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Evaluating Environmental Impacts of Herbicides on Wheat Agroecosystems in the Provinces of Iran Using EIQ Model

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Abstract
There is an increasing need among herbicide users, consumers and policy-makers to acquire more information about the risk of herbicides to human health and the environment. This study analyzed the changes in herbicide use and risk throughout all the provinces of Iran, from 1994 to 2004. Herbicide risk was calculated by multiplying the amount of herbicides used (tone of active ingredient) by the Environmental Impact Quotient (EIQ), a scoring system for the potential risk of pesticides to farm-workers, consumers and the environment based on a 1, 3 and 5 scale. Results indicate that herbicide use has increased in all provinces during this period. At the same time, mean herbicides toxicity, measured as EIQ, has declined from 25.03 to 23.7. Although mean EIQ has decreased, the Environmental Impacts (EI) of herbicides have increased due to high herbicide use in most provinces. Among herbicides registered on wheat, Difenzoquat (30.8) and Dichlorprop-p + Mecoprop-p + MCPA (29.3) have the highest EIQ. The lowest EIQ was calculated for Tribenuron-methyl (15) and Flamprop-M- isopropyl (16). Also, during last decades, eight provinces including Fars, Khuzestan, Golestan, Lorestan, Kermanshah, Khorasan, West Azarbayjan and Ardabil were shown to be more vulnerable to herbicides according to data of herbicide use and their environmental impacts.

Keywords: Environmental Impact, EIQ Model, Herbicide, Risk.

استفاده از مدل EIQ در ارزیابی اثرات زیست محیطی علف‌کش‌ها در اکوسیستم‌های زراعی گندم درکشور

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چکیده
امروزه، نیاز فزاینده‌ای در میان استفاده‌کنندگان علف‌کش‌ها، مصرف‌کنندگان و سیاست‌گزاران برای کسب آگاهی بیشتر در زمینه خطرات بالقوه سموم شیمیایی بر سلامت انسان و محیطی زیست وجود دارد. بدین منظور و برای تعیین اثرات محیطی علف‌کش‌های بکار رفته در مزارع گندم طی ۱۰ سال گذشته در استان‌های مختلف کشور، از مدل ضریب اثر محیطی (EIQ) استفاده گردید. اساس این مدل بر مبنای سیستم نمره دهی می باشد که مقیاس آن ۱، ۳ و ۵ است. نتایج این تحقیق نشان داد که دوعلف‌کش دیکلورپروپ‌پی+ مکوپروپ‌پی+ ام‌سی‌پی‌آ (دوپلسان سوپر) و دیفن‌زوکوات (آونج) جزء علف‌کش‌های پرخطر، و علف‌کش‌های تری‌بنورون‌متیل (گرانستار)، و فلم‌پروپ ام ایزوپروپیل (سافیکس‌بی‌دبلیو) جزء سموم کم‌خطر و ایمن‌تر در میان علف‌کش‌های به ثبت رسیده در گندم در طی ۱۰ سال گذشته می‌باشند. همچنین میزان توزیع (مصرف) و نیز به تبع آن اثرات محیطی (EI) علف‌کش‌ها بر اکوسیستم‌های زراعی گندم در اکثر استان‌های کشور روندی صعودی داشته و احتمال می‌رود این روند همچنان ادامه داشته باشد. با توجه به میزان مصرف و ضرایب اثر محیطی سموم علف‌کش، هشت استان فارس، خوزستان، گلستان، لرستان، کرمانشاه، خراسان، آذربایجان غربی و اردبیل که مجموعا ۶۲ درصد کل گندم تولیدی کشور در آنها می باشد، نسبت به بقیه استان‌ها در ۱۰ سال گذشته بیشتر در معرض خطرات زیست محیطی علف‌کش‌ها قرار داشته‌اند. همچنین طی این دوره (از سال ۷۳ تا ۸۳) اثرات محیطی سموم علف‌کش در تمامی این استان‌ها (به استثنای استان گلستان) سیر صعودی داشته است. افزایش اثرات محیطی سموم علف‌کش در اکثر استان‌های کشور، عمدتاً ناشی از افزایش مصرف (توزیع) سموم در این استان‌ها می‌باشد.

