Assessment of the impact of pesticide use in urban and periurban agriculture in Abidjan, Côte d’Ivoire

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ABSTRACT

Pesticides are used in agriculture for the control of pests and weedy species. Unfortunately, these chemicals are a potential risk for environment contamination and human toxicity. Market gardening soils are vulnerable to human activities because of the pesticide use. The objective of this work was to make a rapid and adequate diagnosis of the conditions of pesticide use by market gardeners. Thus, a view to assess the real impact of their use on the risk of soil pollution has been established. For this purpose, interviews and questionnaires were submitted to 243 market gardeners in Port-Bouët, Songon and Bingerville. 100% of farmers use chemical pesticides on their farms. The most pesticides used are insecticides, fungicides and herbicides. 92% of farmers have a low education level and only 4.33% of them have received a good agricultural practices training. Unsafe practices such as fraudulent use of unregistered pesticides, non-compliance with recommended rates of pesticide, the use of cotton pesticides and persistent molecules have been observed. These practices increase the risk inherent of environment pollution and vegetables.

INTRODUCTION

Urban agriculture plays an important role in the economy of developing countries (Ba et al., 2016). It contributes significantly to poverty reduction through the many jobs and incomes generated (Koffi-Nevry et al., 2011). This agriculture is highly vulnerable to pest leading to a high dependency of farmers on chemical pesticides (Wade, 2003; Hubert et al., 2014). Unfortunately, the toxicity of the molecules used is environmental issue (Mamy, 2008) and real problem for population health (Doumbia et al., 2009; Kouakou et al., 2016). In fact, pesticides can cause cancer, congenital malformations, endocrine, neurological and infertility problems, etc. (Kouakou et al., 2016).

Agriculture must ensure both a food security for the population and a preservation of healthy environment for future generations. Recently, Tano et al. (2012) studying production systems and high-risk practices in urban agriculture in Yamoussoukro, have highlighted the improper habits of mostly illiterate market gardeners. Another study reports scandalous and inappropriate agricultural practices that are not eco-friendly in Abidjan, Anyama and Dabou (Doumbia et al., 2009). Hence, it is necessary to update the current state of phytosanitary practices and the conditions of pesticide use by vegetable producers in Abidjan and suburbs. The aim of this study was to examine the practices of pesticide use; specifically to: i) list all active molecules used in vegetable gardening in the

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sites selected, ii) assess the conditions of their use, iii) identify the practices of farmers which may have an adverse effect on the environment and population health.

MATERIALS AND METHODS
Study site description

The study was carried out in three areas of high vegetables production (Port-Bouët, Songon and Bingerville). Port-Bouët airport is located south-east of Abidjan between 5º20 north latitude and 4º00 west longitude. Songon-M’Brathé-agban-attié is located in west part of Abidjan between 5º19 north latitude and 4º15 west longitude while Bingerville, a suburb north of Abidjan is between 5º21 north latitude and 3º54 west longitude. Figure 1 shows the selected areas that are delineated in red in which red circles represent studied sites.

Data collection

A survey and interviews based on the work of Kadjo et al. (2016) were carried out with market gardeners and Ivorian farmers’ supervisory structure ANADER (Agence Nationale d’Appui au Développement rural). ANADER permitted to select the different study areas. This study was conducted from August to October 2017 and from February to March 2018. The population was made up of growers who are field owners or permanent labours. Most of farmers were malinké, so we have used a translator during survey. The sampling procedure was snowball sampling. 243 market gardeners, including 90 in Songon, 74 in Port-Bouët and 79 in Bingerville were interviewed. Questionnaires focused on different types of pesticides used, frequencies of pesticide application, the use of personal protective equipment (PPE), the storage of pesticide and on the pre harvest interval. Information regarding social status of producers was also collected.

