,900 tonnes pesticide (a.i.) was used by agriculture in 2010 [6], about 32% of which was fungicide.

Adana is a city in the Mediterranean Region of Turkey. In Adana, the major agricultural crops are cotton, cereals, grapes, citrus fruits, *etc*. It is possible to grow two agricultural crops like wheat + cotton, and wheat + corn, in one year due to meteorological conditions and soils. Moreover, the climate in Adana is suitable for greenhouse cultivation for crops such as tomato, cucumber, pepper, cut flower, *etc*. Therefore, more than 1/3 of Turkey's total pesticide use occurs in the Mediterranean and the Aegean Region where intensive agriculture is carried out [7]. In 2012, in the Adana province, the amount of pesticides used was approximately 4850 tonnes, of which approximately 20% was fungicides [8].

Turkey has approximately 16.0 million ha area of cereals, and each year, wheat is grown on about half of that land [9]. Adana has 400,000 ha of agricultural land, about 50% of which is wheat [9]. In 2012, fungicide were applied to 95,000 ha of wheat in Adana from the end of March to mid May [8]. Thirteen trademark fungicides and 14 a.i. were used to control black, brown, and yellow rust (*Puccinia spp*.), and septoria leaf spot (*Septoria spp*.) [8]. These a.i. were azoxystrobin, carbendazim, difenoconazole, epoxiconazole, fluquinconazole, prochloraz, propiconazole, prothioconazole, pyraclostrobin, spiroxamine, tebuconazole, thiophanate-methyl, triadimenol, and trifloxystrobin. The a.i. consumption for these was 5000 kg for prochloraz, 4685 kg for epoxiconazole, 4175 kg for propiconazole, 2500 kg for carbendazim, 1800 kg for difenoconazole, 1750 for prothioconazole, 1700 kg for pyraclostrobin, 1550 kg for thiophanate-methyl, 1500 kg for spiroxamine, 1002 kg for tebuconazole, 880 kg for trifloxystrobin, 750 kg for azoxystrobin, 500 kg for fluquinconazole, and 258 kg for triadimenol [8]. Total a.i. used for fungus control in wheat was 28,050 kg. Descriptions of a.i. were given as below [10].

Azoxystrobin is post-emergence broad spectrum strobilurin fungicide used mainly for cereals. Carbendazim is used to control a range of diseases including Septoria, Fusarium and Sclerotina. Difenoconazole is novel broad-range activity used as a spray or seed treatment. Epoxiconazole is a broad-spectrum fungicide for control of diseases caused by Ascomycetes, Basidiomycetes and Deuteromycetes. Fluquinconazole is fungicide used to control Ascomycetes, Deuteromycetes and Basidiomycetes spp. on cereals, beets and fruit. Prochloraz is used against a wide range of diseases affecting field crops, fruit, turf and vegetables. Propiconazole is used to address a broad range of activity including diseases caused by *Cochliobolus sativus*, *Erysiphe graminis* and *Leptosphaeria nodorum*. Prothioconazole is used both as a seed treatment and foliar spray to treat a variety of diseases in cereals. Pyraclostrobin is used to control major plant pathogens including *Septoria tritici*, *Puccinia spp*. and *Pyrenophora teres*. Spiroxamine is a used to control powdery mildew, leaf spots, rusts and other diseases. Tebuconazole is effective against various smut and bunt diseases in cereals and other field crops. Thiophanate-methyl is effective against a broad spectrum of diseases in fruit, vegetables, turf and other crops including eyespot, scab, powdery mildew and grey mould. Triadimenol is used for cereals, beet and brassicas used to control a range of diseases including powdery mildew, rusts, bunts and smuts. Trifloxystrobin is foliar applied fungicide for cereals which is particularly active against Ascomycetes, Deuteromycetes and Oomycetes.

Most fungicide residues were retained in plant roots, whereas small amounts were carried to the above ground-parts [11]. Dikic *et al*. (2011) determined that repeated low doses, especially the combination of carbendazim with cypermethrin, had additive cytotoxic effects on the tissue and physiology of metabolic pathways [12]. Battaglin *et al*. (2011) showed that fungicide occurrence will likely increase in the environment in response to increases in fungicide applications to prevent fungal disease outbreaks such as soybean rust and to increase crop yields [4].

