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RESEARCH ARTICLE
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Evaluation of the environmental impact of pesticides for pest control in the main horticultural crops of the Chancay-Huaral valley, Lima

Evaluación del impacto ambiental de los pesticidas utilizados para el control de plagas en los principales cultivos hortícolas en el valle de Chancay-Huaral, Lima

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Abstract

An environmental impact assessment was carried out in the Chancay-Huaral valley for tomato, bell pepper, cucumber, carrot, and lettuce crops. Additional surveys and interviews were conducted to 96 farmers and 10 of the main pesticide supplies in the area. We determined that for the tomato crops between 33 to 42 pesticides applications were made with 27 active ingredients; for the bell pepper crops 36 to 45 applications with 28 active ingredients; for the cucumber crops 22 applications with 19 active ingredients; for the carrot crops 8 applications with 11 active ingredients; and for the lettuce crops 12 applications with 15 active ingredients. For these applications, the farmers prepared the mixtures using commercial formulations or according to their own criteria, guided by the suppliers. Due to the number of applications carried out, the pesticide withdrawal periods were not respected, and phytosanitary management was based mainly on chemical control without consideration of an Integrated Pest Management program. The environmental impact per hectare of pesticides per campaign for the crops studied was 541.30 for tomato, 595.97 for bell pepper, 959 for cucumber, 125.38 for carrot, and 81.88 for lettuce. This study will serve as a baseline for the assessment of environmental impacts of various agricultural crops, and to evaluate the implementation of Integrated Pest Management programs.

Key word: *Environmental impact assessment, pesticides, horticultural crops.*

Resumen

Se realizó una evaluación de impacto ambiental en el valle de Chancay-Huaral para los cultivos de tomate, pimiento, pepino, zanahoria y lechuga. Adicionalmente se realizaron encuestas y entrevistas a 96 agricultores y a 10 de los principales proveedores de plaguicidas de la zona. Se determinó que para los cultivos de tomate se realizaron entre 33 y 42 aplicaciones de plaguicidas con 27 ingredientes activos; para los cultivos de pimiento entre 36 y 45 aplicaciones con 28 ingredientes activos; para los cultivos de pepino 22 aplicaciones con 19 ingredientes activos; para los cultivos de zanahoria 8 aplicaciones con 11 ingredientes activos; y para los cultivos de lechuga 12 aplicaciones con 15 ingredientes activos. Para estas aplicaciones, los agricultores

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prepararon las mezclas utilizando formulaciones comerciales o según sus propios criterios, guiados por los proveedores. Debido al número de aplicaciones realizadas, no se respetaron los periodos de retirada de plaguicidas, y la gestión fitosanitaria se basó principalmente en el control químico sin tener en cuenta un programa de Gestión Integrada de Plagas. El impacto ambiental por hectárea de plaguicidas por campaña para los cultivos estudiados fue de 541.30 para el tomate, 595.97 para el pimiento, 959 para el pepino, 125.38 para la zanahoria y 81.88 para la lechuga. Este estudio servirá como línea de base para la evaluación de los impactos ambientales de diversos cultivos agrícolas, y para evaluar la aplicación de programas de Gestión Integrada de Plagas.

Palabra clave: *Evaluación del impacto ambiental, plaguicidas, cultivos hortícolas.*

Introduction

The Chancay-Huaral valley, located 80 kilometers from Lima, is considered one of the main suppliers of the vegetable market, and one of the main food pantries for the Lima population. At present, pesticides are the main way to combat pests in vegetables production for this domestic market. These are poorly managed due to misinformation and ignorance of their effects, causing soil degradation, and contamination of water and air, which in turn affects wildlife and generates health problems in the population exposed to gas emanations and by-products (Guerrero-Padilla & Otiniano-Medina, 2012). According to Centro Agronómico Tropical de Investigación y Enseñanza (CATIE, 2017), the environmental impact of Integrated Pest Management (IPM) considers the use of pesticides on the environment, and health of farmers and consumers. Thus, information on the use of pesticides in the IPM program should be available or baseline studies must be done. Small farmers link pest management with unilateral control of pesticides, and use them without considering withdrawal periods, applying individual active ingredients, mixing them, overdosing, successively, and in many cases applying the same active ingredient or one from the same toxicological group. Farmers do acknowledge the danger of pesticides for human consumption; but the Environmental Impact (EI) is not considered as an indicator for the potential risk caused by their use (Kovach et al., 2004). It is a relatively simple methodology, which requires information from a pesticide that can be easily obtained, such as the number of applications, dosage, and EIQ (Environmental Impact Quotient) value calculated based on different studies (Kovach et al., 2004; Ortiz & Pradel, 2009). The objective of this study was to determine the environmental impact of the use of pesticides in vegetables such as tomato, bell peppers, cucumbers, carrots and lettuce in the Chancay-Huaral, area, and to create a baseline to evaluate the environmental impact in different agricultural crops to evaluate the implementation of agricultural managements of an Integrated Pest Management (IPM) program.

Materials and methods

Due to the growing practice of renting plots with tenants that migrate after each campaign without a formal registry, there is not an updated registry of farmers of the Chancay-Huaral valley to determine the number of farmers to survey. Therefore, an estimated sample number (n) with unknown population was calculated, resulting in a sample of 96 farmers (Aguilar-Barojas, 2005). Farmers and pesticide suppliers were surveyed to find out which pesticides were most commonly used. To determine the environmental impact (EI), we followed the methodology suggested by Kovach et al. (2004). In addition, 10 technicians were interviewed among the suppliers and consultants of the main pesticide supply stores in the valley. Products that did not have an individual EIQ value were homologated with one of the same nature, for example: phenthoate for chlorpyrifos, cadusafos for chlorpyrifos, and pyrimethanil for prochloraz

Results and discussion

Our results coincide with that indicated by CATIE (2017), that when assessing the environmental impact, a baseline on the use of pesticide must be established, in our case in tomato, bell pepper, cucumber, carrot and lettuce crops, as these are the most representative crops of the Chancay-Huaral valley. Similar works were done by Muhammetoglu & Uslu (2007) in Kumuluca, Turkey, an area known for intensive use of pesticides, and is considered a tool for environmental impact studies of Integrated Pest Management. In melon crops this type of study was conducted in the Lagunera region, Mexico by Vargas-González et al. (2019), they identified the pesticides and the production areas with the greatest negative environmental impact.

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Tomato crop

In the bell pepper crop, 33 pesticides applications were carried out; and 42 applications could have been made if some were repeated, namely ones for *Prodiplosis longifila* control (Table 1). Likewise, we observed that many pesticides were mixed. Pesticide mixtures were available from suppliers or made by the farmers themselves. We determined that the EI/ha per campaign was of 541.90.

During the tomato campaigns, 27 active ingredients were applied; of these, 15 were insecticides (55.56 %), 7 fungicides (25.93 %), 3 nematicides (11.11 %), and 2 herbicides (7.41 %) (Table 2). Likewise, 54 applications were made of insecticides (77.14 %), 11 of fungicides (15.71 %), 3 of nematicides (4.29 %), and 2 of herbicides (2.86 %).

Among the applied pesticides during the tomato campaign, dinotefuran was applied the most with 11 applications, followed by chlorpyrifos and fipronil with 8 applications each, spirotetramat with 6 applications, and alphacypermethrin with 5 applications (Figure 1). Fipronil had the highest EIQ among the active ingredients used during the tomato campaign with a value of 88.25, followed by copper pentahydrate with 69.83, carbedazim with 50.5, and lambdacyhalothrin with 44.17 (Figure 2).

The EI/ha values per tomato crop campaign depend on the concentration of the formulated product, the times applied throughout the crop season and the EIQ value (Table 1).

Among the pesticides used during the tomato campaign, the highest EI/ha value corresponds to liquid sulfur with 114.31, followed by fipronil with 76.78, chlorpyrifos with 71.27, cadusafos with 67.13, and dinotefuran with 43.85 (Figure 3).

Among the pesticide types used during the tomato campaign, the insecticides with 15 active ingredients (55.56 %) had the highest EI/ha of

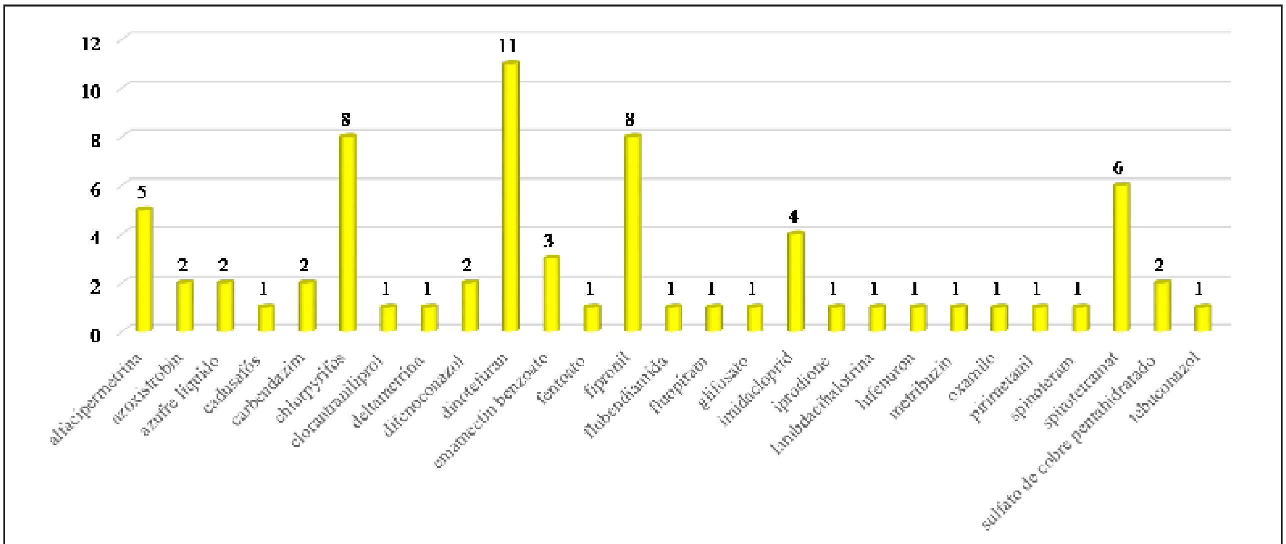

Figure 1. Number of applications of each active ingredient used per tomato campaign in the Chancay-Huaral valley (2018-2019).

Table 1. Environmental impact (EI) value per tomato campaign in the Chancay-Huaral valley (2018-2019).