Figure 1: Map of study site.
RESULTS
Market gardeners characteristics
Of the 243 farmers, 228 (94%) were men. The most representative age group was 31 to 45 years (Figure 2). The results showed a high level of illiteracy among the farmers (92%). The highest level of education recorded was primary school. Only 4.33% of producers have received training on good agricultural practices. Half of the producers (55.14%) interviewed have more than 10 years of activity and report using pesticides since they started market gardening. 28.80% of the actors have between 5 and 10 years of agricultural activity, while 16.04% have less than 5 years of activity. Producers did not let the land lie fallow because of the great demand for vegetables. Several speculations are practised, including tomatoes, lettuce, pepper, cabbage, cucumber, leafy vegetables, eggplants, okra, leafy onion, carrots, turnips, parsley, mint, etc., with a specialization for each production area.

Pesticide used
All gardeners use chemical pesticides for crop protection. The most pesticides used was insecticides which represented 72.50% of the pesticides used, followed by fungicides (17.70%) and herbicides which represented 9.80%. The results are shown in Figures 3 and 4.

43 pesticides were regularly applied in the fields (Table 1), many of them intended for the cotton culture. Cotton pesticides are used on the 3 study sites. Persistent active substances such as Bromacil and Diuron were used. Farmers also use prohibited molecules such as carbofuran. The use of unregistered pesticides such as Gramoquat 200 SL, Bravo and Super 360 SL were also reported. Moreover, farmers use pesticides such as "Bien-bien", “Feu-vert”, “Solution”, “karakoro”, “Killer”, “Machette”, “Bôrô”, "Krakon". These latter are not listed in the phytosanitary guidebook of Côte d'Ivoire (Danho et al., 2015). The majority of the pesticides used in the study sites belong to synthetic pyrethroid. All chemical groups and active ingredients of pesticides used in the different study sites are listed in Table 1.

The results indicated that the most active ingredients used are glyphosate, cypermethrin and mancozeb. The most chemical groups represented in the study are pyrethroid, dithiocarbamate, organophosphorus and aminophosphonate. Figure 5 shows different chemical groups of pesticides used.

Supply sources, storage, pesticide spraying method and means of protection
The producers from Songon and Bingerville sites purchase pesticides from authorized distributors and local markets. However, producers at Port-Bouët airport have three sources of supply, these are authorised distributors, local markets and small retailers located on the production sites. After purchasing pesticides, the respondents store pesticides at home and on production sites. Knapsack sprayers are the only spraying equipment used for the application of pesticides. During spraying, producers do not use full personal protection equipment such as goggles, gloves, masks, suitable shoes or boots, coveralls, etc. They are partially protected by using masks or nose protection only (67%), while 33% do not use any protection at all.

Applied rates, management of remaining pesticide solution after application and frequency of crop treatment with chemical pesticides
The majority of vegetable producers have great difficulty to respect the prescribed doses because of the high illiteracy rate (92%). After full application of the plot, the remaining pesticide solution is re-applied on the plot. The washing of equipment used for pesticide application (knapsack sprayers) is done in the farms and near the wells from which water was drawn for crops watering.

For the dame crop, the number of treatments differs from one farmer to another. All farmers treat the soil with pesticides especially nematicides before sowing. Crop treatments are generally carried out every 7
days with insecticides. In the event of heavy attacks, producers use to treat the fields every week, but in the absence of pest attacks, crop treatments are still carried out. Treatments with insecticides and nematicides start before sowing and continue until the vegetables harvest. These latter were used 15 to 20 times depending on the speculation practiced. For tomatoes, cabbage and lettuce, the number of treatments with nematicides and insecticides was respectively 16, 17 and 7.

Pre-harvest interval and management of empty pesticide containers

The pre-harvest intervals of pesticide used were 3, 7, 15, 21 and 45 days (Figure 6). All growers recognized that they must respect the time between the last pesticide application and the harvest time. 47% of growers observe 7 days waiting period before harvest for all pesticides used, while 27% of them respect a time of 15 days, only 3% of producers apply 21 days waiting period and 20% have a 3 days waiting period. For instance, for active ingredient chlorpyriphos-ethyl with 45-day pre-harvest intervals, none of farmers observe this time limit.