Sustainability means the ability to use a organism or substance without doing any damage to other organisms. In agriculture, sustainability provides a balance between the ecological environment and environmentally friendly agricultural applications such as tillage, fertilizing, spraying of pesticides, harvesting, *etc*. Pesticides should be carefully used for sustainable agriculture. If not, pesticides will eradicate the ecological environment with long-term effects. Farmers should take care in pesticide selection and application for sustainable agriculture. Generally, the side effects of the use of pesticides include toxicity risks to the person applying the pesticide (farmer), reductions in the threshold in food, development of resistant pathogens and the accumulation of a.i. in natural resources [13]. Awareness of these side effects has led the authorities to promote sustainable agriculture which incorporates environmentally friendly use of pesticides and the development of alternative protection methods [13].

If operators use inappropriate equipment and carry out activities under unsuitable meteorological conditions for pesticide application, pesticides have the potential to cause damage to non-target organisms that are indicators for sustainable agriculture. Non-target organisms are mainly classified as human health and environment According to the Council Directive 91/414/EC, human health is divided into three categories: operator, worker and bystander. Operators are persons who mix, load and apply the pesticide formulation [13–15]. Workers are considered to be the persons who come in contact with the treated crop by re-entry tasks, such as pruning, thinning, scouting, harvesting, bending and tying up of the crop required for the commercial production of agricultural crops [14–17]. Bystanders are people who are located within or directly adjacent to the area at the moment of pesticide application [14,16–19]. Environment is divided into seven categories according to the Council Directive 91/414/EC. These are aquatic organisms, birds, earthworms, bees, beneficial arthropods, persistence in soil and leaching to groundwater [17,20]. The aim of this study was to determine the potential risk on non-target organisms, for sustainable agriculture, of active ingredients used in fungicide application to control black, brown, and yellow rust (*Puccinia spp*.), and septoria leaf spot (*Septoria spp*.) in wheat cultivation areas in Adana province, Turkey, in 2012.

2. Material and Methods

The fungicides assessed in this study were the 14 a.i. used for fungus control in wheat cultivation areas in Adana province, Turkey, in 2012, namely azoxystrobin, carbendazim, difenoconazole, epoxiconazole, fluquinconazole, prochloraz, propiconazole, prothioconazole, pyraclostrobin, spiroxamine, tebuconazole, thiophanate-methyl, triadimenol, and trifloxystrobin [8]. The applied dose (kg a.i. ha-1) of these a.i. were taken from manufacturer's recommended application rates in the product labels. In fungicide applications, the toxicity data for each a.i. was obtained from environmental fate, ecotoxicology, and human health and protection of a.i. [11].

In this study, the German Ganzelmeier drift curve was used to predict the drift at certain distances in downwind field by Equation (1), as given below [17].

$$\%drift = A \times z^{B} \tag{1}$$

where "A" and "B": coefficients for the German drift equation (these coefficients for field crops are A = 2.7593 and B = −0.9778), and
z: the distance between the field border and a point downwind the field (m).

In this study, the total risk of a.i. for non-target organisms was assessed by POCER (The Pesticide Occupational and Environmental Risk) indicators [20].

2.1. Estimation of the Risk Index (RI) for Non-Target Organisms

According to the toxicity data of the each a.i., risk indices (RI) of non-target organisms were determined with respect to equations between 2 and 15.

Descriptions and defaults of the parameters in equations between 2 and 15 were given in Table 1.

Table 1. Descriptions and defaults of the parameters, [17,20].

