KENYA ORGANIC AGRICULTURE NETWORK

Pesticide use in Kirinyaga and Murang'a Counties:

A wake up call for better pest control strategies

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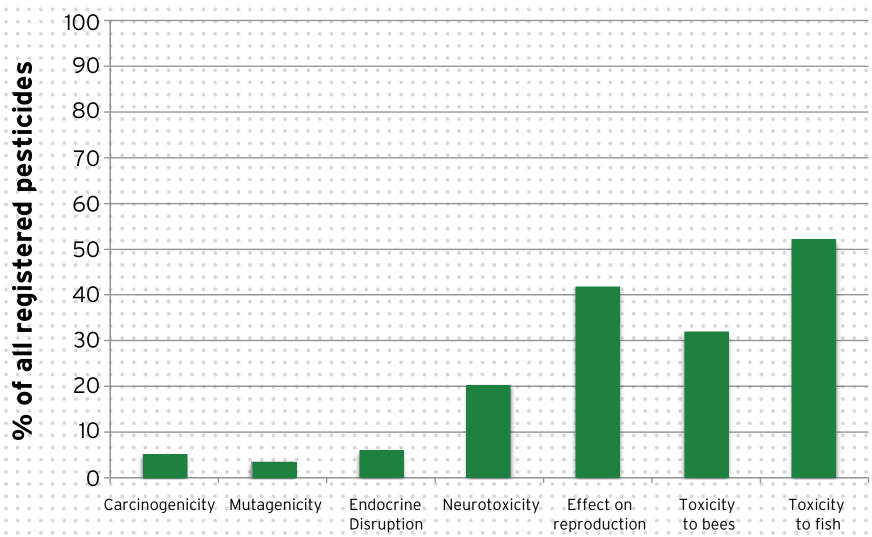
> Pesticides affect organisms in the environment and can cause acute and chronic human health effects. A research report published by the Route to Food Initiative (RTFI) in 2019 illustrated that many pesticides registered by the Pest Control Products Board (PCPB) in Kenya, have the potential to cause serious health and environmental effects.

1.0 Introduction

Agricultural activities are among the most important source of income for rural and also urban citizens of Kenya. Approximately 70% of the rural population rely on agricultural activities for their livelihoods. Although there is a growing appreciation for Integrated Pest Management (IPM) and organic farming, most farmers still use conventional pest control practices. Pesticides are viewed as the solution to control pests, diseases and weeds. Lack of proper information and knowledge on the use of pesticides among the majority of farmers poses risks to food production and food safety in the country. According to Kenya's Food and Nutrition Security Policy of 2011, there are 20 legislative acts established to address food safety, standards and quality issues. The implementation of legislation and the mandate of various government authorities is not well harmonized, leaving citizens exposed to potential consumption of contaminated foods.

Pesticides affect organisms in the environment and can cause acute and chronic human health effects. A research report published by the Route to Food Initiative (RTFI) in 2019 illustrated that many pesticides registered by the Pest Control Products Board (PCPB) in Kenya, have the potential to cause serious health and environmental effects. Of the pesticides registered, 5% of the active ingredients have been proven to be carcinogenic (cause cancer), 4% are mutagenic (affect genetic makeup), 6% are endocrine disruptors (affect the hormonal system), 20% are neurotoxic (affect the nervous system) and 41% have effects on male reproductive systems, including causing infertility. Registered pesticides can also harm the environment. The report found that 32% of the registered active ingredients are toxic to bees and other pollinators, and 52% are toxic to fish (Figure 1).

FIGURE 1 Percentage of pesticides registered in Kenya showing proven chronic health and environmental effects (Route to Food Report, 2019).



The RTFI report also revealed that 34% of the active ingredients registered in Kenya are withdrawn from the European market or are heavily restricted in Europe due to potential chronic health effects, environmental persistence and high toxicity towards fish or bees. Pesticide registration standards have been benchmarked against the European (EU) system for the following reasons:

- The EU is setting best practices in food safety
- The EU follows a comprehensive registration regime
- The EU strictly applies the Precautionary Principle
- The EU is the second highest exporter of pesticides to Kenya

It is better to be safe than sorry

The Precautionary Principle applies where scientific evidence is insufficient, inconclusive or uncertain and preliminary scientific evaluation indicates that there are reasonable grounds for concern that the potentially dangerous effects on the environment, human, animal or plant health may be inconsistent with a high level of protection (EU, 2000).

However, the RTFI report only captured the registration status of pesticides in Kenya, and not their actual use and residues in local food items. For this reason, this study carried out by the Kenya Organic Agricultural Network (KOAN) sought to find out from farmers and local pesticides sellers if pesticides are used and if they are found in soil, water and food.

This paper documents the use of pesticides in Murang'a and Kirinyaga counties in Central Kenya. It specifically investigates pesticide use on crops, and the prevalence of pests and diseases. Additionally, an analysis of pesticide residues in commonly consumed vegetables namely kale and tomatoes, highlights food safety issues in the two counties.

The purpose of the study is to provide evidence in support of a process of withdrawing certain pesticides from the Kenyan market based on their toxicity to human health and the environment, as well as to provide motivation for regular pesticide residue monitoring programmes by government authorities. Additionally, the study provides guidance to policymakers on how to prioritise the pesticides and crops that require attention. The study promotes safer alternatives to chemical pesticides, for crop and pest management.

2.0 Methodology of the surveys

The partners (KOAN and Eco-Trac Consulting) undertook two main studies in Murang'a and Kirinyaga counties. The first was a rapid assessment survey conducted between January and February 2020. The second was a pesticide residue analysis on kales and tomatoes sourced from Kutus, Kagio and Makutano markets, which was conducted in July 2020. The two counties were selected for the following reasons:

1. Agriculture is the main economic activity in both counties. Farmers mainly grow horticultural produce for domestic and export markets.
2. The counties are among the highest producers of horticultural crops and therefore rely heavily on pesticides.
3. Both county governments have expressed interest in supporting the transition to sustainable agricultural practices. Murang'a County is subsidizing organic inputs. Kirinyaga County has included establishment of an organic city within its County Integrated Development Plan (CIDP).

Three different groups took part in the survey. Using purposive random sampling methodology, the first group included 280 smallholder farmers with an average land size of 1.37 acres were interviewed (140 households per county), the second group featured 20 county and NGO extension service providers and the final group comprised of 20 local agrovet dealers retailing agrochemical products to farmers in both counties. Information was collected on the use of insecticides, herbicides and fungicides, targeted pests, diseases, weeds and managed crops.

Objectives of the rapid assessment survey

1. To assess the extent of pesticide use, specific pesticides used and on what crops by farmers in the two counties
2. To determine the influence of agrovet dealers on pesticides use
3. To identify crops and pests which should be prioritised for better pest and disease management

3.0 Pesticide hazards

While farmers and rural residents are most frequently and directly exposed to pesticides, consumers are also at risk through residues in food and drinking water.

In terms of chronic health effects, pesticides can be classified as causing carcinogenicity, mutagenicity / genotoxicity, reproductive toxicity and neurotoxicity (UN, 2017). Additionally, many pesticides are classified as endocrine disrupters, meaning they interfere with the hormonal system, causing adverse effects such as increase or decrease in the activity of male or female hormones. This is not surprising since most pesticides are deliberately designed to act on the hormone system of plants and insects and accordingly their toxicity derives from the resulting change in hormones activities.

Since pesticides are deliberately designed to kill insects, many have an impact on the ecosystem, including fish, pollinators, earthworms and other important soil organisms. These effects are made worse, if mitigation measures such as buffer zones, recommended spraying times and spraying rates, and directions on target crops are not followed.