As depicted in Figure 7, the majority of sampled growers namely 68.31% release empty pesticide containers into the environment and on the production site, 17.69% of them bury it and 14.00% incinerate it.

Figure 2 : Distribution of producers by age.
Figure 3: Distribution of pesticides used by study site.

Figure 4: Proportion of various pesticides used by market gardeners.
Table 1: List of pesticide used in the study areas.

| Trading Names   | Active ingredients | Chemical group     | Culture                  | Faø/toxicological class |
|-----------------|--------------------|--------------------|--------------------------|-------------------------|
| **INSECTICIDES**|                    |                    |                          |                         |
| Calfos 500 EC   | profenofos         | organophosphate    | cotton                   | II                      |
| Cybog 50 EC     | cypermethrin       | pyrethroid         | vegetable, vegetable     | II                      |
| Cypercal 50 EC  | cypermethrin       | pyrethroid         | Food crop, cotton        | III                     |
| Cypercal P 186 EC | profenofos     | Organophosphate    | cotton                   | III                     |
| Cyperax 50 EC   | cypermethrin       | pyrethroid         | vegetable                | II                      |
| Décis 12,5 EC   | deltamethrin       | pyrethroid         | Vegetable, Food crop, fruit | III                     |
| Dragonforce 50 SC | lambda-cyhalothrin | pyrethroid         | cocoa                    | II                      |
| Duel 186 EC     | cypermethrin       | pyrethroid         | cotton                   | II                      |
| Furadan 10 GR   | profenofos         | organophosphate    | pineapple                | Ib                      |
| Kart 500 SP     | cartap             | carbamate          | Banana, oil palm         | II                      |
| K- optimal 35 EC| lambda-cyhalothrin | pyrethroid         | vegetable                | II                      |
| K- total        | lambda-cyhalothrin | Pyrethroid         | vegetable                | III                     |
| Lamdac 46 EC    | lambda-cyhalothrin | pyrethroid         | cotton                   | II                      |
| Lampfos 168 EC  | lambda-cyhalothrin | Pyrethroid         | cotton                   | II                      |
| Legumax 12 EC   | profenofos         | organophosphate    | vegetable                | III                     |
| Miracle 50 EC   | lambda cyhalothrin | pyrethroid         | vegetable                | II                      |
| Orthène 75% SP  | acephate           | organophosphate    | vegetable                | III                     |
| Polythrone C 186 EC | cypermethrin | Pyrethroid          | vegetable, cotton        | III                     |
| Pysical 480 EC  | chlorpyriphos-ethyl| organophosphate    | pineapple                | II                      |
| Pyriforce 480 EC| chlorpyriphos-ethyl| organophosphate    | pineapple                | II                      |
| Tout maraîcher 50 EC | cypermethrin     | pyrethroid         | vegetable                | II                      |
| Trading Names      | Active Ingredients | Chemical Group     | Culture     | Fao/who toxicological class |
|-------------------|--------------------|--------------------|-------------|----------------------------|
| Baratchè 360 SL   | glyphosate         | aminophosphonate   | fallow      | III                        |
| Bibana 360 SL     | glyphosate         | aminophosphonate   | fallow      | III                        |
| Bravo super 360 SL| glyphosate         | aminophosphonate   | fallow      | III                        |
| Curacron 500 EC   | profenofos         | organophosphate    | cotton      | II                         |
| Daba              | glyphosate potassium salt | aminophosphonate | fallow      | III                        |
| Dragonflash 720 SL| 2, 4-D amine salt  | aryloxy-acetic acid| cereal      | III                        |
| Glyphader 360 SL  | glyphosate         | aminophosphonate   | fallow      | III                        |
| Gramoquat 200 SL  | glyphosate         | aminophosphonate   | fallow      | III                        |
| Herbextra 720 SL  | 2, 4-D amine salt  | aryloxy-acetic acid| rice        | II                         |
| Herbigro 720 SL   | 2, 4-D amine salt  | aryloxy-acetic acid| cereal      | II                         |
| Iko kadigne 108 EC| haloxyfop-R-methyl | arloxyphénoxypropionate | Cotton vegetable | III                        |
| Kalach 360 SL     | glyphosate         | aminophosphonate   |            | III                        |
| Ladaba 480 SL     | glyphosate         | aminophosphonate   | Hevea, oil palm, banana, Fallow | III                        |
| Rangro 360 SL     | glyphosate         | aminophosphonate   | fallow      | III                        |
| Round up 360 SL   | glyphosate         | aminophosphonate   | All fallow crops | III                        |
| Super 30 WP       | bromacil           | uracil             | Pineapple   | III                        |