Description of the parameters	Unit	Default for this study
AR : Application rate	kg a.i. ha^{-1}	
AOEL : Acceptable Operator Exposure Level	mg kg^{-1} day^{-1}	
DE : Dermal exposure	mg/person/day	
Ab_{DE} : The dermal absorption factor	---	0.1
LAI : Leaf Area Index	m^2	field crops: 1
TF : Transfer Factor	cm^2/person/h	field crops: 5000
T : The duration of re-entry	H	8
P : The factor for personal protective equipment (PPE)	---	no PPE: 1
$IE_{bystander}$: Internal exposure of bystander	mg kg^{-1}	
BW : Body weight	kg	70
D : Applied dose of a.i.	mg m^{-2}	
%drift : Downwind a.i. deposits(in % of applied dose),		
EA : Exposed area skin	m^2 $person^{-1}$ day^{-1}	0.4225
I_a : Inhalation exposure of applicator	mg kg^{-1}	0.008
ST : Spraying time	min ha^{-1}	field crops: 7
Ab_I : The absorption factor for inhalation exposure	---	0.1
n : number of applied doses,	---	1
$d_{ditches}$: depth of the ditch	m	1.5
$min(NORM_w)$: the toxicological reference for water organisms	mg L^{-1}	
LC_{50} : the median lethal concentration	mg kg^{-1}	
EC_{50} : the median effect concentration	mg L^{-1}	
NOEC : the No Observed Effect Concentration	(mg L^{-1})	
PEC_{BIRD} : the estimated total daily pesticide intake	mg day^{-1}	
LD_{50} : the acute LD_{50} for birds	mg kg^{-1}	
BW : the body weight of birds	kg	0.01
PEC_{bottom}: the bottom pesticide concentration in soil	mg kg^{-1} soil	
f : the fraction of depositing a.i. intercepted by crops		0.88
d_{bottom} : the depth of the bottom	m	0.05
ρ_{bottom} : the density of the bottom	kg m^{-3}	1350
RC : the reduction in capacity of the organism by pesticide application	%	
DT_{50} : the half-life of the pesticide in soil.	days	
$PEC_{groundwater}$: the predicted concentration in groundwater	µg L^{-1}	

2.1.1. Pesticide Operator ($RI_{operator}$)

The risk index for pesticide operators is calculated by Equation (2) [14,15,20,21].

$$RI_{operator} = \frac{AR \times 0.292}{AOEL} \tag{2}$$

2.1.2. Worker (RI_{worker})

The risk index for workers is calculated with Equations (3) and (4) [14,15,17,20,21].

$$RI_{worker} = \frac{DE \times Ab_{DE}}{AOEL} \tag{3}$$

$$DE = 0.01 \times \frac{AR}{LAI} \times TF \times T \times P \tag{4}$$

2.1.3. Bystander ($RI_{bystander}$)

The risk index for bystanders is calculated with Equations (5) and (6) [14,20,21].

$$RI_{bystander} = \frac{IE_{bystander}}{BW \times AOEL} \tag{5}$$

$$IE_{bystander} = (D \times \%drift \times EA) \times Ab_{DE} + \left(\frac{D \times I_a}{ST}\right) \times Ab_1 \tag{6}$$

2.1.4. Aquatic Organisms ($RI_{aquatic\ organisms}$)

The risk index for aquatic organisms is calculated with Equation (7) [15,17,22].

$$RI_{AquaticOrganisms} = \frac{\left(\frac{D \times \%drift \times n}{d_{ditch} \times 1000}\right)}{\min(NORM_w)} \tag{7}$$

The toxicological reference for water organisms ($\min(NORM_w)$) is based on the acute toxicity for three groups of water organisms. These are;

Fish = $\frac{LC_{50}}{100}$, LC_{50} = the median lethal concentration (mg kg^{-1})

Daphnia = $\frac{EC_{50}}{100}$ EC_{50} = the median effect concentration (mg L^{-1})

Algae = $\frac{NOEC}{10}$ NOEC = the No Observed Effect Concentration (mg L^{-1})

The lowest of the three quotients is used as the toxicological reference. In this study, daphnia was used as the toxicological reference for azoxystrobin, carbendazim, difenoconazole, prothioconazole, thiophanate-methyl and trifloxystrobin a.i. due to having $\min(NORM_w)$. Fish has $\min(NORM_w)$ for fluquinconazole, propiconazole, and pyraclostrobin a.i. Algae was used for epoxiconazole, prochloraz, spiroxamine, tebuconazole and triadimenol a.i. in Equation (7) [17,20].