The survey confirmed that different pesticides were used by farmers. The active ingredient in each pesticide was identified. For each active ingredient, toxicity data was investigated in the Pesticide Properties Database (PPDB) (FOOTPRINT, 2006), which provides toxicity information on all active ingredients worldwide.

Table 1. Categories of toxicity according to PPDB

Wildlife toxicity (Bees, fish) [mg/L]		Chronic human health	
Very toxic	< 0.1	Yes	Carcinogenicity
Toxic	0.1-1.0	Possible	Mutagenicity
Moderately toxic	1.0 -10	No	Reproduction Toxicity
Low toxic	10-100	No data	Neurotoxicity
Not toxic	>100		Endocrine disruption

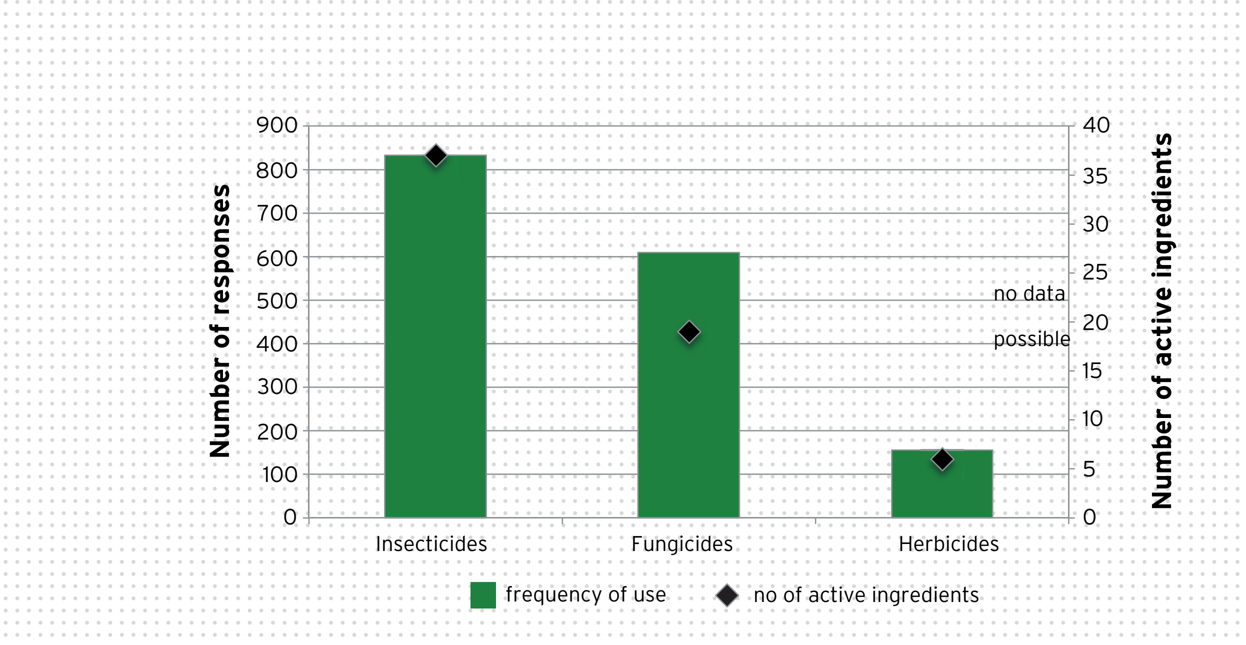
Different toxicity classification scores were assigned to prioritize the most toxic and most frequently used pesticides according to the methodology proposed by Dabrowski *et al.* (2014), (see Appendix 1). Those with the highest toxicity score were identified through summation.

4.0 Pesticide use in the two counties

Farmers in Kirinyaga and Murang'a were found to use 64 active ingredients and 142 different product formulations. These active ingredients are used for 32 different crops to control 30 pests, 11 diseases and 24 weeds.

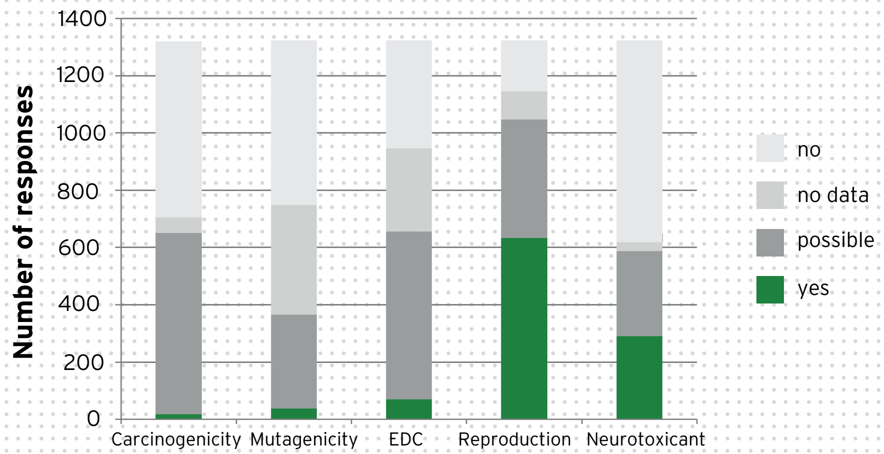
Insecticides were the most frequently used with 833 positive responses and containing 37 different active ingredients, followed by fungicides with 609 responses and containing 19 active ingredients and lastly, herbicides, with 156 responses and containing 6 active ingredients (Figure 2).

FIGURE 2 Percentage of pesticides registered in Kenya showing proven chronic health and environmental effects (Route to Food Report, 2019).



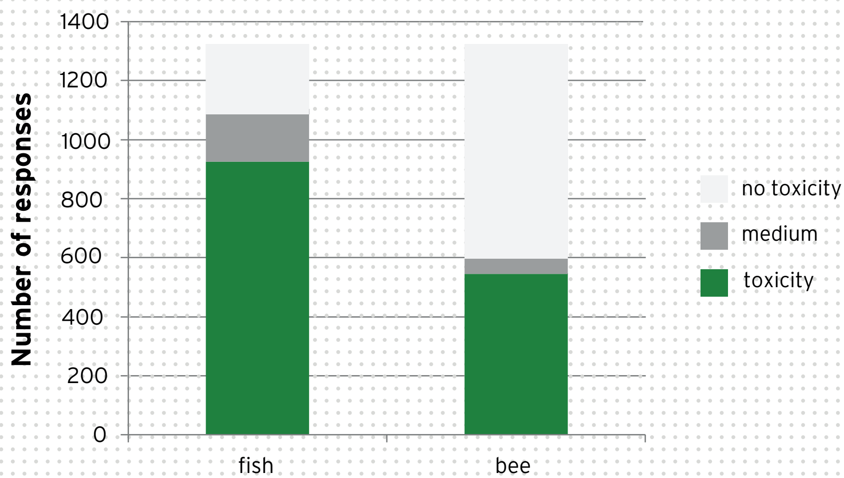
Of the 1324 collected responses; 1.4% (18 responses) used pesticides proven to be carcinogenic, 2.9% (38 responses) were mutagenic, 5.4% (71 responses) used pesticides known to act as endocrine disrupters and 23% (291 responses) used pesticides proven to be neurotoxic (Figure 3). The majority of farmers, 48%, use pesticides, which are proven to have an effect on human reproduction systems. This is especially worrying since 30% of the respondents reported they did not wear any Personal Protection Equipment (PPE) while spraying.