II: moderately dangerous; III: slightly dangerous; Ib: Highly dangerous
| TRADING NAMES | ACTIVE INGREDIENTS | CHEMICAL GROUP | CULTURE | FAO/WHO TOXICOLOGICAL CLASS |
|---------------|-------------------|----------------|---------|-----------------------------|
| Banko PLUS 650 SC | chlorothalonin carbendazim | chloronitrile benzimidazole carbamate | vegetable | III |
| Ivory 80% WP | mancozeb | dithiocarbamate | vegetable | III |
| Monjardin 80 WP | mancozeb | dithiocarbamate | vegetable | III |
| Ortiva 250 SC | strobilurin azoxystrobin | azoxystrobin | mango | III |
| Qualico 46 %WP | dimetomorph copper oxychloride | cinnamic acid | cocoa | III |
| Zebra 800 WP | mancozeb | dithiocarbamate | vegetable | III |

II: moderately dangerous; III: slightly dangerous; Ib: Highly dangerous

Figure 5: chemical groups of pesticides used by producers.
Organo = organophosphate; pyrethroid = pyrethroid; carbamate = carbamate; amino = aminophosphonate; Neonic = neonicotinoid; dithiocar = dithiocarbamate; chloro = chloronitrile
Figure 6: Proportion of farmers according to respect of different pre-harvest intervals.

Figure 7: Distribution of producers according to the management of empty pesticide containers.
DISCUSSION

Characteristics of the vegetable growers

This study showed that the actors involved in agriculture in Abidjan and its suburb were predominantly men (94%). The results obtained in this study are in agreement with those of Tano et al. (2012) done in Yamoussoukro. These authors observed a high proportion (88%) of men in urban agriculture. This can be explained by the fact that men have more financial capacity to buy or rent a land than women. The low representation of women (6%) in this activity could be justified by the fact that women's investment choice depends on the prior agreement of men (Séry, 2012).

The survey results showed the presence of all age groups. Market gardening is dominated by individuals aged 31 to 45 years (79.01%). This tendency may be due to the unemployment of this age group resulting from rural exodus, forcing them to fall back on market gardening. That was also demonstrated in other studies conducted by (Matthys et al., 2006; Kanda et al., 2009; Ducroquet et al., 2017). In our study, the proportion of young farmers (79.01%) was higher than that found by Bayendi et al. (2017) and Le Bellec et al. (2017) in Gabon and Mauritania, who reported an aging of vegetable growers of 63% and 60% respectively. The financial profitability of market gardening would also explain young people's interest in this sector of activity. The low rate of vegetable producers over 45 years of age in this sector can be explained by the difficulty of this activity. It must be noted that market gardening requires physical constraints such as long working hours, huge physical tasks such as weeding and harvesting.

The low education level amongst the producers (92%) constitutes a real constraint for the development of this activity. This situation leads to the inability of vegetable growers to read the instructions on the pesticide packagings and increases the risk of misuse of pesticides, which may contribute to the pollution of the soil. Previous works carried out by Ngom et al. (2012), Wognin et al. (2013), Diop (2013); Naré et al. (2015) and Dao et al. (2016) corroborated our results namely (92%). These authors diagnosed a low education level among producers which leads to an irrational use of pesticides and therefore to the contamination of vegetables. These observations are corroborated by the work of Ahouangninou et al. (2011) in Benin, who observed that producers did not apply the dosages indicated on packagings because of their difficulty in reading the instructions for use and carrying out a precise dosage.