N°	Phenological or handling stage	Phytosanitary problem	Pesticide category	Active ingredient			Comercial dose (kg.L^{-1}.ha^{-1}) (2)	No. of applications (4)	Water consumption (L.ha^{-1})	EIQ (1)	EI.ha^{-1} (1*2*3*4)
				Denomination	Concentration of the commercial product	Concentration (%) (3)					
1	pre-transplant	weeds	herbicide	glyphosate	480 g/L SL	0.48	2	1	200	15.33	14.72
2	pre-transplant	annual weeds	herbicide	metribuzin	480 g/L SC	0.48	0.3	1	200	28.37	4.09
3	transplant	damping-off	fungicide	carbendazim	500 g/L SC	0.5	0.2	1	200	50.5	5.05
4	transplant	damping-off	fungicide	copper sulfate pentahydrate	247 g/L SC	0.247	0.5	1	200	69.83	8.62
5	transplant and growth	nematodes	nematicide	cadusafos	100 g/kg GR	0.1	25	1	-	26.85	67.13
6	transplant and vegetative growth	nematodes	nematicide fungicide	oxamyl + copper sulfate pentahydrate	240 g/L SL 247 g/L SC	0.24 0.247	1 0.5	1	200	33.3 69.83	7.99 8.62
7	transplant and growth	nematodes	nematicide	fluopyram	500 g/L SC	0.5	1.5	1	300	17.83	13.37
8	vegetative growth	whitefly and aphids	insecticide	dinotefuran	500 g/kg WG	0.5	0.3	1	300	22.26	3.34
9	vegetative growth	whitefly and aphids	insecticide	chlorpyrifos + alpha cypermethrin	375 g/L 25 g/L EC	0.375 0.025	0.75	1	300	26.85 36.35	7.55 0.68
10	vegetative growth	whitefly and aphids	insecticide	deltamethrin	25 g/L EC	0.025	0.375	1	300	28.38	0.27
11	vegetative growth, flowering and fruiting	*Prodiplosis*	insecticide insecticide insecticide	spirotetramat + dinotefuran + fipronil	150 g/L OD 500 g/kg WG 200 g/L SC	0.15 0.5 0.2	0.225 0.3 0.375	2	300	35.29 22.26 88.25	2.38 6.68 13.24
12	vegetative growth, flowering and fruiting	*Prodiplosis*	insecticide insecticide insecticide insecticide	dinotefuran + fipronil + imidacloprid + chlorpyrifos + alpha cypermethrin	500 g/kg WG 200 g/L SC 350 g/L SC 375 g/L 25 g/L EC	0.5 0.2 0.35 0.375 0.025	0.4 0.5 0.5 0.5	2	400	22.26 88.25 36.71 26.85 36.35	8.90 17.65 12.85 10.07 0.91
13	vegetative growth, flowering and fruiting	*Prodiplosis*	insecticide insecticide insecticide insecticide	spirotetramat + dinotefuran + chlorpyrifos + liquid sulfur	150 g/L ED 500 g/kg WG 480 g/L EC 875 g/L SL	0.15 0.5 0.48 0.875	0.3 0.4 0.8 2	2	400	35.29 22.26 26.85 32.66	3.18 8.90 20.62 114.31
14	vegetative growth, flowering and fruiting	*Prodiplosis*	insecticide	spirotetramat	150 g/L	0.15	0.3	2	400	35.29	3.18
15	vegetative growth, flowering and fruiting	*Prodiplosis*	insecticide	fipronil + dinotefuran	400 g/kg 400 g/kg WG	0.4 0.4	0.4	2	400	88.25 22.26	28.24 7.12
16	vegetative growth, flowering and fruiting	*Prodiplosis*	insecticide	fipronil	200 g/L SC	0.2	0.5	2	400	88.25	17.65
17	vegetative growth, flowering and fruiting	*Prodiplosis*	insecticide	dinotefuran	500 g/kg WG	0.5	0.4	2	400	22.26	8.90
18	cvegetative growth, flowering and fruiting	*Prodiplosis*	insecticide	imidacloprid	350 g/L SC	0.35	0.5	2	400	36.71	12.85
19	vegetative growth, flowering and fruiting	*Prodiplosis*	insecticide	chlorpyrifos + alpha cypermethrin	375 g/L 25 g/L EC	0.375 0.025	1	2	400	26.85 36.35	20.14 1.82
20	vegetative growth, flowering and fruiting	*Prodiplosis*	insecticide	chlorpyrifos	480 g/L EC	0.48	1	1	400	26.85	12.89
21	vegetative growth, flowering and fruiting	*Prodiplosis*	insecticide	phentoate	500 g/L EC	0.5	1	1	400	26.85	13.43
22	vegetative growth, flowering and fruiting	powdery mildew and Alternaria	fungicide	difenoconazolee	250 g/L EC	0.25	0.5	1	500	41.5	5.19
23	vegetative growth, flowering and fruiting	powdery mildew and Alternaria	fungicide	azoxystrobin + tebuconazolee	120 g/L 200 g/L SC	0.12 0.2	0.5	1	500	26.92 40.33	1.62 4.03
24	vegetative growth, flowering and fruiting	powdery mildew and Alternaria	fungicide	azoxystrobin + difenoconazolee	200 g/L 120 g/L SC	0.2 0.12	0.5	1	500	26.92 41.5	2.69 2.49
25	flowering	*Botrytis*	fungicide	iprodione	500 g/kg WP	0.5	1.25	1	500	24.25	15.16
26	flowering	*Botrytis*	fungicide	carbendazim	500 g/L SC	0.5	0.5	1	500	50.5	12.63
27	flowering	*Botrytis*	fungicide	pyrimethanil	400 g/L SC	0.4	0.5	1	500	22.23	4.45
28	flowering and fruiting	lepidoptera larvae	insecticide	chlorantraniliprole	200 g/L SC	0.2	0.1875	1	500	18.34	0.69
29	flowering and fruiting	lepidoptera larvae	insecticide	spinoteram	60 g/L SC	0.06	0.25	1	500	27.78	0.42
30	flowering and fruiting	lepidoptera larvae	insecticide	flubendiamide	200 g/kg WG	0.2	0.25	1	500	19.36	0.97
31	flowering and fruiting	lepidoptera larvae	insecticide	emamectin benzoate	50 g/kg, WG, SG	0.05	0.5	1	500	26.28	0.66
32	flowering and fruiting	lepidoptera larvae	insecticide	emamectin benzoate + lufenuron	50 g/kg 100 g/kg WG	0.05 0.1	0.25	1	500	26.28 16.29	0.33 0.41
33	flowering and fruiting	lepidoptera larvae	insecticide	emamectin benzoate + lambdacyhalothrin	50 g/kg 100 g/kg WP	0.05 0.1	0.5	1	500	26.28 44.17	0.66 2.21
								42			**541.90**

Table 2. Number of active ingredients and applications of various pesticide types applied per tomato campaign in the Chancay-Huaral valley, Lima (2018-2019).

Pesticide category	**Active ingredients**		**Applications**	
	N°	**%**	**N°**	**%**
Fungicides	7	25.93	11	15.71
Herbicides	2	7.41	2	2.86
Insecticides	15	55.56	54	77.14
Nematicides	3	11.11	3	4.29
Total	27	100	70	100

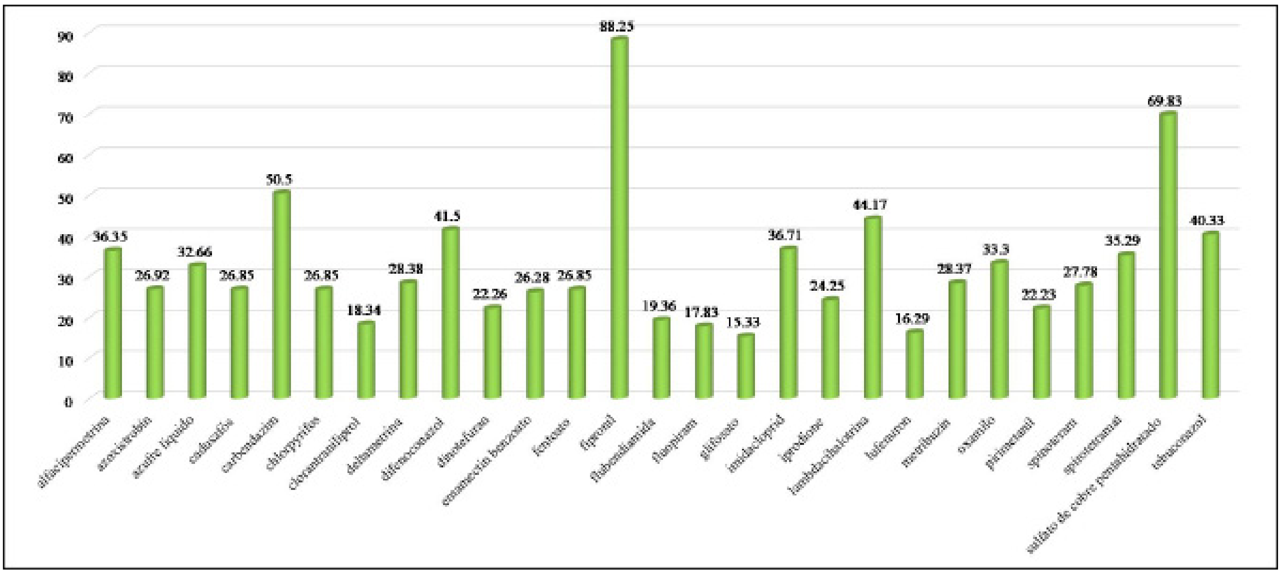

Figure 2. Total EIQ value of pesticides applied per tomato campaign in the Chancay-Huaral valley (2018-2019).

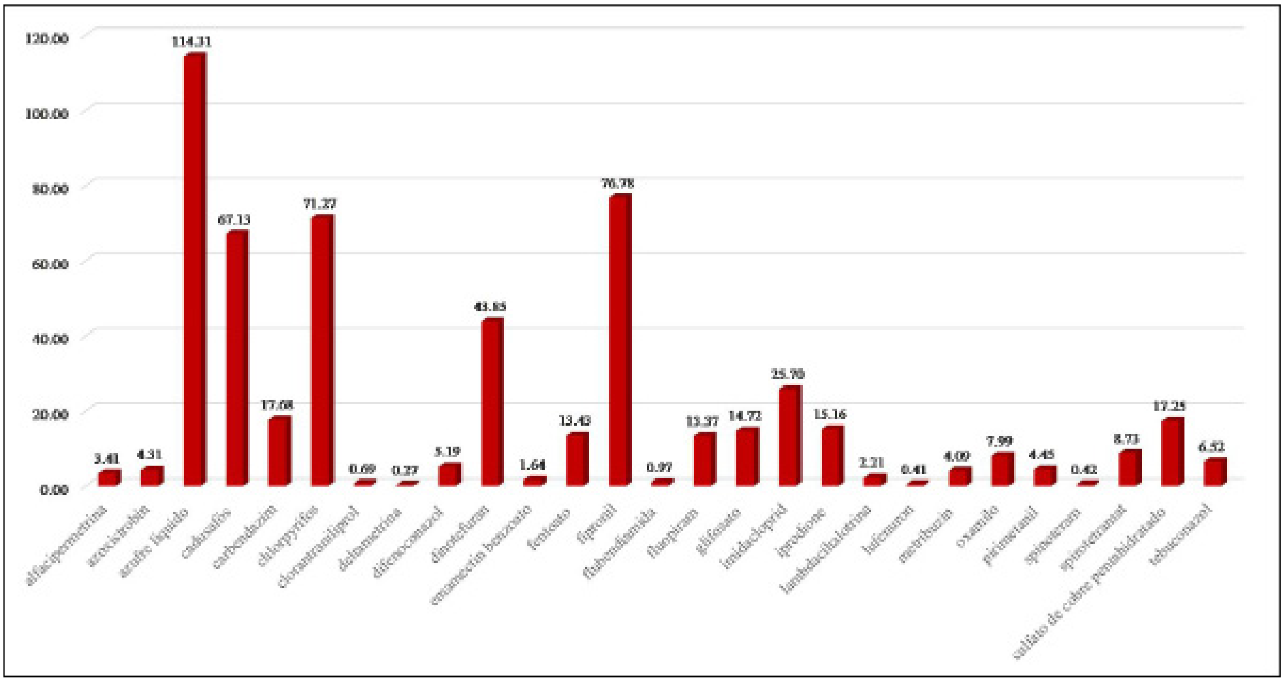

Figure 3. EI/ha value of pesticides applied per tomato campaign in the Chancay-Huaral valley (2018-2019).