FIGURE 3 Pesticide use with various chronic health effects (BASED ON FOOTPRINT, 2006).



The use of pesticides, which are toxic to fish and bees is very high. A total of 70% of the respondents (925 responses) used pesticides with high or very high toxicity towards fish and 41% (545 responses) used pesticides with high or very high toxicity towards bees (Figure 4). These trends may negatively affect food production in the future, as the population of pollinators is expected to reduce with continued use.

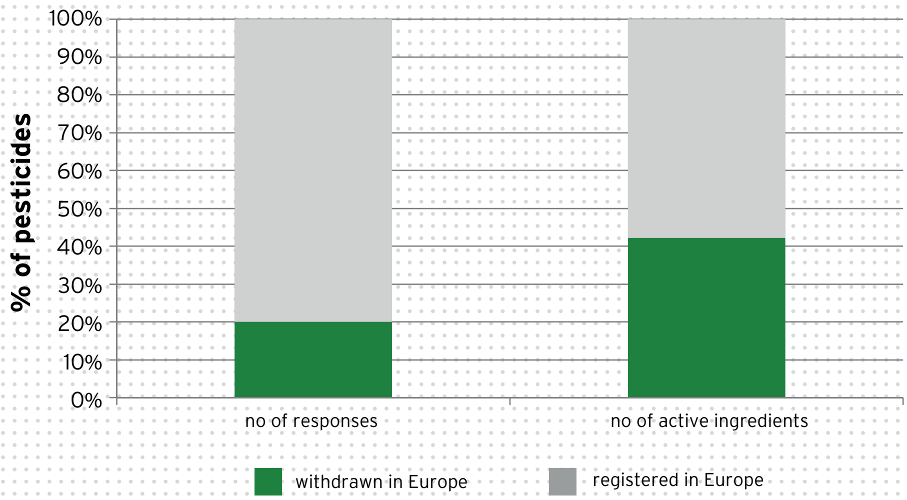
FIGURE 4 Pesticide use showing bee and fish toxicity



The percentage of pesticides in use, which show carcinogenicity, mutagenicity and endocrine disrupting activity, is relatively low. In contrast, the percentage of pesticides, which show neurotoxicity and effects on reproduction, is very high.

Of all the responses, 20% of farmers use 27 active ingredients (42%) which are withdrawn in Europe (Figure 5). This means that of the 77 active ingredients that are registered in Kenya but withdrawn in Europe, 35% are used by farmers in Murang'a and Kirinyaga counties.

FIGURE 5 Percentage of active ingredients withdrawn in Europe



NEED TO KNOW

35% of the 77 active ingredients registered in Kenya, but withdrawn in Europe, are used in Murang'a and Kirinyaga counties.

Chlorpyrifos, which has recently been withdrawn in Europe, is the most frequently used active ingredient (71 responses in 8 products), followed by propineb (29 responses in 3 products), beta cyfluthrin (26 responses in 1 product) and carbendazim (24 responses in 4 products). The full list of the pesticides being used in the two counties but withdrawn in Europe can be seen in Appendix 2.

The pesticide active ingredients reported to be used in the counties were ranked according to their toxicity towards the environment (aquatic toxicity, bee toxicity and mobility) and towards human health (carcinogenicity, mutagenicity, reproduction effect, endocrine disrupter, neurotoxicity). A higher score will translate to higher toxicity towards environment and human health with the maximum worst score case being 45. The combined scores are shown in Appendix 3.

NEED TO KNOW

The insecticides permethrin*, bifenthrin*, malathion, diazinon*, carbaryl*, cypermethrin and chlorpyrifos* and the fungicides carbendazim*, chlorothalonil* and mancozeb are top ten in terms of their environmental and human health toxicity. Efforts should be taken to substitute these pesticides with less toxic alternatives (*withdrawn in Europe).

Agrovet recommendations: In the study, 201 recommendations were collected from agrovet dealers. Farmers used the products based on the recommendations from the agrovet dealers. They recommended 43 products of which 10 products are withdrawn in Europe. One of the products recommended contained permethrin which is proven to be carcinogenic and mutagenic (containing thiophanate-methyl), 5 products recommended show endocrine disrupting effects and negative effects on reproduction and 12 products can be neurotoxic. Moreover, 33% of all recommended products are toxic to bees and 60% are toxic to fish. According to the survey data, the recommendations provided by agrovet shops is key since they provide the greatest source of information for farmers.

Extension officer recommendation: In the study, 136 recommendations were collected from extension officers. They recommended 63 products of which 15 products are withdrawn in Europe containing e.g. carbendazim, carbosulfan, bifenthrin and fenitrothion.

NEED TO KNOW

Agrovets and extension officers provide the greatest source of information for farmers and it is worrying that they are recommending pesticide products that are toxic to human health, bees and fish.

Misuse of pesticides: From the survey, it became evident that some farmers were incorrectly using products by applying pesticides on pests they have not been registered for, or they use an insecticide to control a fungal disease or a fungicide to control weeds or insect pests. Although this was observed on few incidences (7%), the consequences can be problematic and it reflects the wider underlying problem of misinformation and misunderstanding when it comes to pesticide use. The issue requires follow up with relevant agencies.

NEED TO KNOW

Misuse of pesticides among farmers reflects the underlying problem of misinformation and misunderstanding when it comes to pesticide use. For example, the wrong type of pesticide is being used to control a certain pest.

5.0 Prioritizing crops and pests for Integrated Pest Management (IPM)

Integrated Pest Management (IPM) aims to avoid the use of toxic pesticides and implements different strategies to control pests and diseases efficiently.

These strategies include:
1. Good agricultural practices (practices such as crop rotation to prevent pest and disease incidences)
2. Use of biocontrol methods (such as traps to control leafminers/caterpillars)
3. Use of biopesticides (for example neem-based products to control termites and other insects)
4. Use of the least toxic synthetic pesticides as a last option. These are pesticides from categories in the World Health Organisation classification schedules III and U.

Example for the integrated pest control of thrips would be the use of Halt Neo (Bacillus Thuringiensis) as biocontrol, the use of neem products or homemade solutions (garlic, chillies) as biopesticides or the use of less toxic pesticides containing e.g. Spinosad.