کلید واژه‌ها: علف‌کش، خطر محیطی، مدل EIQ.

Introduction

Weeds are one of the limiting factors on crop production worldwide and cause serious yield losses. As about a half of human labor in small-holder farming is devoted to weeding, weeds could be considered as a socio-economic problem in these systems (Zand *et al.* 2002). Various herbicides have been produced and registered worldwide to overcome this problem. However, a substantial increase in pesticide and especially herbicide use for maximizing crop production has resulted in severe impacts on existing agroecosystems.

As the environmental hazards of pesticides were discovered, efforts were begun to decrease or even eliminate their use in agricultural systems. In most cases, reduction of pesticide use will lessen its hazardous impacts on humans and the environment. In other words, decline in pesticide use means decreasing exposure to pesticides. Most researchers argue that programs for reducing pesticide use should be based on reducing pesticide risk for consumers and non-target organisms; i.e. a reduction in application rate (active ingredients) should result in the decrease of pesticide risk (Gallivan *et al.*, 2001). Following the new emerging need for awareness of pesticide impacts on human and ecosystem health among workers, consumers and policy-makers, quantifying pesticide risk has became a necessity. Sampling, monitoring and tracking pesticides is an approach used in environmental risk assessment, but the procedure is extremely expensive. So, methods have developed for predicting the environmental impacts (EI) of pesticides which assess their risks before application (Reus *et al.*, 2002). Models that evaluate the complex of various factors including consumers, the environment and living organisms are more effective and precise in environmental risk assessments (Dunn, 2004).

In the present paper, the history of herbicide use during last decade in the Project on National Wheat Self-Sufficiency and changes in their environmental risk throughout various provinces in Iran is studied and analyzed. The objective of the study was to evaluate the changes in herbicide use and risk in each province, using EIQ model for environmental risk assessment of registered herbicides on wheat during the last decade.

Materials and Methods

The list of herbicides registered on wheat during 1968-2004 and their formulation, dosage and mode of action was prepared according to data provided by the Iran Plant Protection Organization (IPPO, 2002). The data required for this project were: the amount of herbicide (active ingredient) used in each individual province, the risk of each herbicide, and the area of wheat production. Data on amount (tone) of each herbicide and total pesticide used on wheat (insecticide, fungicide, etc.) in all provinces were also obtained from the database of IPPO. The area of wheat production was obtained from the office of Agriculture Statistics for Iran (Iran Ministry of Jihad -e- Agriculture, 1995, 1997, 1999, 2001, 2002, 2003, 2004).

The first stage of the risk assessment was to survey the literature on pesticide scoring systems to select those applicable to the situation in Iran. Selected scoring systems had to provide for a broad range of environmental impacts (human, avian, aquatic, and beneficial, etc.). After examining the available scoring systems, the most appropriate was the Environmental Impact Quotient (EIQ), a system developed by the Integrated Pest Management Program at Cornell University (Kovach *et al.*, 1992), as a measure of the risk of individual pesticides:

All the input variables are scored as 1, 3 and 5. Some indicators like toxicity for honey bees, beneficial insects, leaching and runoff potential, chronic toxicity and mode of action are categorical indicators; i.e. for their low, medium and high measures, their scores were 1, 3 and 5 respectively (Table 1). The ranking system for numerical indicators (such as dermal acute

$$EIQ = C\,[(DT \times 5) + (DT \times P)] + (C \times ((S+P)/2) \times SY) + (L) + (F \times R) + (D \times ((S+P)/2) \times 3) + (Z \times P \times 3) + (B \times P \times 5))/3$$

C = Chronic toxicity
S = Soil residue half-life
F = Fish toxicity
Z = Lethality to honey bees
DT = Dermal toxicity (acute)
SY = Systemicity
R = Run-off potential
B = Beneficial organism toxicity
P = Plant surface residue half-life
L = Leaching potential
D = Bird toxicity

Equation 1. Environmental Impact Quotient (EIQ) model for evaluating of herbicide risk. (Kovach *et al.*, 1992; Gallivan *et al.*, 2001; Gallivan *et al.*, 2005)

toxicity, toxicity for birds, half-life in soil and plant surface are given in Table 1.