364.067 (67.18 %), followed by fungicides with 7 active ingredients (25.93 %) and an EI/ha value of 70.54 (13.02 %). The nematicides with 3 active ingredients and an EI/ha of 88.49, and finally, the herbicides with 2 active ingredients (7.41 %) and an EI/ha of 18.80 (3.37 %) (Table 3). The total EI/ha of the tomato crop was 541.90.

Bell pepper crop

In the bell pepper crop, 33 pesticides applications were carried out; and 45 applications may have been reached if some were repeated, namely ones for *Prodiplosis longifila* control (Table 4). Pesticide mixtures were available from suppliers or made by the farmers themselves. The EI/ha per season was determined at 595.97. Products that did not have an individual EIQ value were homologated with one of the same nature: phentoate for chlorpyrifos, cadusofos for chlorpyriphos, and pirimetanil for prochloraz.

During a bell pepper campaign, 28 active ingredients were applied. Of these, 16 were insecticides (57.14 %), 7 fungicides (25.00 %), 3 nematicides (10.71 %), and 2 herbicides (7.41 %). For each type of pesticide, 55 applications of insecticides (76.39 %), 12 of fungicides (16.67 %), 3 of nematicides (4.17 %), and 2 of herbicides (2.78 %) were made (Table 5).

Among pesticides applied in the bell pepper campaign, dinotefuran is applied 11 times (Figure 4), followed by chlorpyrifos and fipronil with 8 times each, spirotetramat 6 times and alphacypermethrin 5 times. The EIQ of the pesticide products (Figure 5) with the highest values are: 88.25 fipronil, 69.83 copper

Table 3. Number of active ingredients, EI/ha value of pesticides applied per tomato campaign in the Chancay-Huaral valley, Lima (2018-2019).

Pesticide category	Active ingredients		Enviromental impact	
	N°	**%**	**Cumulative value (EI/ha)**	**%**
Fungicides	7	25.93	70.54	13.02
Herbicides	2	7.41	18.80	3.47
Insecticides	15	55.56	364.067	67.18
Nematicides	3	11.11	88.49	16.33
Total	27	100	541.90	100

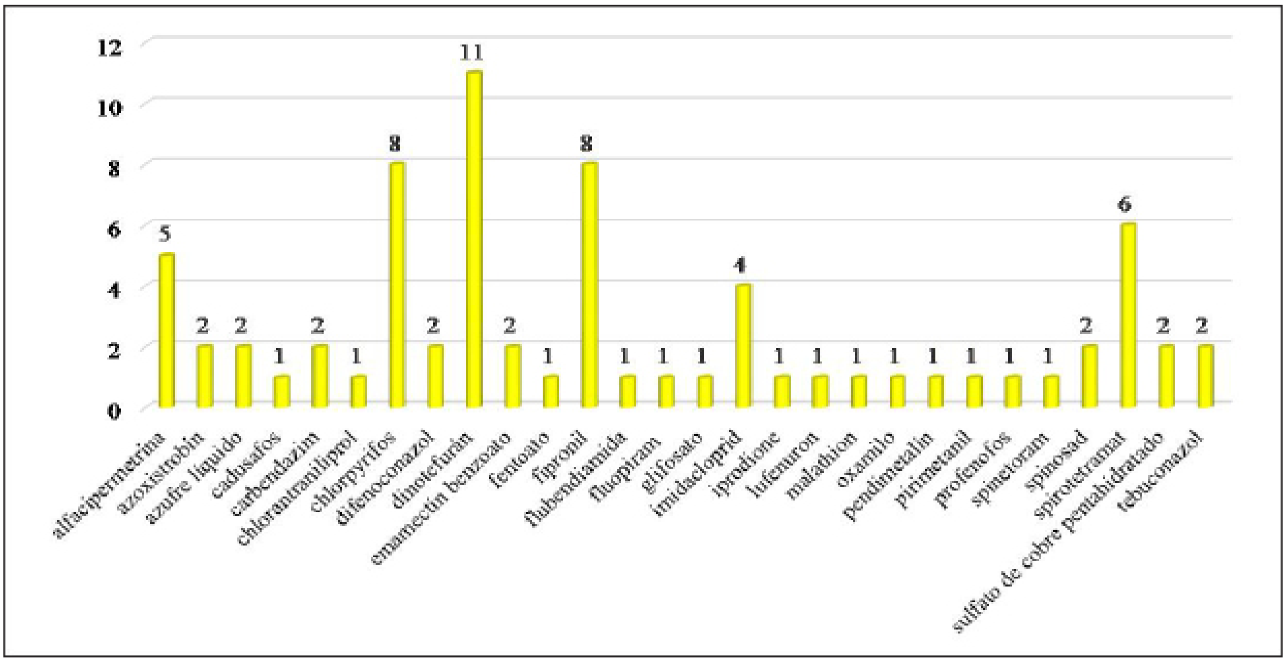

Figure 4. Number of applications of each active ingredient used per bell pepper campaign in the Chancay-Huaral valley (2018-2019).

Table 4. Environmental impact (EI) per bell pepper campaign in the Chancay-Huaral valley (2018-2019).

N°	Phenological orhandling stage	Phytosanitary problem	Pesticide category	Active ingredient			Comercial dose ($kg.L^{-1}.ha^{-1}$) (2)	No. of applications (4)	Water consumption ($L.ha^{-1}$)	EIQ (1)	$EI.ha^{-1}$ (1*2*3*4)
				Denomination	Concentration of the commercial product	Concentration (%) (3)					
1	pre-transplant	weeds	herbicide	glyphosate	480 g/L SL	0.48	2	1	200	15.33	14.72
2	pre-transplant	annual weeds	herbicide	pendimethalin	455 g/L CS	0.445	1	1	200	30.17	13.43
3	transplant	damping-off	fungicide	carbendazim	500 g/L SC	0.5	0.2	1	200	50.5	5.05
4	transplant and growth	Phytophthora capsici	fungicide	copper sulfate	247 g/L SC	0.247	0.5	1	200	69.83	8.62
5	transplant and vegetative growth	nematodes	nematicide	cadusafos	100 g/kg GR	0.1	25	1		26.85	67.13
6	transplant and vegetative growth	nematodes	nematicide	oxamyl +	240 g/L SL	0.24	1	1	200	33.3	7.99
			fungicide	copper sulfate	247 g/L SC	0.247	0.5			69.83	8.62
7	transplant and vegetative growth	nematodes	nematicide	fluopyram	500 g/L SC	0.5	1.5	1	300	17.83	13.37
8	vegetative growth	whitefly and aphids	insecticide	dinotefuran	500 g/kg WG	0.5	0.3	1	300	22.26	3.34
9	vegetative growth	whitefly and plant louse	insecticide	chlorpyrifos + alpha cypermethrin	375 g/L	0.375	0.75	1	300	26.85	7.55
					25 g/L EC	0.025				36.35	0.68
10	vegetative growth, flowering and fruiting	*Prodiplosis*	insecticide	spirotetramat +	150 g/L OD	0.15	0.225	2	400	35.29	2.38
			insecticide	dinotefuran +	500 g/kg WG	0.5	0.3			22.26	6.68
			insecticide	fipronil	200 g/L SC	0.2	0.375			88.25	13.24
11	vegetative growth, flowering and fruiting	*Prodiplosis*	insecticide	dinotefuran +	500 g/kg WG	0.5	0.4	2	400	22.26	8.90
			insecticide	fipronil +	200 g/L SC	0.2	0.5			88.25	17.65
			insecticide	imidacloprid +	350 g/L SC	0.35	0.5			36.71	12.85
			insecticide	chlorpyrifos + alpha cypermethrin	375 g/L	0.375	0.5			26.85	10.07
					25 g/L EC	0.025				36.35	0.91
12	vegetative growth, flowering and fruiting	*Prodiplosis*	insecticide	spirotetramat +	150 g/L ED	0.15	0.3	2	400	35.29	3.18
			insecticide	dinotefuran +	500 g/kg WG	0.5	0.4			22.26	8.90
			insecticide	chlorpyrifos +	480 g/L EC	0.48	0.8			26.85	20.62
			insecticide	liquid sulfur	875 g/L SL	0.875	2			32.66	114.31
13	vegetative growth, flowering and fruiting	*Prodiplosis*	insecticide	spirotetramat	150 g/L	0.15	0.3	2	400	35.29	3.18
14	vegetative growth, flowering and fruiting	*Prodiplosis*	insecticide	fipronil + dinotefuran	400 g/kg	0.4	0.4	2	400	88.25	28.24
					400 g/kg WG	0.4				22.26	7.12
15	vegetative growth, flowering and fruiting	*Prodiplosis*	insecticide	fipronil	200 g/L SC	0.2	0.5	2	400	88.25	17.65
16	vegetative growth, flowering and fruiting	*Prodiplosis*	insecticide	dinotefuran	500 g/kg WG	0.5	0.4	2	400	22.26	8.90
17	vegetative growth, flowering and fruiting	*Prodiplosis*	insecticide	imidacloprid	350 g/L SC	0.35	0.5	2	400	36.71	12.85
18	vegetative growth, flowering and fruiting	*Prodiplosis*	insecticide	chlorpyrifos + alpha cypermethrin	375 g/L	0.375	1	2		26.85	20.14
					25 g/L EC	0.025			400	36.35	1.82
19	vegetative growth, flowering and fruiting	*Prodiplosis*	insecticide	chlorpyrifos	480 g/L EC	0.48	1	1	400	26.85	12.89
20	vegetative growth, flowering and fruiting	*Prodiplosis*	insecticide	phentoate	500 g/L EC	0.5	1	1	400	26.85	13.43
21	vegetative growth, flowering and fruiting	powdery mildew and Alternaria	fungicide	difenoconazolee	250 g/L EC	0.25	0.5	1	500	41.5	5.19
22	vegetative growth, flowering and fruiting	powdery mildew and Alternaria	fungicide	tebuconazolee	250 g/L EW	0.25	0.5	1	500	40.33	5.04
23	vegetative growth, flowering and fruiting	powdery mildew and Alternaria	fungicide	azoxystrobin + tebuconazolee	120 g/L	0.12	0.5	1	500	26.92	1.62
					200 g/L SC	0.2				40.33	4.03
24	vegetative growth, flowering and fruiting	powdery mildew and Alternaria	fungicide	azoxystrobin + difenoconazolee	200 g/L	0.2	0.5	1	500	26.92	2.69
					120 g/L SC	0.12				41.5	2.49
25	flowering	*Botrytis*	fungicide	iprodione	500 g/kg WP	0.5	1	1	400	24.25	12.13
26	flowering	*Botrytis*	fungicide	carbendazim	500 g/L SC	0.5	0.4	1	400	50.5	10.10
27	flowering	*Botrytis*	fungicide	pyrimethanil	400 g/L SC	0.4	0.4	1	400	22.23	3.56
28	flowering and fruiting	lepidoptera larvae	insecticide	chlorantraniliprole	200 g/L SC	0.2	0.1875	1	500	18.34	0.69
29	flowering and fruiting	lepidoptera larvae	insecticide	spinetoram	60 g/L SC	0.06	0.25	1	500	27.78	0.42
30	flowering and fruiting	lepidoptera larvae	insecticide	flubendiamide	200 g/kg WG	0.2	0.25	1	500	19.36	0.97
31	flowering and fruiting	lepidoptera larvae	insecticide	emamectin benzoate	50 g/kg WG, SG	0.05	0.5	1	500	26.28	0.66
32	flowering and fruiting	lepidoptera larvae	insecticide	emamectin benzoate + lufenuron	50 g/kg	0.05	0.25	1	500	26.28	0.33
					100 g/kg WG	0.1			500	16.29	0.41
33	flowering and fruiting	lepidoptera larvae	insecticide	profenofos	500 g/L EC	0.5	0.375	1	500	59.53	11.16
34	fruit maturity	fruit fly	insecticide	malathion	625 g/L EC	0.625	2.5	1	500	23.83	37.23
35	fruit maturity	fruit fly	insecticide	spinosad	120 g SC	0.12	0.5	1	500	14.38	0.86
36	fruit maturity	fruit fly	insecticide	spinosad	0.24 g/L CB	0.00025	1.25	1	500	14.38	0.00449
								45			**595.97**