2.1.5. Birds (RI_{birds})

The risk index for birds (RI_{birds}) is calculated with Equation (8) [20].

$$RI_{BIRDS} = \frac{(PEC_{BIRD} \times 10)}{(LD_{50} \times BW)} \tag{8}$$

The total daily intake of pesticide for birds (PEC_{birds}) eating treated crops is calculated using Equation (9) [20].

$$PEC_{BIRD} = 31 \times AR \times BW \times 0.3 \tag{9}$$

2.1.6. Earthworms ($RI_{earthworms}$)

The risk index for earthworms is calculated with Equations (10) and (11) [15,17,20,22].

$$RI_{earthworms} = \frac{PEC_{bottom} \times 10}{LC_{50}} \tag{10}$$

$$PEC_{bottom} = \frac{D \times \%drift \times n \times (1 - f)}{d_{bottom} \times \rho_{bottom}} \tag{11}$$

2.1.7. Bees (RI_{bees})

The risk index for bees is calculated with Equation (12) [14,20,22].

$$RI_{bees} = \frac{AR}{LD_{50} \times 10} \tag{12}$$

2.1.8. Beneficial Arthropods ($RI_{beneficial\ arthropods}$)

The risk index for beneficial arthropods is calculated with Equation (13) [15,20].

$$RI_{beneficial\ arthropods} = \frac{(RC - 25)}{(100 - 25)} \tag{13}$$

2.1.9. Persistence in Soil ($RI_{persistence}$)

The risk index for persistence in soil is calculated with Equation (14) [15,20,22].

$$RI_{persistence} = 10^{(DT_{50}/90 - 1) \times 2} \tag{14}$$

2.1.10. Leaching to Groundwater ($RI_{groundwater}$)

The risk index for leaching to groundwater is calculated with Equation (15) [15,20].

$$RI_{groundwater} = \frac{PEC_{groundwater}}{0.1} \tag{15}$$

2.2. Integration of the Risk Indices into a Total Risk Indicator

The risk of a pesticide to different components is determined if the lower limit is exceeded. This exceedence factor (EF) is calculated with Equation (16) [20].

$$EF = \left(\frac{X_{TRANSFORMED} - LL^{+}_{TRANSFORMED}}{UL^{+}{}_{TRANSFORMED} - LL^{+}_{TRANSFORMED}} \right) \quad (16)$$

The relative RI, LL and UL values (RI^+, LL^+ and UL^+) are calculated by dividing, respectively the risk index values (RI), LL and UL by UL. These RI^+, LL^+ and UL^+ values are then transformed using Equation (17) [20].

$$X_{transformed} = \log\left(1 + \frac{1}{X}\right) \quad (17)$$

with

$$X = RI^+, LL^+ \text{ and } UL^+.$$

EF is exceedence factor. X is RI^+, LL^+ and UL^+. LL and UL is lower limit and upper limit for the 10 risk indices.

The total risk of pesticide on non-target organisms that fall under the categories of human health and environment is calculated by summing the values of 10 modules assuming that all modules are equally important. Therefore, using the POCER indicator for calculating the total risk of a pesticide for human health and environment will provide a value from 0–10 [20].

3. Results and Discussion

The applied doses of a.i. used in fungicide applications to control black, brown, and yellow rust (*Puccinia spp*.), and septoria leaf spot (*Septoria spp*.) in wheat are given in Table 2. The EF values of a.i. calculated by Equations (16) and (17) are also provided in Table 2. According to Vercruysse and Steurbaut (2002), EF values lower or equal to 0 are set to 0 to indicate a low risk. EF values higher or equal to 1 are set to 1 to indicate a high risk. An intermediate risk is found for values between 0 and 1 [20].

3.1. Risk to Human Health

In this study, it was determined that all of the fungicide a.i. have a total risk to human health, although the exact cause of the risk varies between the a.i. For instance, as seen in Table 2, azoxystrobin, difenoconazole, prothioconazole, propiconazole, tebuconazole, thiophanate-methyl, triadimenol and trifloxystrobin have a low risk to an operator in fungicide application due to their 0.000 EF values. However, fluquinconazole (0.798), prochloraz (0.438), epoxiconazole (0.352 and 0.378), pyraclostrobin (0.299), spiroxamine (0.258) and carbendazim (0.151) a.i. have intermediate risks for the operator.

Table 2. Applied dose and Exceedence Factor (EF) values for fungicide a.i. applied in wheat cultivation.