Risk is a function of the toxicity of a chemical and the exposure to that chemical (Gallivan *et al.*, 2005; Dunn, 2004, Equation 2):

Risk = f (Toxicity × Exposure) (Eq. 2)

Hence, equation 3 (Gallivan *et al.*, 2001) was used to calculate the environmental impact of registered herbicides in individual province based on amount used:

$$EI_{province\ i} = \sum_{herbicides\ used} (Amount_{herbicide\ i} \times EIQ_{herbicide\ i}) \quad \text{(Eq. 3)}$$

which $EI_{province\ i}$ is the environmental impact of herbicides in the province i, $EIQ_{herbicide\ i}$ is the environmental impact quotient of herbicide i and $Amount_{herbicide\ i}$ is the amount of herbicide i use (tone) in province i.

The toxicity data of registered herbicides including acute toxicity (LD_{50} and LC_{50}), chronic toxicity, carcinogenic potential, impact on human fertility, and mutagenesis potential, as well as herbicide impact on the ecosystem and beneficial organisms like honey bees and birds, were collected from Database (US EPA Extoxnet Database, 1996; Crop Protection Handbook, 2003; US EPA ECOTOX Database, 2003). Then, herbicides were classified according to their use and environmental impacts in each province and, finally, high-use and high-risk herbicides were identified.

Results and Discussion

A Review of Registered Herbicides in Wheat and their EIQ

Results indicate that herbicides accounted for one third of pesticides used in Iran and this reflects the importance of herbicides to weed management in the farming systems in Iran. 37 percent (3708 tone) of total herbicide use (10006 tones in 2004-2005 cropping season) was applied on wheat agroecosystems (Iran Plant Protection Organization, unpublished data). 17 herbicides are registered for wheat which is remarkable in comparison with any other main crop in Iran. From 17 registered herbicides, 7 herbicides were for broadleaves, 7 herbicides for grasses and 3 herbicides were dual-purpose (Table 2).

Table 2 also shows the EIQs of wheat herbicides registered for wheat in Iran. As mentioned before, the EIQ consists of three major categories: effects on farm-workers, consumers and ecological impact. 6 of the herbicides for wheat have the highest EIQ. These herbicides are Difenzoquat (30.8), 2, 4- D + MCPA (29.6), Dichlorprop-p + Mecoprop-p + MCPA (29.3), Dichlofop methyl (29), Fenoxaprop-p ethyl (28.6) and Bromoxynil + MCPA (28.3) (Table 2). The lowest EIQ was calculated for Tribenuron-methyl (15) and Flamprop-M- isopropyl (16). The average EIQs of grass herbicides, broadleaf herbicides and dual-purpose herbicides were respectively 25.2, 23.4 and 19.9 which indicates the higher environmental toxicity of broadleaf herbicides.

Table 1. Criteria for Scoring EIQ Variables.

Variable	Sym	Rating Scores & Criteria		
		1	3	5
Chronic Toxicity *	C	little or none	possible	definite
Acute dermal toxicity (LD_{50} for rabbits/rats mg kg^{-1})	DT	>2000	200-2000	0-200
Bird toxicity (8 day LC_{50})	D	>1000 ppm	100-1000 ppm	1-100 ppm
Lethality to honey bees (at field doses)	Z	relatively non toxic or > 100 µ g	moderately toxic or 2-100 µg	highly toxic or < 2 µg
Beneficial organism toxicity	B	low impact	moderate impact or post-emergent herbicides	severe impact
Fish toxicity (96 hr LC_{50})	F	>10 ppm	1-10 ppm	< 1 ppm
Soil residue half-life (days)	S	<30	30-100	>100
Plant surface residue half-life	P	1-2 weeks and Pre-emergence herbicides	2-4 weeks and Post-emergence herbicides	>4 weeks
Mode of Action (Systemicity)	SY	non-systemic and all herbicides	systemic	-
Leaching and run-off potential Log (half-life) (4-log (Koc))	L, R	Small or < 1.8	Medium or 1.8-2.8	Large or > 2.8

* The chronic toxicity variable (C) is based on long term health impacts, calculated as the average of ratings from laboratory tests on small mammals designed to assess reproductive, teratogenic (causing deformities in offspring), mutagenic (affecting genes and chromosomes), and oncogenic (tumor growth) effects.