Environmental and health risks of pesticide use

The sampled farmers (100%) use pesticides on their farms. The most pesticide used was insecticide (72.50%). Our results confirm those of Kanda et al. (2009), Doumbia et al. (2009) and Tano et al. (2012) who have studied the cultivation practices of vegetable producers. These authors showed the highest level of insecticide use in Togo (78.1%), in Abidjan (78.57%) and in Yamoussoukro (73%). In another study in Benin, conducted by Ahouangninou (2011) with the same aim presented different results. This author has shown the highest level of fungicide use (68%).

Generally, under normal conditions of use, pesticide do not present neither a health nor environmental hazard. The presence of pesticide residues in soils and vegetables is associated with the misuse and overuse of pesticide (Botwe et al., 2011). Various practices such as the use of unregistered pesticides and toxic active ingredients were observed in this study. This situation leads to increase the risks of environmental pollution.
that was described by Ahouangninou et al. (2012) and Kanda et al. (2014). These authors showed the impact of pesticide misuse on aquatic organisms and soil invertebrates, contributing to soil depletion. The use of toxic molecules such as Carbofuran, which is class Ib (highly dangerous) and the use of cotton pesticides in our study are a major hazard to consumers and soil environment. Similar studies conducted by Doumbia et al. (2009); Soulé et al. (2010) and Son et al. (2018) indicated that the pesticide use contribute to environmental pollution, that is a real health risk for vegetables, soil, groundwater and air.

Concerning the organochlorine pesticides, our investigations showed that no farmers use them, which suggests that farmers are aware of the danger of organochlorine pesticides use. However, the present results are in contradiction with those of Tano et al. (2012) and Ba et al. (2016) who reported the use of organochlorine pesticides in market gardening. Our results are in line with those of Agnandji et al. (2018) in Benin. Results of this study point to unsafe practices such as excessive pesticide use, non-compliance with recommended rates of pesticide and repeated pesticide use (reapplication of pesticide and on crops), these practices lead to potential exposures to pesticide residues in vegetables and soils. In other studies conducted by Biego et al. (2009), Naré et al. (2015) and Son et al. (2018) with the aim to assess the attitude and practices of farmers pointed to the pesticide misuse, which was a real risk of vegetables and soils contamination. Non-compliance with pre-harvest intervals observed in our study, increases the presence pesticide residues in vegetables.

Concerning the management of empty pesticide containers (incinerating, discarding, burying) by farmers, the sampled farmers adopted unsafe and not eco-friendly practices, which increases the risk of environmental pollution, similar results have been reported by Tarnagda et al. (2017) in Burkina Faso.

Conclusion

The study on the current situation of pesticide use in Abidjan and its suburban showed that all producers use pesticides on their gardens. The majority of vegetable growers have a low education level and 10 years of agricultural activity. The study reveals the use of many cotton pesticides. The use of unregistered pesticides, banned and persistent molecules have been identified. All these practices lead to the presence of pesticide residues in the environment, which exposes the population to many illnesses. This study highlighted the unsafe practices of producers that expose consumers and the environment. Thus, contamination of the environment by chemical pesticides with proven toxicity exposes the entire ecosystem. It is therefore recommended training programs on the farms for the safe use of pesticide. Given that the results of this study are based on the responses of market gardeners and on observations on-farm, further analysis of the residues of pesticide listed in this study is necessary in order to know the actual real state of pollution of market gardening soils.

COMPETING INTERESTS

The authors state that there is no competing interest between them.

AUTHORS’ CONTRIBUTIONS

The four (4) authors MAP, ONK, EFE and KV together carried out this work. The survey data were collected by MAP, ONK, EFE and KV supervised, read, commented, made corrections and approved the final document.
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