Active ingredients		Human health			Environment						
Name	**Applied dose (kg a.i. ha^{-1}) #**	**Operator**	**Worker**	**Bystander**	**Persistence**	**Beneficial arthropods**	**Aquatic organisms**	**Birds**	**Bees**	**Earthworms**	**Groundwater**
Azoxystrobin	0.0650	0.000	0.625	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Carbendazim	0.1250	0.151	1.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000
Difenoconazole	0.0600	0.000	0.657	0.000	0.505	0.000	0.000	0.000	0.000	0.000	0.000
Epoxiconazole (1) *	0.1122	0.352	1.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000
Epoxiconazole (2)	0.1250	0.378	1.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000
Fluquinconazole	0.1000	0.798	1.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000
Prochloraz	0.5000	0.438	1.000	0.000	0.382	0.000	0.000	0.000	0.000	0.000	0.000
Propiconazole (1)	0.0600	0.000	0.758	0.000	1.000	1.000	0.000	0.000	0.000	0.000	0.000
Propiconazole (2)	0.1125	0.000	0.878	0.000	1.000	1.000	0.000	0.000	0.000	0.000	0.000
Propiconazole (3)	0.1250	0.000	0.897	0.000	1.000	1.000	0.000	0.000	0.000	0.000	0.000
Prothioconazole	0.1750	0.000	0.833	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Pyraclostrobin	0.1700	0.299	1.000	0.000	0.000	0.987	0.411	0.000	0.000	0.000	0.000
Spiroxamine	0.1440	0.258	1.000	0.000	0.000	0.987	0.630	0.000	0.000	0.000	0.000
Tebuconazole	0.1002	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Thiophanate-methyl	0.1860	0.000	0.991	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Triadimenol	0.0258	0.000	0.727	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000
Trifloxystrobin	0.0880	0.000	0.923	0.000	0.000	0.907	0.097	0.000	0.000	0.000	0.000

#: Manufacturer's recommended application rates from the product labels; *: Propiconazole a.i. and epoxiconazole was applied different doses.

As shown in Table 2, all a.i. pose a risk to workers in fungicide application. Carbendazim, epoxiconazole, fluquinconazole, prochloraz, pyraclostrobin, spiroxamine, and tebuconazole have the maximum EF value of 1.000. Carbendazim, epoxiconazole, prochloraz, and tebuconazole fall under the reproduction risk category they can lead to impaired fertility and potentially harm unborn children [10]. Moreover, thiophanate-methyl (0.991), trifloxystrobin (0.923), propiconazole (0.758, 0.878, and 0.897), prothioconazole (0.833), triadimenol (0.727), difenoconazole (0.657), and azoxystrobin (0.625) pose an intermediate risk due to their EF values between 0.000 and 1.000. Triadimenol has the possible risk of impaired fertility and harm to unborn children, and may cause harm to breast-fed babies [10]. In Turkey, generally workers and operators do not generally use personal protective equipment (PPE) during pesticide applications due to the prevailing hot climate. For workers, protective clothes reduce potential risk from 1.000–0.637 in defoliant applications [23]. Minimizing the area of exposed skin by using PPE such as rubber gloves, boots, and aprons also reduces risk [16,23–28]. Claman (2004) suggested that operators need to be warned with simple clear labeling to minimize exposure to toxins by use of protective clothing, gloves and careful application techniques—including the routine use of enclosed/covered tractor cabs—during pesticide application [26].

In this study, although all the a.i. have low risk for bystanders (EF 0.000), because bystanders have no PPE, bystander exposure in pesticide application can be reduced by the appropriate application of techniques and use of nozzles [29,30].

3.2. Risk to Environment

In this study, it was determined that azoxystrobin, prothioconazole, thiophanate-methyl and tebuconazole have low total risk to the environment due to their zero EF values. Epoxiconazole, fluquinconazole, propiconazole, and triadimenol have high risk due to their 1.000 EF value. Difenoconazole (0.505) and prochloraz (0.382) has intermediate risk for persistence in soil.

As seen in Table 2, azoxystrobin, difenoconazole, epoxiconazole, fluquinconazole, prochloraz, prothioconazole, thiophanate-methyl, tebuconazole, and triadimenol have low risk due to their zero EF value for beneficial arthropods. Carbendazim and propiconazole have high risk due to their 1.000 EF value. Pyraclostrobin and spiroxamine a.i. have intermediate risk due to their 0.987 EF value.

Azoxystrobin, carbendazim, difenoconazole, epoxiconazole, fluquinconazole, prochloraz, propiconazole, prothioconazole, thiophanate-methyl, tebuconazole, and triadimenol have low risk 0.000 EF value for aquatic organisms. Spiroxamine (0.630), pyraclostrobin (0.411), and trifloxystrobin (0.097) have intermediate risk. The appropriate application techniques and equipment during application of these a.i. should be taken into account for protecting aquatic organisms [31,32].