Source: adapted from levitan (1997); cross and Edwards-jones (2006).

Changes in Herbicide Use, and Herbicide Risk Based on the EIQ and Environmental Impacts in all Provinces

The EIQ measures the potential risk of a herbicide while the EI measures the risk associated with herbicide use. During the last decade, eight provinces had the highest herbicide use on wheat (Table 3). The highest environmental impacts were also recorded in these provinces. The provinces with the highest environmental impacts in 1994 and 2004 are presented in Figure 1. The highest environmental impacts were recorded in Fars and Golestan during the 1994-1995 cropping season. In 2003-2004, the highest environmental impacts were seen in Khuzestan and Fars. In the whole ten-year period (1994-2004), the changes in the environmental impacts of herbicides in all provinces (but Golestan) were incremental (Figure 1). The highest increase in environmental impacts from herbicides were for Khuzestan and Lorestan, respectively (Figure 1, Table 3). The rise in environmental impacts in most provinces was mainly due to an increase in herbicide use. As the highest wheat production during 2003-2004 cropping season were recorded in these provinces and 62 percent of wheat was produced in these provinces (Iran Ministry of Jihad -e- Agriculture), it can be concluded that the risk of herbicide exposure is higher in these regions. In Khuzestan, herbicide use

Table 2. Herbicides registered on wheat in Iran.

Common name	Trade name	Formulation	Registration year	EIQ
Broadleaf Herbicides				
Bromoxynil + MCPA	Bromicide AM	40 % EC	2002	28.3
2, 4- D + MCPA	U- 46- Kambi	67.5 % SL	1968	29.6
2, 4- D	U- 46- D	72 % SL	1968	22.6
Tribenuron- methyl	Granstar	75 % DF	1990	15
Bromoxynil	Brominal (Pardner)	22.5 % SL	1986	20
Dichlorprop-p + Mecoprop-p + MCPA	Duplosan Super	60 % SL	1995	29.3
Triasulfuron + terbutryne	Logran Extra	64 % WG	2001	22.8
Grass Herbicides				
Dichlofop methyl	Illoxan	36 % EC	1980	29
Fenoxaprop-p ethyl	Puma Super	7.5 % EW	1993	28.6
Clodinafop-propargyl	Tapik	8 % EC	1994	25.3
Tralkoxydim	Grasp	25 % SC	1998	22
Difenzoquat	Avenge	25 % SL	1975	30.8
Flamprop-M- isopropyl	Suffix BW	20 % EC	1991	16
Dual-purpose herbicides				
Mesosulfuron-Methyl + Iodosulfuron-methyl-sodium	Chevalier	6 % WG	2004	21.5
Sulfosulfuron	Apyrus	75 % WG	2003	20.33
Imazamethabenz- Methyl	Assert	25 % SC	1995	18

Sources: (Kovach *et al.*, 1992; Zand *et al.*, 2003; Montazeri *et al.*, 2005).

has increased from 251.9 tone in 1994-1995 to 593 tone in the 2004-2005 cropping season. The data for Fars and Lorestan are 369.7 and 114.9 tone in 1994-1995 and 530 and 283 tone in 2004-2005, respectively. According to these results, the environmental impacts of herbicides in these provinces have risen during this period. In general, results show that, in this period, herbicide use and environmental impacts have increased (Table 3). In all 8 provinces which had highest herbicide use, 2, 4- D + MCPA, Bromoxynil Tribenuron- methyl, Difenzoquat, Dichlofop methyl, Tralkoxydim, Fenoxaprop-p ethyl and Clodinafop-propargyl were used in the 1994-1995 cropping season which their mean EIQ is 25.03. During the past 10 years, with the registering of new herbicides, the average EIQ has declined to 23.7 but their environmental impacts have increased due to a rise in herbicide use. As indicated in Table 3, herbicide use has increased in all provinces during this period (1994-2004). Although mean EIQ has decreased, the environmental impacts of herbicides have increased due to greater herbicide use in most provinces. The lowest herbicide use was recorded in Qom, Guilan, Bushehr and Sistan-Baluchestan