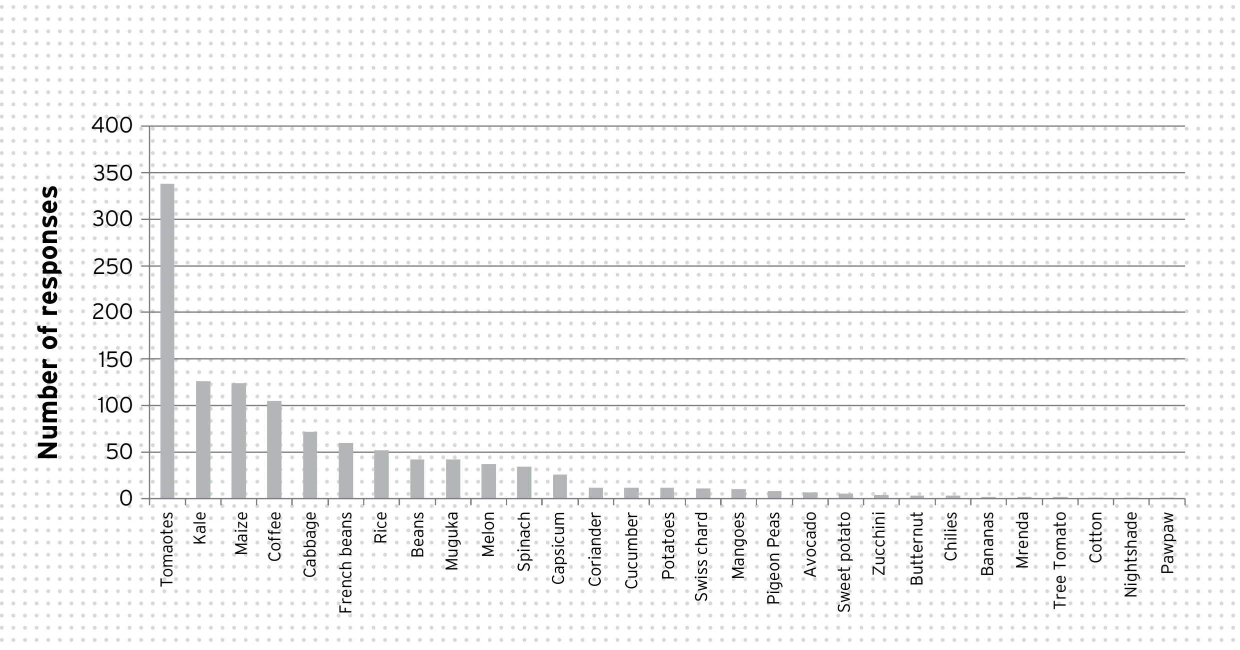
NEED TO KNOW

More details on alternative less toxic pest and disease control strategies can be found at www.saferinputs.com.

5.1 Crops

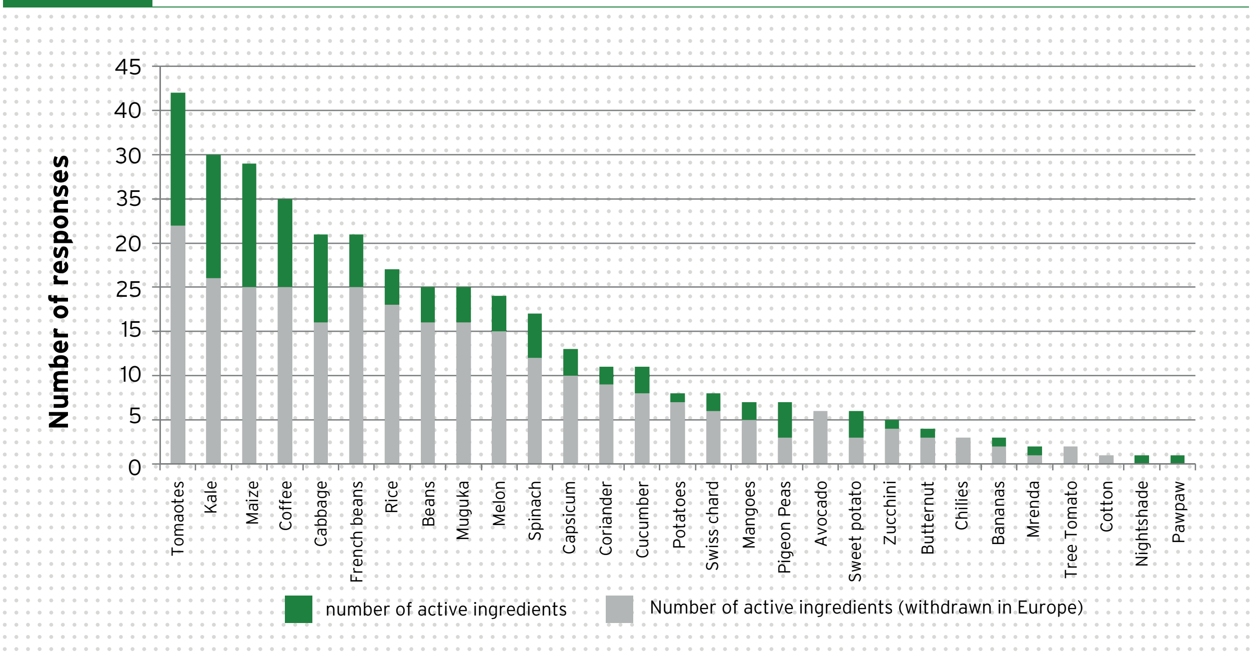
A total of 29 different crops are treated with pesticides in both counties. The extent to which these crops were grown was not established. It is clear that pesticides are most frequently used on tomatoes (338 responses) where 42 different active ingredients were identified. This means that 53% of all responses were using pesticides on tomatoes. This was followed by kale, maize, coffee, cabbage and french beans in that order (Figure 6). As various pesticides were used to control pests, these crops should be monitored regularly to ensure food safety for Kenyans. The toxicity score of the crops can be found in Appendix 4.

FIGURE 6 Frequency of pesticide use on various crops in two counties



The pesticides withdrawn in Europe are mostly used on tomatoes (15 active ingredients), followed by kale (14), maize (14), cabbage (10), coffee (10) and french beans (6) (Figure 7). Since tomatoes, kale, maize and cabbage are part of the daily Kenyan diet, there is a real and significant threat to food safety. The finding underscores the need to establish alternative IPM strategies focusing on these crops, to phase out the above-mentioned pesticides in Kenya.

FIGURE 7 Number of active ingredients per crops



Based on the sum of toxicity scores for each pesticide used on the different crops one can observe a similar order in the food items that give cause for concern.

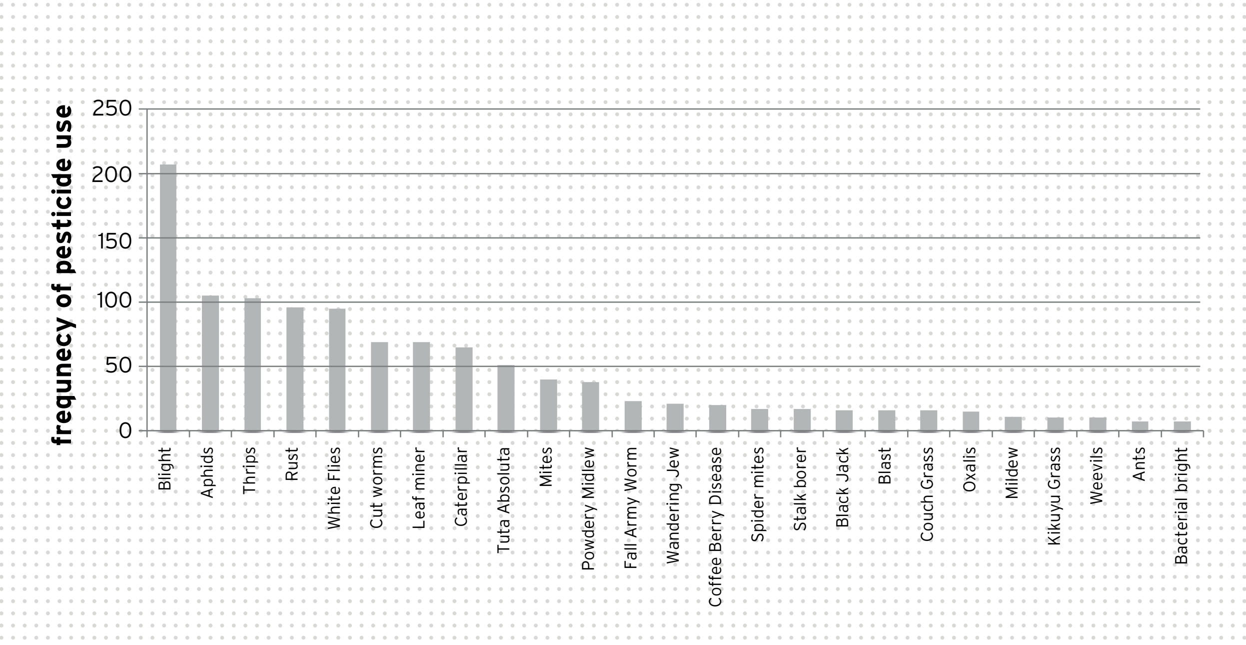
NEED TO KNOW

Tomatoes show by far the highest toxicity score (198), followed by kale (96), maize (93), coffee (87) and rice (69). It is worrying that all these crops (apart from coffee) are foods eaten on a daily basis by Kenyans.