In this study, it was determined that there was no score between 0.000 and 1.000 EF for any a.i. with regard to birds, bees, earthworms, and leaching to groundwater. According to Vercruysse and Steurbaut (2002), in this study, all a.i. have low risk for these non-target organisms [20].

3.3. Total Risks for Non-Target Organisms

The total potential risk values for non-target organisms were shown in Table 2. Total scores ranged between 0 and 3 for human health, and between 0 and 7 for environment. Total EF value for each a.i. ranged between 0 and 10 for non-target organisms. Theoretical total EF value was calculated such that a.i. was multiplied by 3 to provide the total score for human health for each a.i., and by 7 to determine the total score for environment for each a.i. According to this calculation, in this study, it was determined that the human health risk score was higher than the environment risk score. Total risk score values were calculated as 35.18% for human health, and 13.35% for environment. In this study, the sum of non-target organisms risk score was assessed as 19.90% of total score.

As seen in Table 2, the highest total risk value for human health was in fluquinconazole a.i. (1.798) due to the fact that maximum total score of human health is 3 that is sum of worker, operator, and bystander. The human health risk value for fluquinconazole was assessed as 1.000 for workers and 0.798 for operators. Fluquinconazole causes harm if inhaled, and is toxic if swallowed. Moreover, it is capable of causing serious damage to health by prolonged exposure [10]. In this study, all the a.i. pose a risk to human health because they have EF values above zero. The lowest total score for human health was determined for azoxystrobin (EF 0.625).

In this study, it was determined that human health risk score was 53.03% of total risk values in fungicide application for wheat cultivation areas. It means that human health risk is higher than that for the environment. Environment pollution can be reduced by using the proper application technique and nozzles in pesticide application [28–33]. Special education programs are needed in agricultural regions to promote the safe use of pesticides in the field to decrease the risks from exposure to pesticides for farmers, and from secondary exposure to these compounds for their families [34]. During the mixing process, two layer gloves should be worn for minimizing dermal exposure of hands [35]. Educational training programs focusing on basic safety precautions and proper uses of personal protection equipment (PPE) are possible interventions that could be used to control the respiratory diseases associated with pesticide exposure in occupational settings [36]. Kim *et al*. (2013) indicated an increased risk of pesticide poisoning with the lack of proper use of gloves or masks as personal protective equipment during pesticide application [37]. Godyn *et al*. (2012) observed of sprayer technical condition on operator exposure and human health [38]. A variable rate sprayer could be used for spot application of fungicides to reduce chemical usage for the protection of the environment [39]. In EU safety phrases which are defined in Annex II of EU Directive 67/548/EEC as amended by EU Directive 2001/59/EC, it is stated suitable protective clothing, gloves and eye/face protection should be worn during spiroxamine application [10]. According to this Directive, it is sufficient to wear only suitable protective clothing and gloves for epoxiconazole, propiconazole, tebuconazole, and thiophanate-methyl, and gloves for trifloxystrobin [10]. In this study, these a.i. was 13,792 kg, about 50% of which was used in wheat cultivation for fungus control.

4. Conclusions

In this study, it was obtained that propiconazole, spiroxamine, fluquinconazole, and pyraclostrobin have the highest total risk on human health and the environment due to the fact that their EF values are higher than others. In Adana, in 2012, the total use of these a.i. was 7875 kg in wheat cultivation. This value equals approximately 30% of total use, and has high potential risk for non-target organisms. The highest total potential risk was determined in fluquinconazole for human health (1.798), and in propiconazole for the environment (2.000). Azoxystrobin, prothioconazole, tebuconazole, and thiophanate-methyl has low total potential risk on the environment due to 0.000 EF values. The total use of four a.i. was 5052 kg, which equals approximately 20% of total consumption in protecting wheat against fungus. The most important conclusion which can be derived from this study is that some factors such as application techniques and equipment, meteorological conditions, buffer zone and use of personnel protective equipment during fungicide application in wheat cultivation areas should be taken into account for the protection of non-target organisms, human health and the environment for the purposes of agricultural sustainability.

Conflicts of Interest

The author declares no conflict of interest.

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