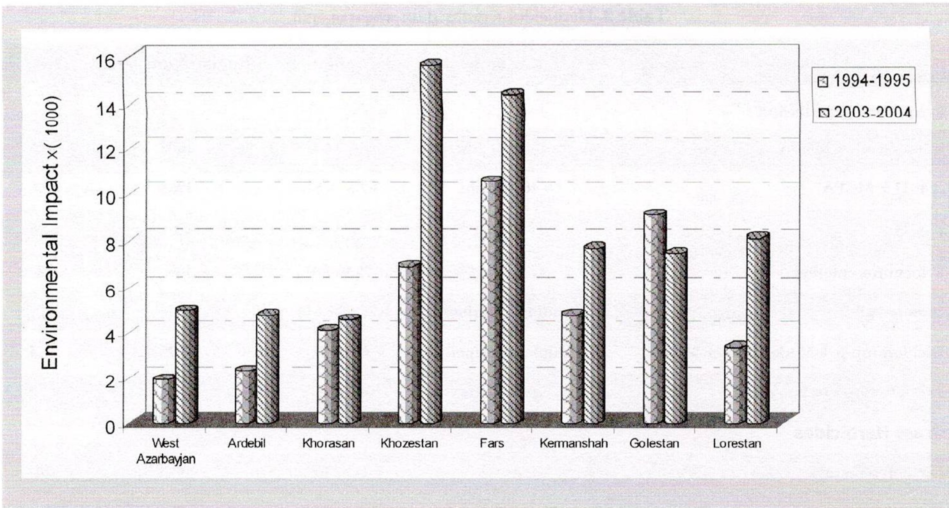

Figure 1. Environmental impacts of wheat herbicides in provinces with the highest use during last decade.

Provinces (Table 3). A few European countries, such as Denmark, Sweden and the Netherlands, have targeted national plans for the reduction of pesticide use in agriculture, calling for a reduction of 50% or more within a 10-year period. Saethre *et al.*, (1999) reported that from 1986 to 1997 the overall reduction in pesticide use was more than 49% in Norway. Brimner *et al.*, (2005) in a study on the environmental impacts of herbicides used on canola in Canada concluded that, during 1995-2000, the amount of active ingredients from herbicides and their environmental impacts per hectare has increased 42.8 and 36.8 percent, respectively.

As herbicide use probably increased due to an increase in wheat-based farming systems, the ratio of herbicide use to crop area has increased in six provinces (but Golestan has the highest herbicide use). This means the herbicide use per area has increased during this period. However, with the exception of Golestan Province in the first year (1994-1995), these ratios remain less than 1; i.e. herbicide use was always less than area. The lowest ratio was recorded in Khorassan in both the first and last years of the study period (Figure 2), while the herbicide use in this province was highest in comparison with most provinces, this is due to it having the highest wheat area (675000 ha). Therefore, it can be concluded that, in relation to its area, herbicide use in this province is low (Figure 2).

Among the rainy provinces (Guilan, Mazandaran and Golestan) only Golestan ranked as province with highest herbicide use and environmental impacts (EI) (Table 3; Figure 1, 2). As in these provinces, the risk of leaching and surface run-off of herbicides and therefore their impact on consumers will accelerate, so it should be denied to high use of herbicides with higher EIQ. Brady *et al.*, (2006) reported that the winter months are the rainy season for the Central Valley, thus creating the potential for greater pesticide transport from rain-induced runoff following winter spray applications and make it an area highly susceptible to contamination.