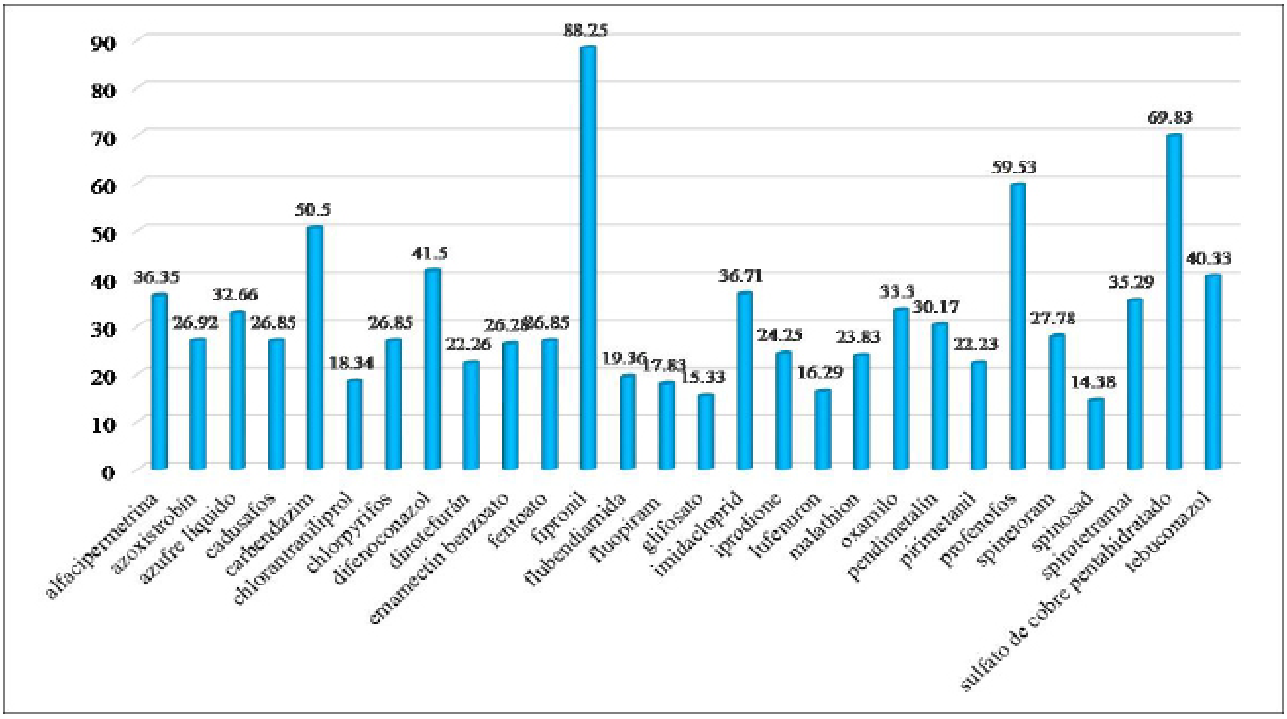

Figure 5. Total EIQ value of pesticides applied per bell pepper campaign in the Chancay-Huaral valley (2018-2019).

sulfate pentahydrate, 40.33 tebuconazole, 36.71 imadacloprid, 36.35 alphacypermethrin, 35.29 spirotetramat, 33.3 oxamyl and 32.66 liquid sulfur.

As in the tomato crop, liquid sulfur is applied at a concentration of 875 g/L at a dose of 2 L/ha of the commercial product and an EIQ of 32.66 (Table 4), therefore, its value EI/ha increases to 114.31, followed by fipronil 76.78, chlorpyrifos 71.27, cadusafos 67.13 and dinotefuran 43.85 (Figure 6).

Table 6 shows that the EI/ha by type of pesticide corresponds to insecticides with 16 active ingredients (57.14 %) and a EI/ha value of 410.199 (68.83 %), fungicides with 7 active ingredients (25 %) and an EI/ha value of 69.14 (11.60 %), nematicides with 3 active ingredients (10.71 %) and an EI/ha of 88.49 (14.85 %), and

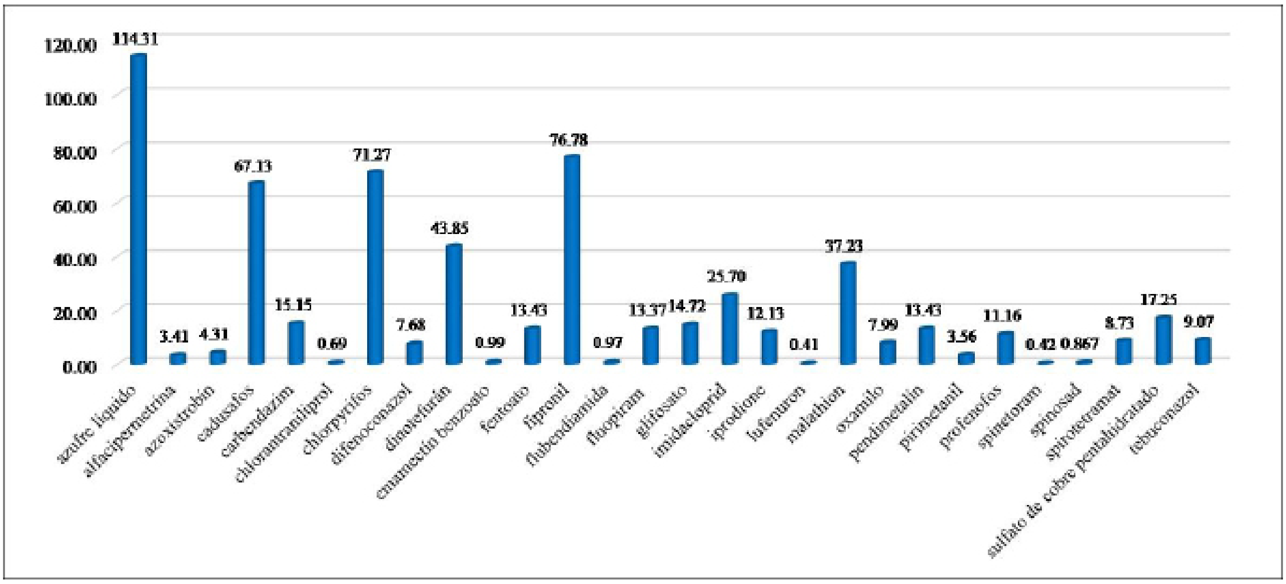

Figure 6. EI/ha value of pesticides applied per bell pepper campaign in the Chancay-Huaral valley (2018-2019).

Table 5. Number of active ingredients and applications of various pesticide types applied per bell pepper campaign in the Chancay-Huaral valley, Lima (2018-2019).

Pesticide category	Active ingredients		Applications	
	N°	%	N°	%
Fungicides	7	25.00	12	16.67
Herbicides	2	7.14	2	2.78
Insecticides	16	57.14	55	76.39
Nematicides	3	10.71	3	4.17
Total	28	100	72	100

Table 6. Number of active ingredients, EI/ha value of pesticides applied per bell pepper campaign in the Chancay-Huaral valley, Lima (2018-2019).

Pesticide category	Active ingredients		Environmental impact	
	N°	%	Cumulative value (EI/ha)	%
Fungicides	7	25.00	69.14	11.60
Herbicides	2	7.14	28.14	4.72
Insecticides	16	57.14	410.199	68.83
Nematicides	3	10.71	88.49	14.85
Total	28	100	595.97	100

finally, herbicides with 2 active ingredients (7.14 %) and an EI/ha value of 28.14 (4.72 %). The total EI/ha of the bell pepper crop is 595.97.

Cucumber crop

In the cucumber crop, between 21 to 22 pesticides applications were carried out, particularly for insect pests and diseases. Pesticide mixtures were available from suppliers or made by the farmers themselves. It was determined that the EI/ha per campaign was of 959.75, a high value due to the use of sulfur for *Prodiplosis longifila*, and due to the fungicidal and acaricidal effect. The dose of dry sulfur powder applied was of 25 Kg/ha (Table 7).

During a cucumber campaign, 19 active ingredients were applied. Nine were fungicides (47.37 %), six were insecticides (31.58 %), two were herbicides (10.53 %), and finally, one nematicide and one acaricide (5.26 % both). Likewise, 14 applications were made of fungicides (46.67 %), 11 of insecticides (36.67 %), 2 of herbicides (6.67 %), 2 of nematicides (6.67 %), and 1 of acaricide (3.33 %) (Table 8).

In Figure 7, it can be seen that chlorpyriphos is applied 5 times, mancozeb and tebuconozaol 3 times each. When analyzing the EIQ of the products applied in the cucumber crop, the highest values are given to fipronil 88.25, copper sulfate pentahydrate 69.83, carbendazim 50.5 and tebuconazole 40.33 (Figure 8).

In Figure 9, it is observed that the highest EI/ha value corresponds to powdered sulfur with 759.35, followed by mancozeb with 56.33, chlorpyriphos with 46.

Table 9 shows that the EI/ha by type of pesticide corresponds to fungicides with 9 active ingredients (47.37 %) with an EI/ha value of 102.45 (10.67 %), followed by insecticides with 6 active ingredients (31.58 %) with an EI/ha value of 64.270 (6.7 %), herbicides with 2 active ingredients (10.53 %) and an EI/ha of 17.70 (1.84 %), nematicides with one active ingredient (5.26 %) and an EI/ha of 15.98 (1.67 %) and finally an acaricide (5.26 %) and an EI/ha value of 759.35 (79.12 %).