5.2 Pests, diseases and weeds

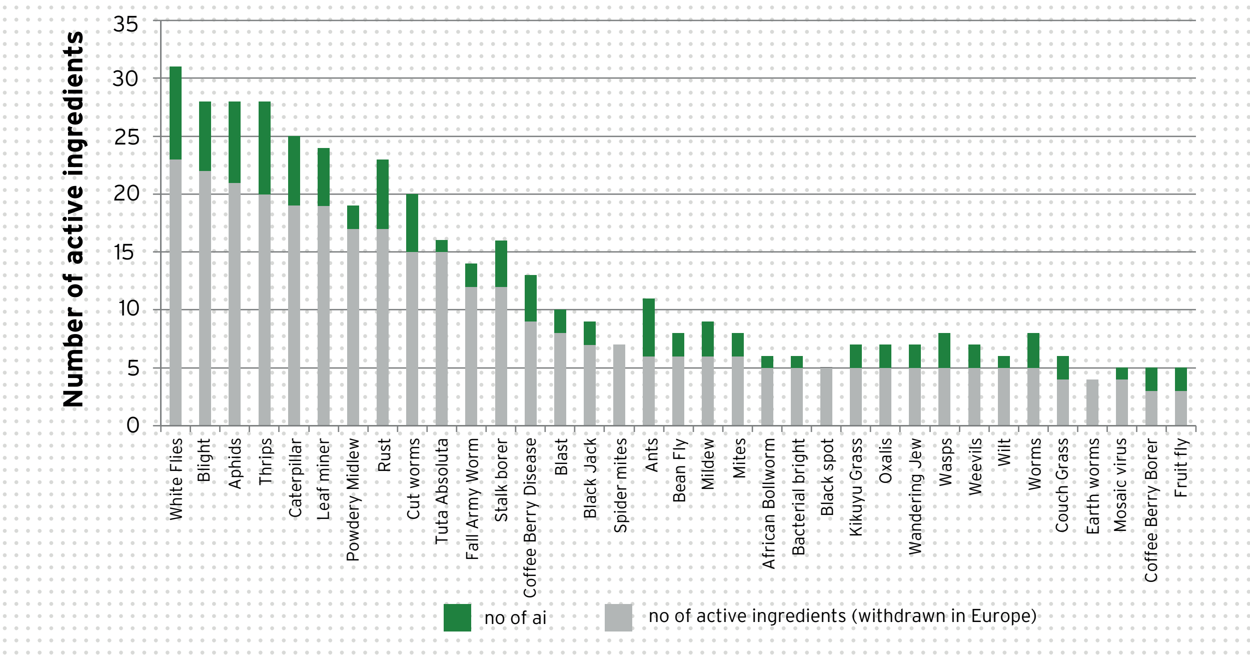
A total of 58 different pests, diseases and weeds need to be controlled in both counties. Figure 8 shows the most common (top 25). The most common fungal diseases were blight (207 responses) and rust (96). The most common insect problems were aphids (105), thrips (103), white flies (95), cutworms (69), leafminer (69), caterpillar (65) and Tuta absoluta (51). The most common weed that required herbicide application was black jack; however, it is not among the top priority problems to control.

FIGURE 8 Frequency of pesticide use on various pest, diseases and weeds



The highest variety of active ingredients (including those ones that are withdrawn in Europe) are used to control white flies (31), blight (28), aphids (28), thrips (28), caterpillar (25) and leafminers (24) (Figure 9). Strategies for reducing the use of toxic pesticides should therefore focus on alternatives for these pests.

FIGURE 9 Number of active ingredients used on various pest, diseases and weeds



The toxicity score of each pest and disease is shown in Appendix 5.

NEED TO KNOW

The fungal disease blight, showed the highest toxicity score, based on the toxicity of the pesticides use to control it, followed by aphids, thrips, white flies and rust. Moreover, Fall Army Worm and Tuta absoluta are among the top 15 most significant pests.

5.3 Pesticide residues in kale (sukuma wiki) and tomatoes

Pesticide residues were analysed in kale and tomatoes, since results had shown that most of the farmers were using pesticides on these two crops with the highest toxicity score. Samples were collected from three different markets (each market from three different sellers). The three samples from each market were combined to one and prepared by Cropnuts for analysis by Groen Agro Control in the Netherlands.

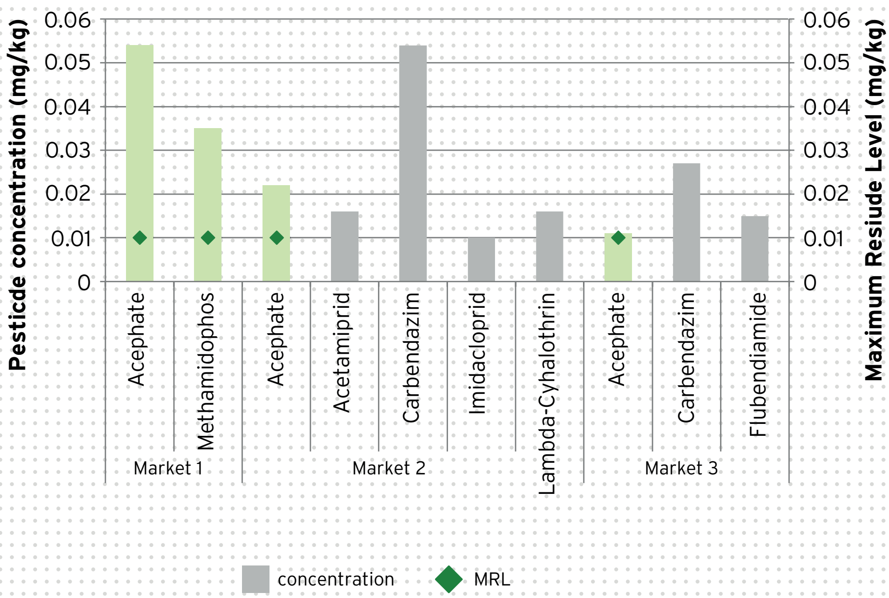
5.3.1 Tomatoes

Pesticide residues were found in all the samples from all three markets and one or more pesticides concentration exceeded the Maximum Residue Level (MRL) set by Kenyan authorities as informed by European standards (Figure 10). Most notably the levels of acephate, a pesticide which is already withdrawn in Europe, exceeded the allowed MRL in all three markets.

Acephate is a strong endocrine disrupter (it disrupts hormone expression in the hypothalamus (FOOTPRINT, 2006)), is a possible carcinogenic and neurotoxicant *(Farag et al.,* 2000*)*. Acephate is normally registered to control aphids, whiteflies and thrips on roses and tobacco and for the control of the Fall Armyworm on maize. The presence of acephate on tomatoes is a threat to food safety in the sampled markets.