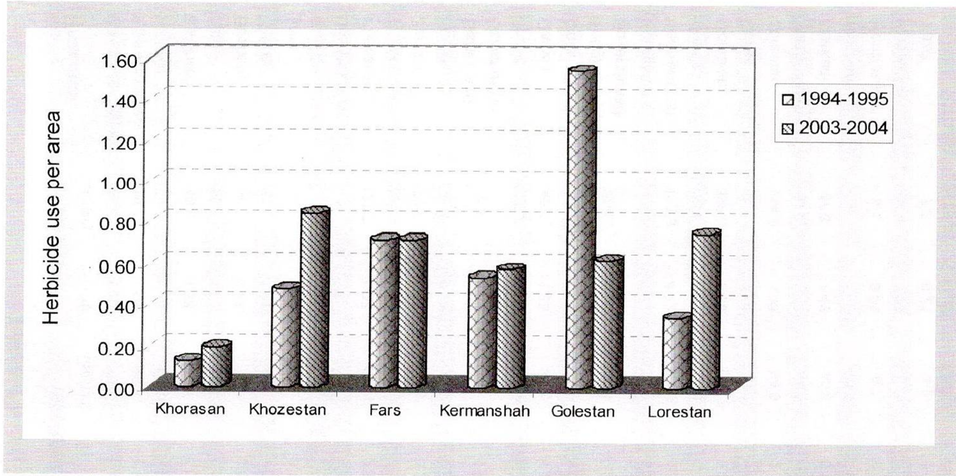

Figure 2. Herbicide use per area in provinces with the highest use during last decade.

Conclusion

The main objective of an integrated weed management (IWM) program is the reduction of herbicide use and dependence. Furthermore, sustainable agriculture seeks for reducing environmental pesticides risks in order to conserve the environment and living organisms. Results of this study showed that herbicide use and its environmental impacts in wheat-based farming systems has accelerated during last decade and prediction shows that this trend will be same in the future.

It can be also concluded that, during the last decades, the eight provinces of Fars, Khuzestan, Golestan, Lorestan, Kermanshah, Khorasan, West Azarbayjan and Ardabil were more vulnerable to environmental herbicide impacts base on data of herbicide use and the environmental impact quotient. On the other hand, herbicide use per area has increased during this period. The lowest ratio was recorded in Khorassan in both the first and last years of the study period; while herbicide use in this province was highest compared with most provinces, this is due to it having the highest wheat area (675000 ha). Therefore, it can be concluded that, in terms of planting area, herbicide use in this province is low.

As changes in wheat area has been more or less similar during last decade, it can be concluded that, production increase has mainly been due to increased inputs, especially herbicides, which have resulted in the sustainability of wheat agroecosystems falling in all provinces. This will continue unless policies are revised and reconsidered. The first step towards this, is the introduction of newer herbicides with lower dosages as well as lower environmental impact quotients (EIQ). Second, the elimination of herbicides with high EIQs. Also, herbicide use should be reduced in the rainy regions of the northern parts of the country to minimize the environmental impacts of herbicides in wheat agroecosystems.

Table 3. Use and environmental impacts of wheat herbicides in the all provinces during last decade.