Table 7. Environmental impact value calculation per cucumber campaign in the Chancay-Huaral valley (2018-2019).

N°	Phenological or handling stage	Phytosanitary problem	Pesticide category	Denomination	Concentration of the commercial product	Concentration (%) (3)	Comercial dose (kg.L^{-1}.ha^{-1}) (2)	No. of applications (4)	Water consumption (L.ha^{-1})	EIQ (1)	EI.ha^{-1} (1*2*3*4)
1	pre-transplant	weeds	herbicide	glyphosate	480 g/L SL	0.48	2	1	200	15.33	14.72
2	pre- sow	annual weeds	herbicide	metribuzin	700 g/kg WG	0.7	0.15	1	200	28.37	2.98
3	transplant	earthworms	insecticide	chlorpyrifos	480 g/L EC	0.48	0.5	1	--	26.85	6.44
4	transplant	damping-off	fungicide	copper sulfate pentahydrate	247 g/L SC	0.247	0.5	1	200	69.83	8.62
5	transplant and vegetative growth	nematodes	nematicide	oxamyl	240 g/L SL	0.24	1	2	200	33.3	15.98
6	vegetative growth	aphids and vectors	insecticide	chlorpyrifos + alpha cypermethrin	375 g/L 25 g/L EC	0.375 0.025	0.5	1	200	26.85 36.35	5.03 0.45
7	vegetative growth	aphids and vectors	insecticide	chlorpyrifos	480 g/L EC	0.48	0.4	1	200	26.85	5.16
8	vegetative growth	red spider mite and others	acaricide insecticide	powder sulfur chlorpyrifos	930 g/kg DP 25 g/Kg	0.93 0.025	25 25	1	--	32.66 26.85	759.35 16.78
9	vegetative growth, flowering and fruiting	whitefly	insecticide	imidacloprid	350 g/L SC	0.35	0.3	1	300	36.71	3.85
10	vegetative growth, flowering and fruiting	whitefly	insecticide	dinotefuran	500 g/kg WG	0.5	0.3	1	300	22.26	3.34
11	vegetative growth, flowering and fruiting	powdery mildew	fungicide	tebuconazole	250 g/L EW	0.25	0.4	1	400	40.33	4.03
12	vegetative growth, flowering and fruiting	powdery mildew	fungicide	azoxystrobin + tebuconazole	120 g/L 200 g/L SC	0.12 0.2	0.4	1	400	26.92 40.33	1.29 3.23
13	vegetative growth, flowering and fruiting	powdery mildew	fungicide	azoxystrobin + tebuconazole	200 g/L 120 g/L SC	0.2 0.12	0.4	1	400	26.92 40.33	2.15 1.94
14	vegetative growth, flowering and fruiting	mildew	fungicide	mancozeb + metalaxyl	640 g/kg 80 g/kg WP	0.64 0.08	1	1	400	25.72 19.07	16.46 1.53
15	vegetative growth, flowering and fruiting	mildew	fungicide	mancozeb + cymoxanil	640 g/kg 80 g/kg WP	0.64 0.08	1.25	1	500	25.72 35.48	20.58 3.55
16	vegetative growth, flowering and fruiting	mildew	fungicide	mancozeb + dimethomorph	600 g/kg 90 g/kg WP	0.6 0.09	1.25	1	500	25.72 24.01	19.29 2.70
17	flowering	*Botrytis*	fungicide	carbendazim	500 g/L SC	0.5	0.5	1	500	50.5	12.63
18	flowering	*Botrytis*	fungicide	pyrimethanil	400 g/L SC	0.4	0.5	1	500	22.23	4.45
19	flowering and fruit set	*Diaphania*	insecticide	chlorpyrifos + alpha cypermethrin	375 g/L 25 g/L EC	0.375 0.025	1.25	1	500	26.85 36.35	12.59 1.14
20	flowering and fruit set	*Diaphania*	insecticide	fipronil	200 g/L SC	0.2	0.5	1	500	88.25	8.83
21	flowering and fruit set	*Diaphania*	insecticide	emamectin benzoate	50 g/kg WG, SG	0.05	0.5	1	500	26.28	0.66
								22			**959.75**

Table 8. Number of active ingredients and applications of various pesticide types applied per cucumber campaign in the Chancay-Huaral valley, Lima (2018-2019).

Pesticide category	**Active ingredients**		**Applications**	
	N°	**%**	**N°**	**%**
Fungicides	9	47.37	14	46.67
Herbicides	2	10.53	2	6.67
Insecticides	6	31.58	11	36.67
Nematicides	1	5.26	2	6.67
Acaricides	1	5.26	1	3.33
Total	19	94.74	30	96.7

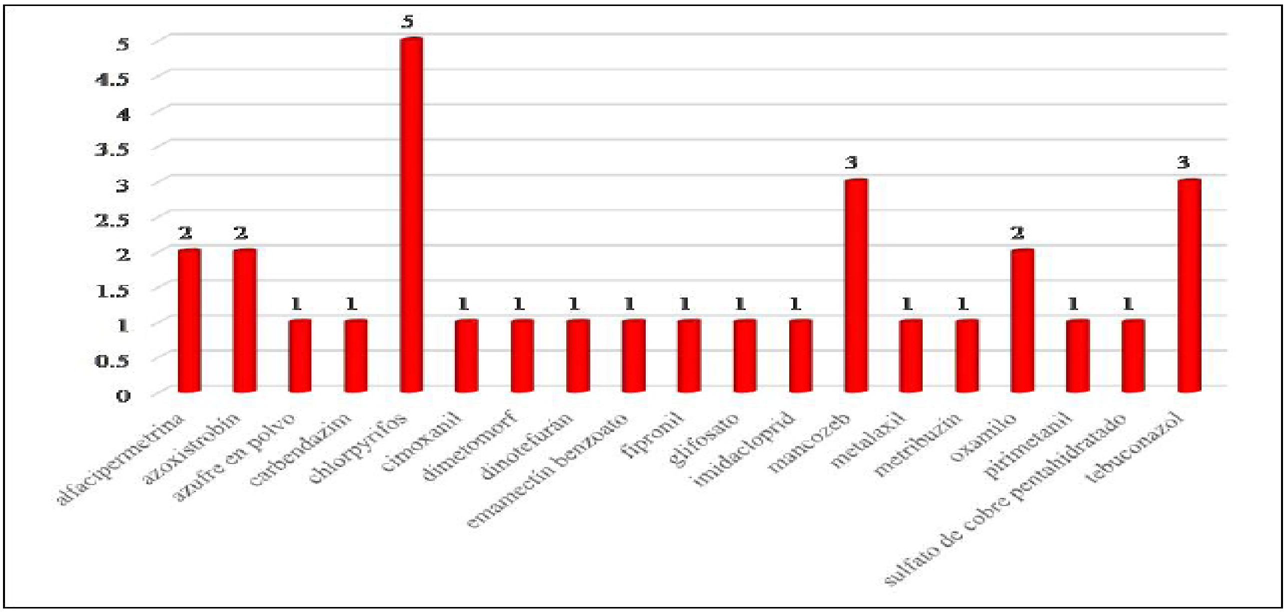

Figure 7. Number of applications of each active ingredient used per cucumber campaign in the Chancay-Huaral valley (2018-2019).

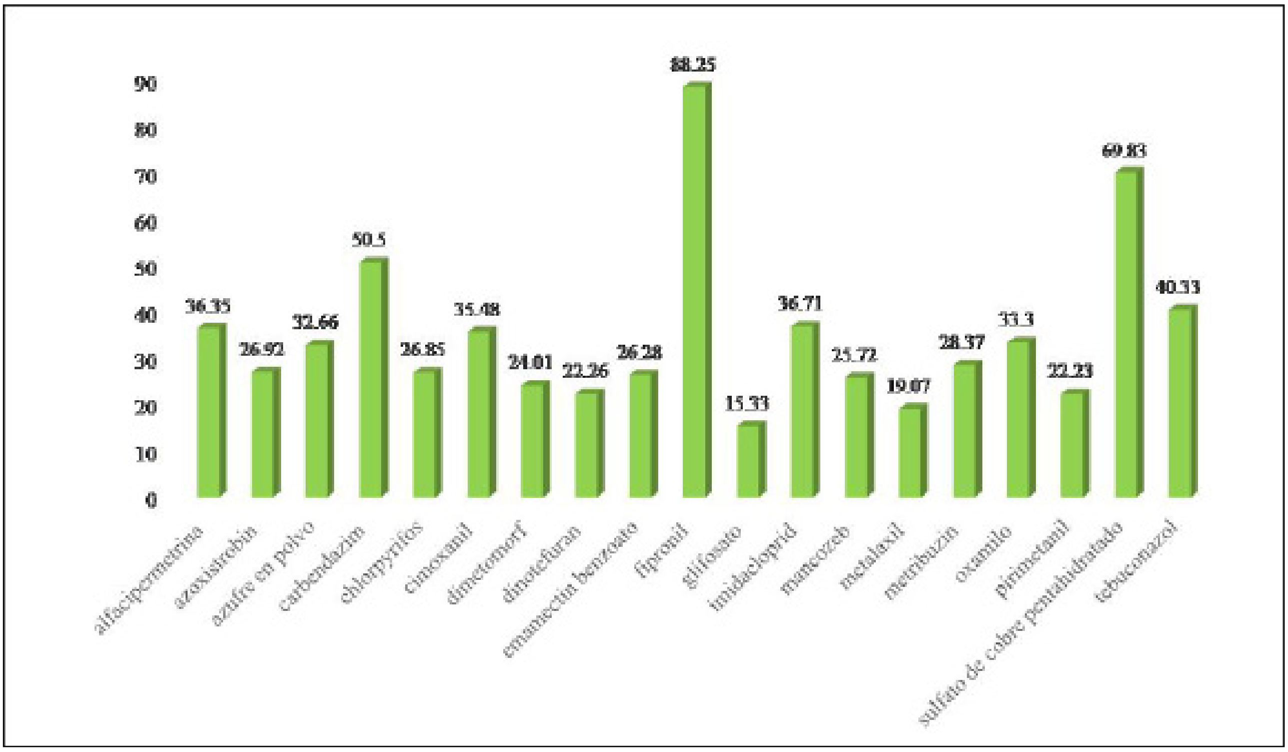

Figure 8. Total EIQ value of pesticides applied per cucumber campaign in the Chancay-Huaral valley (2018-2019).

Carrot crop

In the carrot crop, eight pesticides applications were carried out, some of them were formulated mixtures (Table 10). It was determined that the EI/ha per campaign was 125.38.

During a carrot campaign, 11 active ingredients were applied. Four were fungicides (36.36 %), three herbicides (27.27 %), three nematicides (27.27 %), and one insecticide (9.09 %) (Table 11). For this crop, the applications were not repeated.