Another pesticide, whose level exceeds the MRL is methamidophos. Methamidophos is not registered in Kenya and was also not stated to be used by farmers during the survey. It is proven to be a highly toxic to humans as it is a stong neurotoxic substance and as it causes mutagenicity (FOOTPRINT, 2006). Despite not being registered, its use shows the need for close monitoring of pesticides in the market.

FIGURE 10 Pesticide residues in tomatoes at three different markets in Kirinyaga



NEED TO KNOW

Acephate is registered for use on roses and tobacco but high residue levels were found on tomatoes. No product containing acephate is registered for use on tomatoes by the Pest Control Products Board (PCPB).

NEED TO KNOW

Acephate and methamidophos exceed levels allowed by the European authorities, therefore none of the tomato samples would have been suitable for consumption by European standards. Acephate is withdrawn in Europe and methamidophos is not even registered in Kenya.

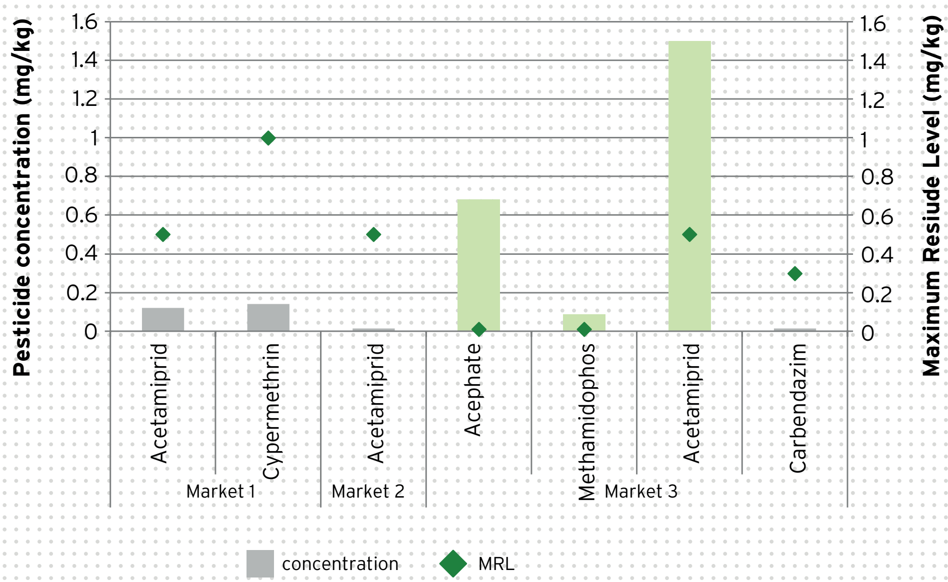
NEED TO KNOW

Most worrying, is the possible health effects on people living in Kenya, arising from the presence of these two active ingredients in the domestic market.

5.3.2 Kale

The same situation is reflected in residue levels in kales (Figure 11). Only the first market (Kutus in Kirinyaga County) shows pesticide residue levels below the MRL and would be acceptable for consumption, but the second (Kagio) and third market (Makutano) sell kale with elevated levels of acephate, methamidophos and acetamiprid. Although there is no evidence that acetamiprid causes any chronic health diseases, the concentration found in Makutano market is very high and triple (x3) the allowed EU MRL (which is taken as Kenyan standard by the PCPB).

FIGURE 11 Pesticide residues in kale at three different markets in Kirinyaga



NEED TO KNOW

The residue levels of acephate, methamidophos and acetamiprid in kale in Makutano and Kagio markets in Kirinyaga County means that food is being sold that is not suitable for consumption.

Perhaps what is most worrying is that the standards set by the Kenyan authority – the PCPB – are based on consumption patterns and diets in Europe. People living in Kenya eat kale more frequently and thus the allowed daily intake concentration should be lower. The toxicity of the active ingredients found in kale and tomatoes is shown in Appendix 5.

6.0 Key insights

6.1 Farmers awareness and knowledge

There is a clear lack of knowledge on the potential toxicity of some of the pesticides being used by farmers in the two counties. Farmers and pest operators are often unaware of the long-term chronic effects on human health and the environment. The use of these type of pesticides is not going to be safer for human and environmental health through training on the safe use of pesticides, because they act in very low concentrations and protection measures are often not in place.

There is also a lack of knowledge about less hazardous alternatives. This is proven by the following data collected in this study:

- Frequent use of pesticides showing proven chronic health effects, and 30% of the farmers are not using any PPE at all.
- Frequent use of pesticides with high toxicity towards fish and bees where farmers are often unaware of the toxicity and mitigation measures. These measures are therefore not implemented.
- Farmers are using pesticides for the wrong pest and disease.
- Certain pesticides are in use (e.g. those with carbendazim, chloratholonil and permethrin as active ingredients), although they are already flagged as toxic in the European pesticides registration regime due to their serious chronic health effects.

Solutions

- This calls for an urgent need for better training of county extension officers and increased budget for extension services. Extension officers should predominantly provide knowledge on sustainable agricultural practices. This firstly should include the implementation of mitigation measures to prevent environmental and human health effects, secondly IPM strategies to substitute the toxic pesticides with biocontrol and biopesticides or even less toxic pesticides and ultimately agroecology principles **(see www.saferinputs.com).**
- The Kenyan Government needs to develop and implement a strategy to remove such harmful pesticides from the market some of which are not registered (top of the priority list on pesticides; Appendices 2 and 3), recognizing that it can take several years for products to be completely unavailable through local shops and dealers.
- Those crops and pests on top of the priority list should be targeted first, as they require the most toxic pesticides and the highest number of EU-withdrawn ones (Appendices 4 and 5).

6.2 Agrovets' awareness and knowledge

Instead of following a sustainable pest management approach, agrovet dealers recommend pesticide products, which are proven to have certain chronic health effects and are toxic to bees and fish. Following the Precautionary Principle, some of these products are already withdrawn from the European market. The advice given by agrovets is very important since they are the main source of information for farmers on pests and diseases management.

Solutions

- Agrovets should advise farmers on sustainable pest management practices to reduce the likelihood of negative impacts on human health and the environment (the principle of sustainability guides the needs of the present without compromising the needs of future generations).
- Agrovet dealers should receive training on the registration status of the products they recommend, as well as the potential human health and environmental effects of these products.
- Agrovet dealers should have the knowledge to advise farmers on proper mitigation measures to avoid harmful effects.
- Incentives for providing sustainable pest control solutions including biocontrol and biopesticides should be provided.
- There should be monitoring and penalties for agrovets selling unregistered products to farmers.
- Resourcing for county environment officers (working in the National Environmental Management Authority (NEMA)) should be adequate to carry out their monitoring mandate as provided for in Kenya's Environmental Management and Coordination Act of 1999 (Amended 2015).
- All agrovet dealers should be formally registered by Pest Control Product Board. All agrovet dealers should have a basic qualification in agriculture, understanding of pesticides and should be registered by the Kenya Drugs and Poisons Board.

6.3 Misuse of pesticides

To address the issue of farmers using pesticides which are not registered in Kenya or which are registered for other purposes (different crops or pests) the following recommendations are made:

Solutions

- The government should implement control strategies to ensure the correct use of pesticides.
- There should be an awareness campaign about the danger of misusing these pesticides.
- There should be stricter monitoring of pesticides sold in local market.