Province	1994-1995		1995-1996		1997-1998		1998-1999		2000-2001		2002-2003		2003-2004	
	Use (ton)	EI ($\times 10^3$)	Use (ton)	EI ($\times 10^3$)	Use (ton)	EI ($\times 10^3$)	Use (ton)	EI ($\times 10^3$)	Use (ton)	EI ($\times 10^3$)	Use (ton)	EI ($\times 10^3$)	Use (ton)	EI ($\times 10^3$)
West Azarbayjan	64.4	1.90	78.7	1.80	797.5	23.59	67.1	1.97	55.6	1.63	77.2	2.27	188.4	4.92
East Azarbayjan	52.1	1.54	49.5	1.14	98.0	2.89	62.1	1.83	51.0	1.49	65.0	1.84	150.4	3.62
Ardabil	77.9	2.30	57.9	1.47	101.1	3.01	77.1	2.29	72.1	2.09	87.2	2.52	174.9	4.71
Esfahan	46.6	1.33	43.8	1.04	54.5	1.51	50.1	1.47	53.5	1.53	57.4	1.62	100.0	2.82
Ilam	59.7	1.73	52.3	1.22	54.2	1.58	47.1	1.37	56.8	1.61	108.4	3.07	131.6	3.67
Bushehr	4.3	0.13	2.3	0.05	5.1	0.15	3.4	0.10	5.1	0.14	9.1	0.24	23.0	0.65
Tehran	62.3	1.71	50.6	1.23	35.8	1.03	45.7	1.35	43.0	1.22	34.0	0.93	72.3	2.02
jiroft	6.4	0.19	5.9	0.14	10.5	0.30	2.9	0.07	4.1	0.11	13.4	0.36	38.5	1.08
Cheharmahal and Bakhtiari	43.5	1.24	24.0	0.54	34.5	1.02	32.7	0.96	27.5	0.81	32.1	0.94	54.4	1.54
Khorasan	137.7	4.07	127.1	2.91	170.5	4.55	116.6	3.41	87.3	2.48	136.9	3.88	160.8	4.52
Khuzestan	251.9	6.89	301.1	7.16	204.0	5.82	227.5	6.44	306.1	8.37	396.4	10.90	593.6	15.56
Zanjan	20.4	0.60	10.6	0.25	21.7	0.64	13.0	0.37	10.5	0.30	10.7	0.30	24.0	0.65
Semnan	26.1	0.71	22.7	0.51	21.4	0.62	9.9	0.29	16.6	0.46	16.1	0.44	33.6	0.88
Sistan and Baluchestan	7.5	0.22	3.1	0.07	6.3	0.17	4.3	0.13	3.3	0.09	3.7	0.11	3.3	0.10
Fars	369.7	10.52	340.8	8.45	234.9	6.52	228.1	6.38	396.3	11.05	398.4	10.87	530.1	14.34
Qazvin	45.1	1.33	42.5	1.01	46.4	1.36	23.3	0.68	33.3	0.95	42.2	1.18	61.2	1.71
Qom	0.0	0.00	0.0	0.00	15.0	0.38	8.7	0.24	6.8	0.19	4.6	0.12	10.2	0.28
Kohgiluyeh and Boyerahmad	26.5	0.78	16.3	0.38	14.1	0.39	9.5	0.28	29.5	0.85	59.3	1.67	86.1	2.43
Kordestan	27.8	0.82	21.9	0.50	36.7	1.08	33.9	1.00	26.0	0.76	33.2	0.98	81.0	2.33
Kermanshah	162.6	4.72	152.5	3.51	200.0	5.85	160.4	4.70	98.1	2.81	177.7	5.01	273.1	7.68
Kerman	13.0	0.38	18.0	0.47	14.0	0.40	62.3	1.82	22.3	0.60	27.5	0.74	42.3	1.11
Golestan	320.6	9.09	334.2	8.80	260.2	6.83	171.5	4.96	325.2	9.26	262.6	7.28	276.4	7.44
Guilan	4.7	0.14	2.3	0.05	1.1	0.03	2.0	0.06	1.5	0.04	1.0	0.03	1.0	0.03
Lorestan	114.9	3.33	94.5	2.19	200.4	5.56	173.5	5.12	141.8	4.06	162.6	4.66	283.8	8.09
Mazandaran	61.6	1.72	44.3	1.04	32.8	0.88	15.4	0.44	26.5	0.73	43.8	1.14	71.3	1.97
Markazi	47.6	1.42	40.8	0.97	59	1.72	37.9	1.12	25.1	0.73	27.6	0.81	49.4	1.39
Moghan	-	-	28.4	0.67	-	-	-	-	14	0.39	-	-	29.6	0.75
Hormozgan	3.1	0.09	6.7	0.17	10.0	0.29	6.2	0.18	5.5	0.15	9.0	0.24	22.1	0.59
Hamedan	64.4	1.90	61.7	1.41	71.8	1.99	51.7	1.48	29.8	0.86	25.8	0.74	71.1	2.00
Yazd	7.2	0.21	4.9	0.13	5.0	0.14	5.5	0.16	8.2	0.23	10.8	0.31	13.3	0.38
Total	**2129.3**	**61.00**	**2039.5**	**49.27**	**2816.3**	**80.31**	**1749.2**	**50.65**	**1982.2**	**56.01**	**2333.4**	**65.19**	**3650.4**	**99.25**

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References

Brady, J. A., W. W. Wallender, I. Werner, B. Mostafazadeh Fard, F.G. Zalom, N. Oliver, B. W. Wilson, M. M. Mata, J. D. Henderson, L. A. Deanovic and S. Upadhaya (2006). Pesticide runoff from orchard floors in Davis, California, USA: A comparative analysis of diazinon and esfenvalerate. *Agri. Ecosys. and Envi*, 115: 56–68.