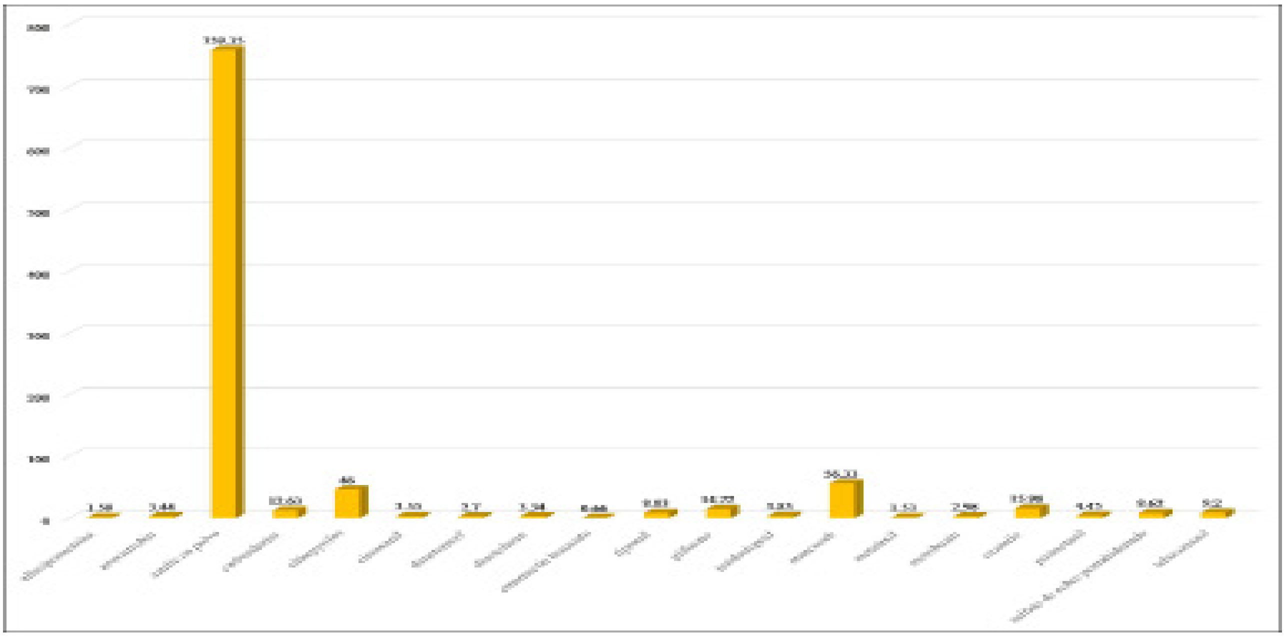

Figure 9. Cumulative EI/ha value of pesticides applied per cucumber campaign in the Chancay-Huaral valley (2018-2019).

Table 9. Number of active ingredients, EI/ha value of pesticides applied per cucumber campaign in the Chancay-Huaral valley, Lima (2018-2019).

Pesticide category	Active ingredients		Environmental impact	
	N°	%	Cumulative value (EI/ha)	%
Fungicides	9	47.37	102.45	10.67
Herbicides	2	10.53	17.70	1.84
Insecticides	6	31.58	64.270	6.70
Nematicides	1	5.26	15.98	1.67
Acaricides	1	5.26	759.35	79.12
Total	19	100	959.75	100

Table 10. Environmental impact (EI/ha) value per carrot campaign in the Chancay-Huaral valley (2018-2019).

N°	Phenological or handling stage	Phytosanitary problem	Pesticide category	Active ingredient			Comercial dose (kg.L^{-1}. ha^{-1}) (2)	No. of applications (4)	Water consumption (L.ha^{-1})	EIQ (1)	EI.ha^{-1} (1*2*3*4)
				Denomination	Concentration of the commercial product	Concentration (%) (3)					
1	pre-sow	annual weeds	herbicide	metribuzin	700 g/kg WG	0.7	0.15	1	200	28.37	2.98
2	sow	damping-off	fungicide	carbendazim	500 g/L SC	0.5	0.2	1	200	50.5	5.05
3	sow and vegetative growth	nematodes	nematicide	cadusafos	100 g/kg GR	0.1	25	1	--	26.85	67.13
4	sow and vegetative growth	nematodes	nematicide	oxamyl +	240 g/L SL	0.24	1	1	200	33.3	7.99
				copper sulfate pentahydrate	247 g/L SC	0.247	0.5			69.83	8.62
5	sow and vegetative growth	nematodes	nematicide	fluopyram	500 g/L SC	0.5	1.5	1	300	17.83	13.37
6	vegetative growth	earthworms	insecticide	chlorpyrifos	480 g/L EC	0.48	0.4	1	200	26.85	5.16
7	vegetative growth	broadleaf weeds and grasses	herbicide	linuron +	500 g/L SC	0.5	1	1	200	19.32	9.66
				clethodim	125 g/L EC	0.125	0.5			17	1.06
8	vegetative growth	*Cercospora*	fungicide	azoxystrobin+ difenoconazole	200 g/L +	0.2	0.4	1	400	29.62	2.37
					120 g/L SC	0.12				41.5	1.99
								8			**125.38**

Table 11. Number of active ingredients and applications of various pesticide types applied per carrot campaign in the Chancay-Huaral valley, Lima (2018-2019).

Pesticide category	Active ingredients		Applications	
	N°	%	N°	%
Fungicides	4	36.36	4	36.36
Herbicides	3	27.27	3	27.27
Insecticides	1	9.09	1	9.09
Nematicides	3	27.27	3	27.27
Total	11	100	11	100

In Figure 10 shows the EIQ values of the products applied to carrot crop. It is observed that the product with the highest value is copper sulfate pentahydrate with 69.83, followed by carbendzaim with 50.5 and difenoconazole with 41.5.

In Figure 11, it is observed that the hightest EI/ha per pesticide corresponds mainly to cadusafos with 67.13 followed by fluopyram with 13.37 and linuron with 9.66.

In Figure 12, it is observed that the nematicides have the highest EI/ha value with 88.49 and have 3 active ingredients applied. This is due to the fact that the product to be harvested is part of a root and that it is the organ to protect from the presence of nematodes, especially *Meloidogyne incognita*.

Lettuce crop

In the lettuce crop, 12 pesticides applications were carried out, for which farmers tend to use mixtures to control phytosanitary problems (Table 12). It was determined that the EI/ha per campaign was 81.88.

During lettuce campaigns, 15 active ingredients were applied. Of these, seven were insecticides (46.67 %), 6 fungicides (40 %), and 2 herbicides (13.33 %). In this crop, the applications were not repeated.

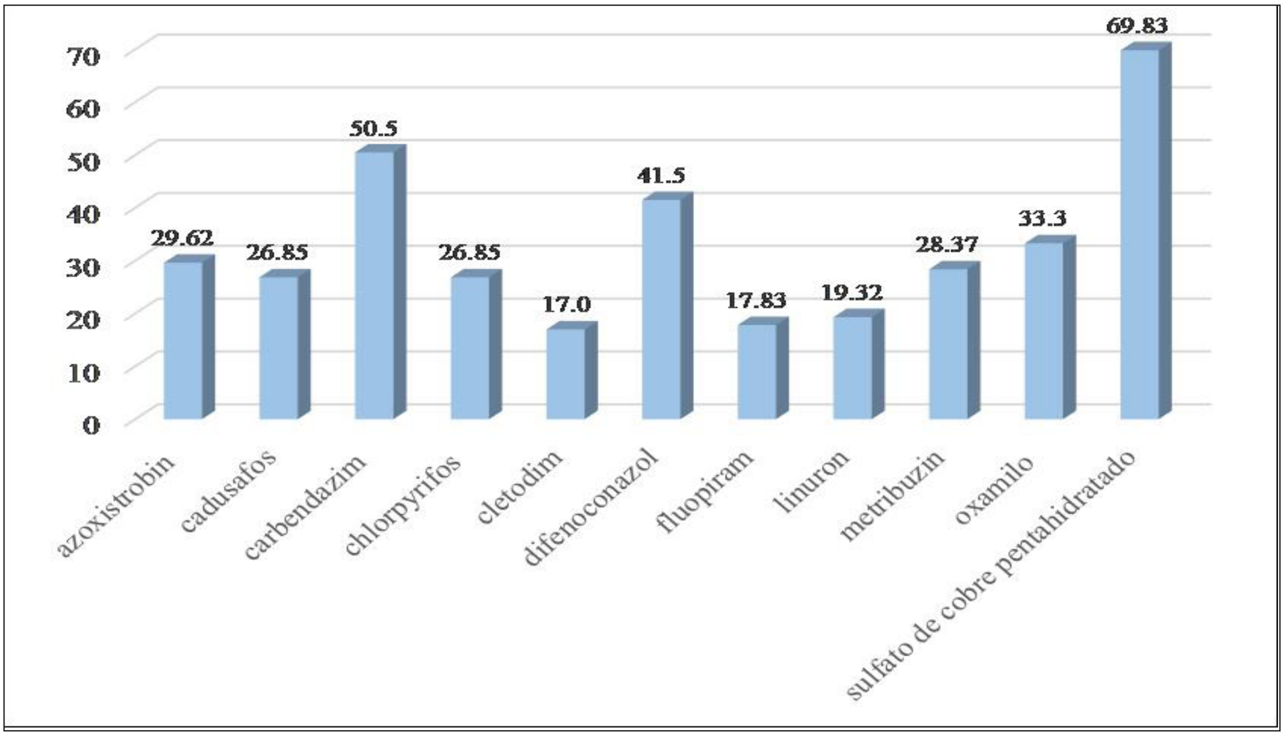

Figure 10. Total EIQ value of pesticides applied per carrot campaign in the Chancay-Huaral valley (2018-2019).