6.4 Pesticide residues in food

Despite the fact that local food often contains high pesticide levels (as the results of this study have shown, in addition to monitoring data collected by the Kenya Plant Health Inspectorate Service (KEPHIS) in 2018)), there are no adequate monitoring and reporting systems for pesticide residues in local food. As for MRLs whose calculations are based on people's consumption patterns, one needs to take into consideration that the Kenyan diet consists of much more kale and maize than European diets. This should result in lower MRLs for acephate and other pesticides in Kenya as an example. Consumers are not aware of pesticide residues in food and the danger of chronic exposure to pesticides.

Solutions

- Increased budget and political will as well as more capacity for institutions like Kenya Plant Health Inspectorate Service (KEPHIS), Kenyan Bureau of Standards (KEBS) and National Environmental Management Authority (NEMA) to implement monitoring strategies of food and water. Monitoring should also include regular farm inspections to ensure that recommended mitigation measures are implemented.
- Adaptation of MRL's according to the Kenyan diet. This should be the mandate of Pest Control Products Board at registration stage.
- Routine update of MRL's allowed in Kenya and pesticide safety information based on the most recent scientific literature. Globally, new research on the safety and toxicity of pesticide active ingredients is being conducted. It would be prudent to consider this new information/data and conduct additional studies based on local diets and plant species.
- Need to implement a national traceability system, which places responsibility of MRLs to farmers.

6.6 Promotion of alternatives

Generally, there is still a lack of knowledge among farmers, extension officers, regulators and the public, on sustainable farming systems that use less or no pesticides.

Solutions

- Farming systems need to be redesigned or adjusted based on the available knowledge on agroecology. Agroecological farming systems prevent pesticide exposure; enhance biodiversity; help to improve air, soil, and water quality; and mitigate climate change.
- Farmers and policy-makers in county governments should be encouraged and supported in transitioning to and understanding agroecological practices like crop rotation, soil fertility management, push–pull technology, and crop selection adapted to local conditions.
- Measures can include trainings, direct payments, and market development for agroecological products, for example via public procurement.

7.0 Conclusion

The results of this study show that small-scale farmers regularly using a wide range of pesticides. Many of them are toxic to human health and the environment and some of them are withdrawn in Europe.

Farmers are not protecting themselves while spraying and are not always aware of mitigation measures to avoid toxic effects on fish and bees. Some pesticide residues in tomatoes and kale exceeded the regulation standards, so that none of the samples would have been suitable for consumption. This is not surprising, as these two crops require most of the pesticide use with a high amount of different active ingredients.

The priority list of pesticides provided in this study can be used to prioritize pesticides for phasing out based on their toxicity and also based on the frequency of use. The list of crops and pests can be used to prioritize those that require more sustainable pest control methods.

Although this is a snapshot within two counties in Kenya, and only focuses on the local crop production, it supports the need for urgent changes in pest management strategies in the country.

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Appendices

Appendix 1. Methodology and toxicity scores

Each active ingredient was categorized according to its toxicity as follows.

For each active we looked up the following different toxicity data in the Pesticide Properties Database (FOOTPRINT, 2006), which provides toxicity information on all active ingredients worldwide (Table 1).

Table 1. Categories of toxicity according to PPDB

Wildlife toxicity (Bees, fish) [mg/L]		Chronic human health	
Very toxic	< 0.1	Yes	Carcinogenicity Mutagenicity Reproduction Toxicity Neurotoxicity Endocrine disruption
Toxic	0.1-1.0	Possible	
Moderately toxic	1.0 -10	No	
Low toxic	10-100	No data	
Not toxic	>100		

Table 2. Categories for mobility according to PPDB

<2.8	High mobility
2.8-1.8	Medium
<1.8	Low
No KOC or DT50 value	No data

Accordingly, we assigned scores to each given toxicity value following the below criteria (applied and published by Dabrowski *et al.,* 2009).

Table 3. Scoring system used to rank pesticides for environmental and human health effects

Toxic effect	Classification	Value
Environment		
Bees, fish, etc.	< 0.1	4
	0.1-1.0	3
	1.0 -10	2
	10-100	1
	>100	0
	No data	2
Mobility (solubility, persistence)	<2.8	4
	2.8-1.8	2
	<1.8	1
	No data	1.5

Human Health		
Endocrine Disrupting Activity	Yes	8
	Possible	6
	No data	3
	No	0
Carcinogenicity	Yes	8
	Possible	6
	No data	3
	No	0
Mutagenicity	Yes	6
	Possible	4
	No data	2
	No	0
Reproduction	Yes	4
	Possible	2
	No data	1
	No	0
Neurotoxicity	Yes	4
	Possible	2
	No data	1
	No	0

Prioritizing hazard potential of pesticides

All scores were summed up for the environment (fish, daphnia, bee, algae, mobility) and for human health (carcinogenicity, mutagenicity, reproduction, EDC, neurotoxicity)

Prioritizing hazard potential of crops and pests

The crops and pests listed were based on the toxicity of pesticides used on them.
In this instance, the toxicity score for each pesticide applied to each crop was used. For each crop, the total hazard potential was calculated by summing the toxicity scores for each active ingredient applied to that crop.

Appendix 2. Active ingredients used by farmers that are witdrawn in Europe

	Number of responses	Number of products	Number of crops	Number of pests
Chlorpyrifos	71	8	16	17
Beta-cyfluthrin	29	3	10	9
Propineb	26	1	13	4
Carbendazim	24	4	7	7
Esfenvalerate	23	1	10	11
Fenitrothion	23	1	10	11
Chlorothalonil	15	2	8	5
Hexaconazole	14	2	8	2
Carbosulfan	12	1	5	11
Profenofos	11	2	1	8
Atrazine	10	1	*	8
Paraquat Dichloride	10	2	*	7
Diazinon	9	2	5	6
Triadimefon	7	2	5	4
Dimethoate	5	1	5	3
Linuron	5	1	4	2
Omethoate	4	1	1	4
Thiamethoxam	4	3	4	2
Carbaryl	3	2	2	3
Acephate	2	1	2	2
Bifenthrin	2	1	1	2
Ethoprophos	2	1	2	1
Permethrin	2	2	2	1
Thiocyclam hydrogen oxalate	2	1	1	2
Bronopol	1	1	1	1
Carbofuran	1	1	1	1
Methomyl	1	1	1	1

Appendix 3. Toxicity score of pesticides used in the two counties: Prioritization list

Active ingredient	Frequency	Environmental score[1]	Human Health Score[2]	Total Score	No of crops	No of pests
Permethrin	2	17	24	41	2	1
Bifenthrin	2	16	24	40	1	2
Malathion	28	14	22	36	11	10
Diazinon	9	13	22	35	5	6
Carbaryl	3	14	20	34	2	3
Alpha-cypermethrin	172	17	16	33	21	20
Carbendazim	24	11	22	33	7	7
Chlorothalonil	15	13	20	33	8	5
chlorpyrifos	71	19	14	33	16	17
Mancozeb	209	13	20	33	24	22