Brimner, T. A., G. J. Gallivan and G. R. Stephenson (2005). Influence of herbicide-resistant canola on the environmet impact of weed management. *Pest Manag. Sci.*, 61: 47-52.

Crop Protection HANDBOOK. 2003. *The gold standard platinum.* Biesterfeld.

Cross, P. and G. Edwards-Jones (2006). Variation in pesticide hazard from arable crop production in Great Britain from 1992 to 2002: pesticide risk indices and policy analysis. *Crop Prot.* (Article in press).

Dunn, A. M. (2004). A relative risk ranking of pesticides used in Prince Edward Island. Surveillance Report. *Environmental protection Branch*, Atlantic Region. Canada.

Gallivan, G. J., H. Berges and B. McGee (2005). Evaluation of the changes in pesticide risk. *Research Project SR9128.* Ontario Ministry of Agriculture and Food. Guelph.

Gallivan, G. J., G. A. Surgeoner and J. Kovach (2001). Pesticide risk reduction on crops in the province of Ontario. *J. Environ. Qual.*, 30:798-813.

Iran Plant Protection Organization (2002). *The list of registered pesticides in Iran.*

Iran Ministry of Jihad -e- Agriculture. (2003). Agriculture Statistices. Vol. 1 Crops and horticulture plants. Available at http://www.maj.ir/.

Kovach, J., C. Petzoldt, J. Degni and J. Tette (1992). A method to measure the environmental impact of pesticides. New York's *Food and Life Sciences Bulletin.* NYS Agricul. Exp. Sta. Cornell University, Geneva, NY.

Levitan, L., I. Merwin and J. Kovach (1995). Assessing the relative environmental impacts of agricultural pesticides:the quest for a holistic method. *Agri. Ecosys. and Envi.,* 55: 153-168.

Levitan, L. (1997). A review of pesticide impact assessment systems. *Workshop on Pesticide Risk Indicators.* Copenhagen, Denmark. April, 21-23.

Montazeri, M., E. Zand and M. A. Baghestani (2005). Weeds and Their Control in Wheat Fields of Iran. Agricultural Resaerch and Education Organization. Ministry of Jihad -e- Agriculture.

Peterson, R. K. D., A. G. Hulting (2004). A comparative ecological risk assessment for herbicides used on spring wheat: the effect of glyphosate when used within a glyphosate-tolerant wheat system. *Weed Sci.*, 52: 834-844.

Pretty, J. (2005). The Pesticide Detox: Towards a More Sustainable Agriculture. Earthscan, London.

Reus, J., P. Leendertse, C. Bockstaller, I. Fomsgaard, V. Gutsche, K. Lewis, C. Nilsson, L. Pussemier, M Trevisan, H. Van der Werf, F. Alfarroba, S. Blumel, J. Isart, D. McGrath and T Seppala (2002). Comparison and evaluation of eight pesticide environmental risk indicators developed in Europe and recommendations for future use. *Agri. Ecosys. and Envi.*, 90:177-187.

Sæthre, M. G., H. M. ørpen, T. Hofsvang (1999). Action programmes for pesticide risk reduction and pesticide use in different crops in Norway. *Crop Prot.*, 18: 207-215.

US EPA EXTOXNET Database. (1996). < http://extoxnet.orst.edu/pips/.

US EPA ECOTOX Database. (2003). ECOTOX User Guide: ECOTOXicology Database System. Available online at .

Zand, E., M. A. Baghestani, P. Shimi and A. Phaghih. 2003. Analysis of Herbicides Management in Iran. Agricultural Resaerch and Education Organization. Ministry of Jihade- e- Agriculture.