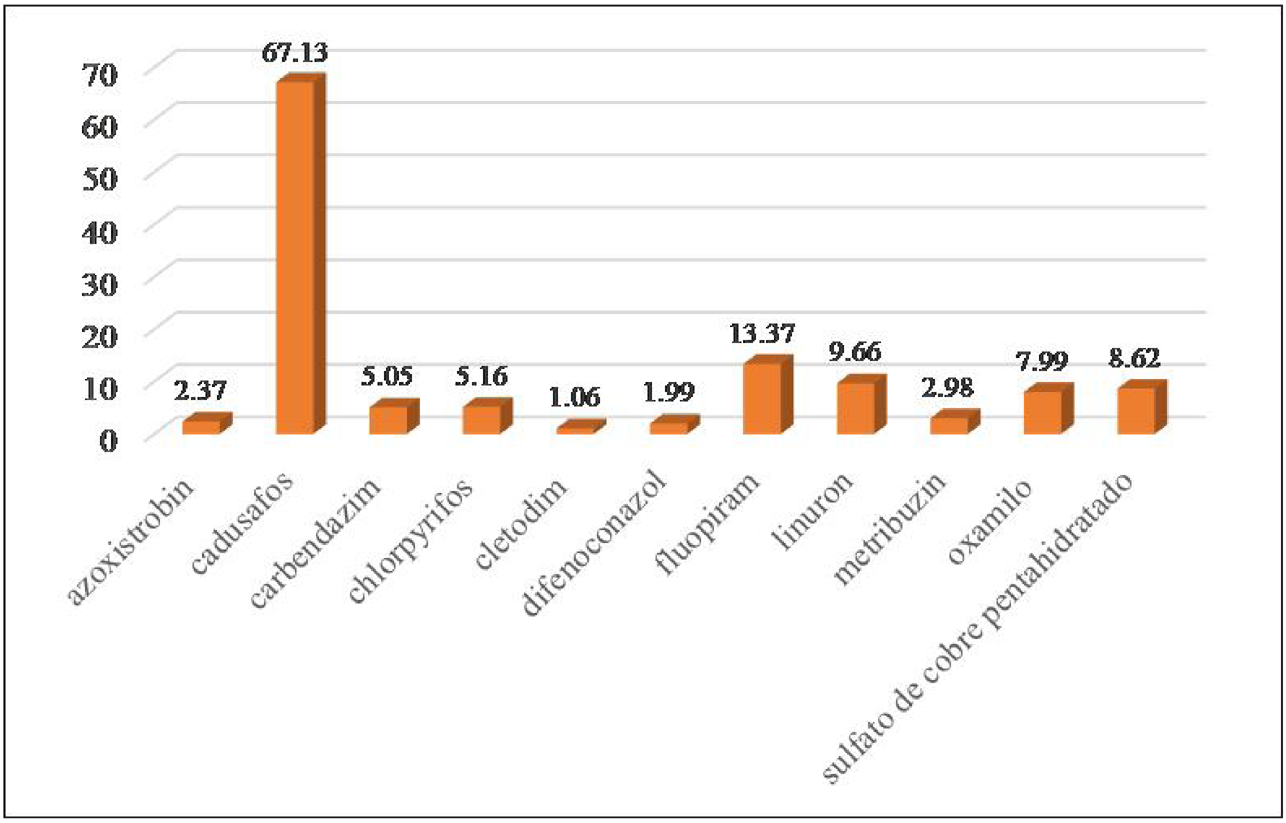

Figure 11. Cumulative EI/ha value of pesticides applied per carrot campaign in the Chancay-Huaral valley (2018-2019).

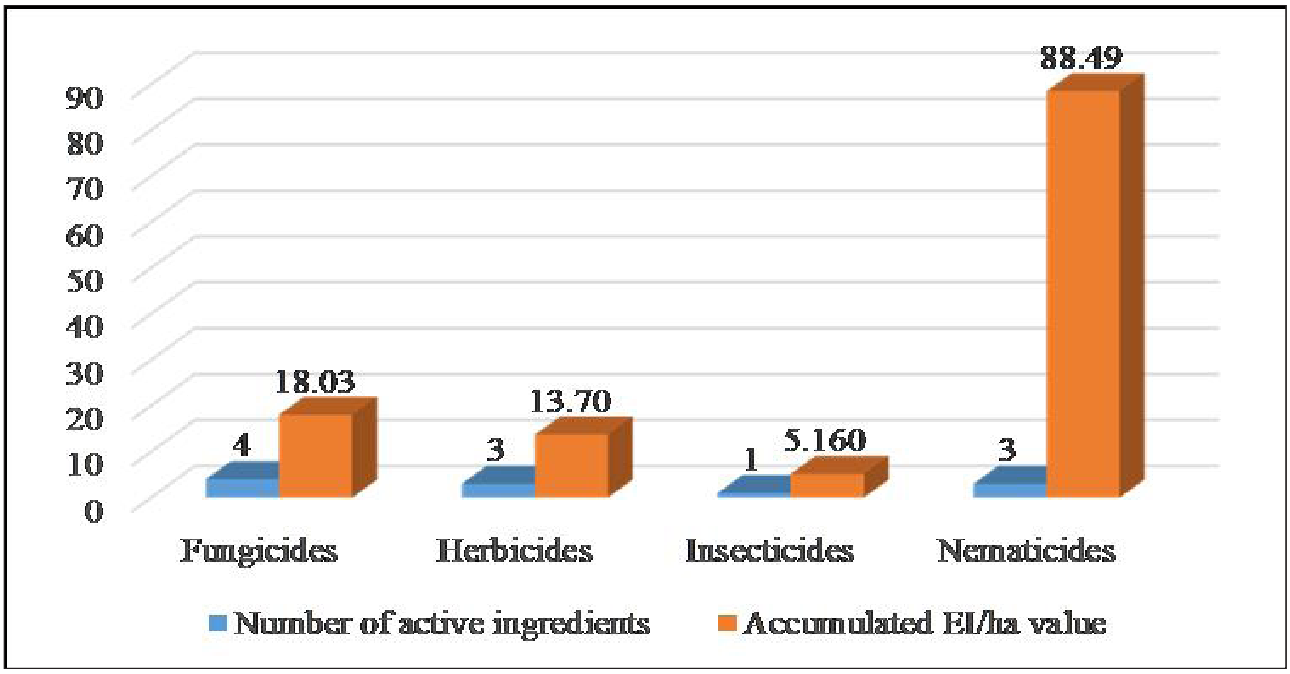

Figure 12. Number of active ingredients applied and EI/ha value of pesticides per carrot campaign in the Chancay-Huaral valley (2018-2019).

Table 12. Environmental impact (EI/ha) value per lettuce campaign in the Chancay-Huaral valley (2018-2019).

N°	Phenological or handling stage	Phytosanitary problem	Pesticide category	Active ingredient			Comercial dose (kg.L^{-1}.ha^{-1}) (2)	No. of applications (4)	Water consumption (L.ha^{-1})	EIQ (1)	EI.ha^{-1} (1*2*3*4)
				Denomination	Concentration of the commercial product	Concentration (%) (3)					
1	pre-transplant	weeds	herbicide	paraquat	276 g/L SL	0.28	1	1	200	24.73	6.83
2	pre-transplant	annual weeds	herbicide	pendimethalin	455 g/L CS	0.46	1	1	200	30.17	13.73
3	transplant	earthworms	insecticide	chlorpyrifos	480 g/L EC	0.48	0.5	1	--	26.85	6.44
4	transplant and vegetative growth	damping-off	fungicide	carbendazim	500 g/L SC	0.50	0.2	1	200	50.5	5.05
5	transplant and vegetative growth	chupadera fungosa	fungicide	copper sulfate pentahydrate	247 g/L SC	0.25	1.25	1	200	69.83	21.56
6	head formation	leaf-mining fly	insecticide	cyantraniliprole	100 g/L OD	0.10	0.45	1	300	18.34	0.83
7	head formation	leaf-mining fly	insecticide insecticide	abamectin + deltamethrin	18 g/L EC 25 g/l	0.02 0.03	0.375 0.375	1	300	34.68 28.38	0.23 0.27
8	head formation	Spodoptera spp.	insecticide	chlorantraniliprole	200 g/L SC	0.20	0.1125	1	300	18.34	0.41
9	head formation	Spodoptera spp.	insecticide	emamectin benzoate + lufenuron	50 g/kg + 100 g/kg WG	0.05 0.10	0.15	1	300	26.28 16.29	0.20 0.24
10	head formation	*Sclerotinia*	fungicide	benomyl	500 g/kg WP	0.50	0.3	1	300	30.24	4.54
11	head formation	*Botrytis*	fungicide	pyrimethanil	400 g/L SC	0.40	0.4	1	400	22.23	3.56
12	head formation	mildew	fungicide	mancozeb + metalaxyl	640 g/kg + 80 g/kg WP	0.64 0.08	1	1	400	25.72 19.07	16.46 1.53
								12			81.88

In Figure 13 shows the EIQ values of the products applied to the lettuce crop. It is observed that the product with the highest value is copper sulfate pentahydrate with 69.83, followed by carbendazim with 50.5 and abamectin with 34.68.

In Figure 14, it is observed that the highest EI/ha value per product corresponds mainly to copper sulfate pentahydrate with 21.56, followed by mancozeb with 16.46 and pendimethalin with 13.73.

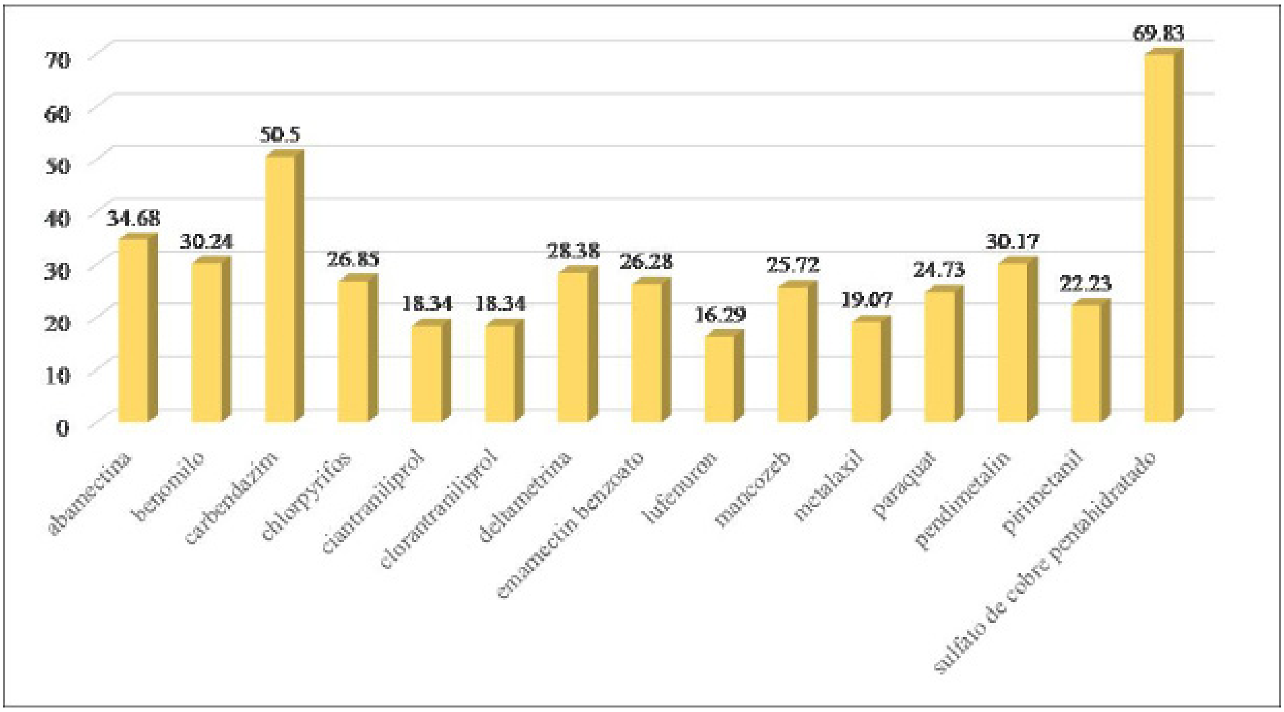

Figure 13. Total EIQ value of pesticides applied per lettuce campaign in the Chancay-Huaral valley (2018-2019).