Carbofuran	1	14,5	18	32,5	1	1
Deltamethrin	19	15	14	29	8	8
Beta-cyfluthrin	29	14	14	28	10	9
Indoxacarb	40	14	14	28	8	11
Triadimefon	7	8	20	28	5	4
Dithianon	3	12	15	27	1	3
Omethoate	4	11	16	27	1	4
Cyproconazole	2	10	16	26	1	2
Flubendiamide	14	16	10	26	5	3
Pyridaben	2	17	9	26	2	2
Abamectin	78	15,5	10	25,5	14	10
Esfenvalerate	23	12	13	25	10	11
Imidacloprid	26	12	13	25	14	12
Tebuconazole	1	10	15	25	1	1
Propineb	26	11	13	24	13	4
acephate	2	4	19	23	2	2
Ethoprophos	2	10	13	23	2	1
Hexaconazole	14	8	15	23	8	2
Profenofos	11	14	9	23	1	8
Fenitrothion	23	12	10	22	10	11
Thiophanate-methyl	12	5	17	22	5	5
Atrazine	10	11	10	21	na	8
Methomyl	1	12	9	21	1	1
Thiocyclam hydrogen oxalate	2	11	10	21	1	2
zink phosphide	4	8,5	12	20,5	3	3
2,4 D-Amine	23	3	17	20		15
Carbosulfan	12	14	6	20	5	11
Difenoconazole	17	10	10	20	6	5
Dimethoate	5	8	12	20	5	3
lambda cyhalothrin	37	16	4	20	14	13
Azandrachtin	2	9,5	10	19,5	1	1
Emamcetin benzoate	92	8	11	19	17	15
primiphos-methyl	6	12	7	19	2	1
Pyraclostrobin	3	12	7	19	1	2
Trifloxystrobin	2	13	6	19	1	2
Azoxystrobin	39	11	7	18	12	7
Fluopyram	2	9	9	18	1	2
Pendimethalin	3	2	16	18	na	2
Spiromesifen	1	13	5	18	1	1
Chlorantraniliprole (Rynaxypyr)	19	11	6	17	7	5
Sulphur	11	13	4	17	6	4
Bronopol	1	9	6	15	1	1
Cymoxanil	75	6	9	15	19	14
Linuron	5	11	4	15	4	2

Propamocarb Hydrochloride	1	4	11	15	1	1
Pyriproxyfen	12	11	3	14	5	5
Copper	72	11,5	1	12,5	11	13
Metalaxyl-M	85	10	2	12	18	16
Cyromazine	1	2	9	11	1	1
Spirotetramat	7	7	4	11	4	2
Thiamethoxam	4	8	2	10	4	2
acetamiprid	44	5	3	8	14	7
Glyphosate	105	2	6	8	na	26
Paraquat Dichloride	10	2	4	6	na	7

[1] worst score 20 (all values >10 coloured in red= high toxicity)

[2] worst case 30 (all values >15 coloured in red= high toxicity)
na not applicable. For herbicides no specific crops were identified.

Appendix 4. Toxicity score of crops growing in the two counties based on the pesticides used on them: Prioritization list

Crops	Frequency of pesticide use	Environmental Health Score	Human Health Score	Total Score	No of active ingredients	No of pests
Tomatoes	338	4229	4093	8321	42	27
Kale/ Sukuma Wiki	126	1679	1595	3274	34	17
Maize	124	1578	1661	3239	35	26
Coffee	105	1307	949	2256	26	14
Cabbage	72	944	869	1813	30	14
French beans	60	819	722	1540	26	17
Rice	52	630	754	1383	20	13
Muguka	42	551	499	1051	17	7
Melon	37	503	461	965	19	12
Beans	42	51	419	930	22	14
Spinach	34	402	395	797	20	8
Capsicum	26	336	333	669	11	9
Cucumber	12	167	166	332	11	4
Swiss chard	11	132	165	297	7	2
Coriander	12	151	142	292	13	3
Potatoes	12	133	122	255	8	6
Mangoes	10	129	116	246	8	7
Avocado	7	94	100	194	6	4
Pigeon peas	8	70	120	190	5	6
Sweet potato	5	65	72	137	6	2
Zucchini	4	37	80	117	7	3
Chillies	3	41	42	82	4	3
Butternut	3	35	43	69	2	3
Tree Tomato	2	30	36	66	2	2
Mrenda	2	26	27	53	3	2

Bananas	2	20	23	43	3	2
Paw Paw	1	17	16	33	1	1
Nightshade	1	12	13	25	1	1
Cotton	1	8	11	19	1	1

Appendix 5. Toxicity score of pests being controlled in the two counties based on the pesticides used on them: Prioritization list

Pests, Diseases and weeds	Frequency	Environmental score	Human Health Score	Total Score	No of active ingredients	No of crops
Blight	207	2341	2481	4822	22	20
Aphids	105	1462	1241	2703	21	15
Thrips	103	1323	1209	2532	20	12
White Flies	95	1268	1152	2420	23	14
Rust	96	1076	935	2011	17	16
Cut worms	69	1017	948	1965	15	9
Caterpillar	65	888	868	1756	19	11
Leaf miner	69	910	784	1694	19	10
Fall Army Worm	23	627	649	1276	12	7
Tuta Absoluta	51	571	511	1082	15	6
Mites	40	605	472	1077	6	8
Powdery Midlew	38	424	456	880	17	10
Mildew	11	222	329	551	6	6
Blast	16	136	284	420	8	4
Stalk borer	17	213	205	418	12	8
Spider mites	17	241	173	414	7	6
Coffee Berry Disease	20	241	135	376	9	1
Wandering Jew	21	122	159	281	5	na
Weevils	10	121	124	245	5	2
Black Jack	16	90	147	237	7	na
Couch Grass	16	104	123	227	4	na
Oxalis	15	93	132	225	5	na
Wasps	6	93	114	207	5	4
Ants	7	107,5	77	184,5	6	2
Nematodes	7	81	78	159	3	6
Bacterial bright	7	73	77	150	5	6
Kikuyu Grass	10	66	66	132	5	na
African Bollworm	4	55	72,5	127,5	5	2
Scales	4	64	62	126	3	2
Wilt	5	58	63	121	5	3
Earth worms	4	66	46	112	4	2
Melons Wasps	2	41	63	104	3	1
Bean Fly	5	58	43	101	6	1
Grass Weeds	7	38	63	101	3	na

Macdonald eye/ Gallant Soldiers	5	39	57	96	3	na
Black spot	5	38	46	84	5	4
Double thorn	6	36	40	76	2	na
Clovers	6	28	47	75	2	na
Grasshopper	3	39	35	74	2	3
Mosaic virus	3	39	31	70	4	3
Nut grass	5	23	41	64	2	na
Cricket	2	30	28	58	1	2
Kiragu	4	18	35	53	2	na
Worms	3	35	18	53	5	2
Fruit fly	2	33	18	51	3	2
Leaf spots	2	24	24	48	2	2
Star Grass	4	23	22	45	2	na
Moles	2	17	24	41	1	2
Natal Grass	3	18	16	34	2	na
Mexican Marigold	3	15	18	33	1	na
Coffee Berry Borer	2	17	14	31	3	1
Diamondback moth	1	14	14	28	1	1
Pigweed	2	10	12	22	1	na
Billygoat Weed	1	11	10	21	1	na
Maize lethal necrosis	1	8	12	20	1	1
Stem borer	1	8	11	19	1	1
Anthracnose	1	11,5	1	12,5	1	1
Poverty Grass	1	5	6	11	1	na

na: not applicable. Control of weeds was not specified for specific crops.

Appendix 6. Summary of human health toxicity for the pesticides found in tomatoes and kale

	Carcinogenic	Mutagenic	Endocrine Disruptor	Reproduction	Neurotoxic	Toxicity Score
Carbendazim	Possible	Yes	Possible	Yes	No	22
Acephate	Possible	No	Yes	No data	Yes	19
Cypermethrin	Possible	No	Possible	Possible	Possible	16
Methamidophos	No	Yes	Possible	Possible	Yes	15
Imidacloprid	No	Possible	No data	Yes	Possible	13
Flubendiamid	No	No	Yes	Possible	No	10
Lambda-Cyhalothrin	No	No	No	Possible	Possible	4
Acetamiprid	No	No	No data	No	No	3

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