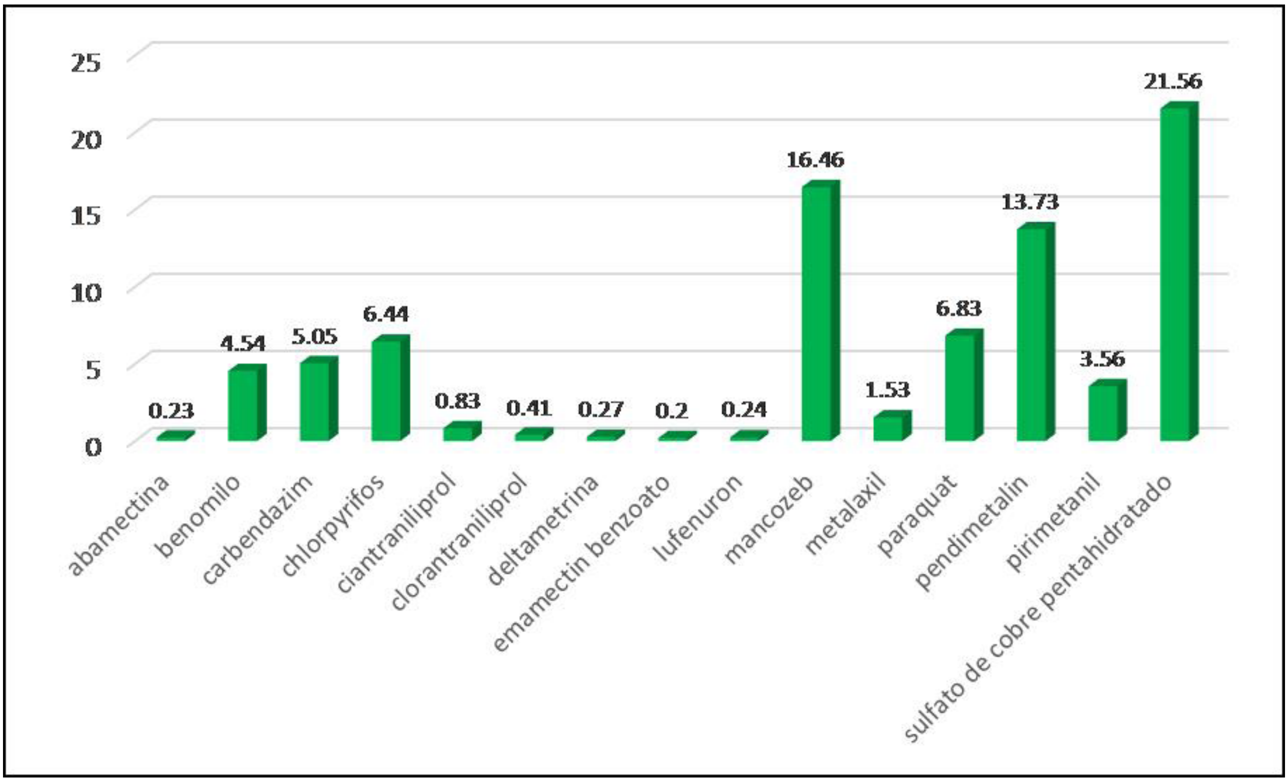

Figure 14. Cumulative EI/ha value of pesticides applied per lettuce campaign in the Chancay-Huaral valley (2018-2019).

In Figure 15, it is observed that fungicides have the highest EI/ha value with 52.7 and 6 active ingredients, followed by herbicides with 20.56 EI/ha with 2 active ingredients and finally, insecticides with 2 active ingredients with 8.62 EI/ha and 7 active ingredients.

Fungicides with 6 active ingredients (40 %) have the highest EI/ha value, 52.7 (64.36 %) (Table 14).

Farmers carry out numerous phytosanitary applications. These are scheduled every 3 to 4

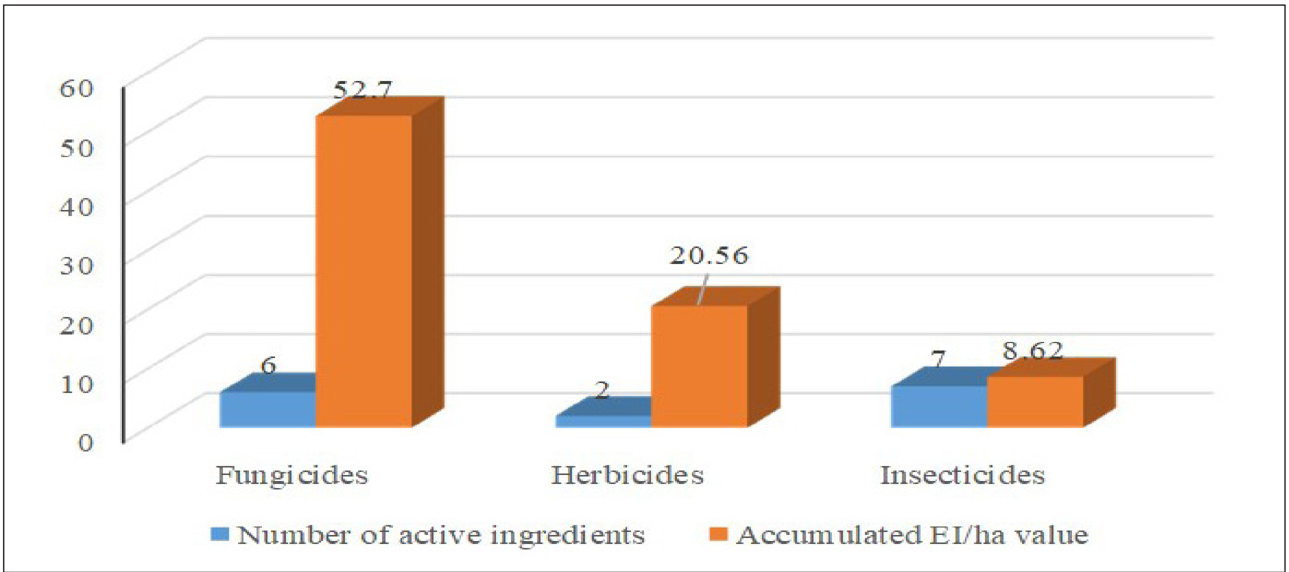

Figure 15. Number of active ingredients applied and EI/ha value of pesticides per lettuce campaign in the Chancay-Huaral valley (2018-2019).

Table 13. Number of active ingredients and applications of various pesticide types applied per lettuce campaign in the Chancay-Huaral valley, Lima (2018-2019).

Pesticide category	Active ingredients		Applications	
	N°	%	N°	%
Fungicides	6	40	6	40
Herbicides	2	13.33	2	13.33
Insecticides	7	46.67	7	46.67
Total	15	100	15	100

Table 14. **N**umber of active ingredients, EI/ha value of pesticides applied per lettuce campaign in the Chancay-Huaral valley, Lima (2018-2019).

Pesticide category	Active ingredients		Environmental impact	
	N°	%	Cumulative value (EI/ha)	%
Fungicides	6	40	52.7	64.36
Herbicides	2	13.33	20.56	25.11
Insecticides	7	46.67	8.62	10.53
Total	15	100	81.88	100

days, in tomato, bell pepper and cucumber crops, they are slightly more spaced out in carrot and lettuce crops. These applications are sometimes made without regarding the withdrawal periods, becoming a problem to consumers. In the tomato crops, per campaign, 27 active ingredients are applied, including 15 insecticides, and 33 to 42 applications are made varying on the presence of *Prodiplosis longifila*, a pest present in most vegetables and some fruit trees along our coast (Castillo, 2018; Castillo et al., 2020). For the bell pepper crops, 28 active ingredients were applied per campaign, of these 16 are insecticides, during 36 to 45 applications. In the cucumber crops, 22 foliar applications were made with 19 active ingredients, fungicides being the most used due to the plant susceptibility to foliar diseases attacks. In the carrot crops, eight pesticide applications were made, being fungicides and nematicides the most applicated pesticide types. In the lettuce crops, 12 applications were made, being insecticides the most applied pesticide type. Both carrot and lettuce crops do not present *Prodiplosis longifila* as the main pest. In the carrot crop, the application of nematicides stands out due to this crop being sensitive to the attack of *Meloidogyne incognita*, and what is sold is the root of the plant. In the lettuce crop, both insecticides and fungicides stand out, to avoid foliar damage leaves and to cosmetic damage, respectively.

According to interviews and surveys carried out with farmers and technicians, farmers mix pesticides on their own or at indications of their suppliers. Farmers mix up to four products for a single foliar application. Regarding the environmental impact assessment (EI/ha) proposed by Kovach et al. (2004), cucumber crops have the value of 959, followed by bell pepper crops with 595.97, tomato crops with 541.30, carrot crops with 125.38, and lettuce crops with 81.88. The highest value was for the cucumber crops due to the application of dry sulfur powder with a dose of 25 Kg/ha. Even though sulfur is considered a safe product for the consumer; the impact evaluation methodology also considers products in the impact on the producer and environment. Technical farmers and supply shop consultants only relate to the danger of pesticide products with the value of the average lethal dose (DL50), considering only the effect on consumers and producer, but neglecting the effects on the environment. Arrebola et al. (2004), mentions all the effects that sulfur has on human health, the environment and plants. The EI/ha values that result from the pest management represents a threat to internal consumption due to the intense applications that are made because withdrawal periods nor maximum residue limits are not respected. This study differs from the one of Muhammetoglu & Uslu (2007), which analyzes pesticide products of different crops within a region of Turkey, in this case the product is analyzed within the same crop, and from the one of Vargas-González et al. (2019), which only studies melon crops in three areas with the highest production.

Farmers use chemical control to avoid pests without an IPM, similar to results of Guerrero-Padilla & Otiniano-Medina (2012), who mentioned the problems generated by this type of management in the agricultural valleys. The implementation of an IPM is an option to improve this reality. The integration of professionals in the impact evaluation, as Ortiz & Pradel (2009) mention, will allow to review the technical portion of the IPM, and also involve the livelihoods of farmer, including various capitals, such as human capital (their knowledge), social capital (their network of contacts), natural capital (their land, and the biodiversity and environment they manage), and financial capital (ability to convert other capitals into money).

Conclusions

During one campaign, tomato crops have 33 to 42 pesticide applications that involve the use of 27 active ingredients; among these, insecticides are the most used and involve the use of 15 active ingredients. Bell pepper crops have 36 to 45 pesticide applications that involve the use of 28 active ingredients; among these, insecticides are the most used and involve the use of 16 active ingredients. Cucumber crops have 22 pesticide applications that involve the use of 19 active ingredients; among these, fungicides are the most used. Carrot crops have eight pesticide applications that involve the use of 11 active ingredients.

Finally, lettuce crops have 12 pesticide applications that involve the use of 15 active ingredients.

Farmer apply formulated mixtures that involve two active ingredients, or mixtures of commercial products that add up to four active ingredients chosen based on their criteria or on suggestion of their supplier. The frequency of the applications ranges between 3 - 4 days and may take place even during the fructification of the products to be harvested and without considering withdrawal periods. The phytosanitary management carried out by the farmers of the Chancay-Huaral valley is based on chemical control without an IPM structure where the EI/ha was of 541.30 per campaign for the tomato, 595.97 for bell pepper, 959 for cucumber,125.38 for carrot, and 81.88 for lettuce.

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Author contributions

Elaboration and execution, development of methodology, conception and design; editing of articles and supervision of the study have involved all authors.

Conflicts of interest

The signing authors of this research work declare that they have no potential conflict of personal or economic interest with other people or organizations that could unduly influence this manuscript

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