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# Phytosanitary and Technical Quality Challenges in Export Fresh Vegetables and Strategies to Compliance with Market Requirements: Case of Smallholder Snap Beans in Kenya

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**Abstract:** Kenya is one of the leading exporters of snap beans (*Phaseolus vulgaris*) to Europe, but the export volume has remained below potential mainly due to failure to meet the market quality standards. The quality concerns include the presence of regulated and quarantine pests, pesticide residues, harmful organisms, and noncompliance with the technical standards. These challenges call for the development of alternative approaches in overcoming the phytosanitary and quality challenges in the export of snap beans and other fresh vegetables. These may include integrated pest management (IPM) approaches that incorporate non synthetic chemical options, such as diversified cropping systems, plant and microbial-based pesticides, varieties with multiple disease and pest resistance, insecticidal soaps, pheromones and kairomones, entomopathogens and predators. These approaches, coupled with capacity-building and adherence to the set quality standards, will improve compliance with export market requirements. The aim of this paper is to increase knowledge on implementing good practices across the value chain of fresh vegetables that would lead to improved quality and thereby meeting institutional requirements for the export market. The novelty of the current review is using snap beans as a model vegetable to discuss the challenges that must be mitigated for the quest of achieving high quality and increased volume of fresh export products. Whilst many of the publications have focused on alternatives to synthetic pesticides in addressing MRLs in fresh vegetable exports, there is a disconnect between research and industry in achieving chemical residue and pest free export vegetables. This review describes the phytosanitary and technical challenges faced by smallholder farmers in accessing export markets, evaluates the phytosanitary and quality requirements by the niche markets, and explores the strategies that could be used to enhance compliance to the institutional and market requirements for fresh vegetables.

**Keywords:** fresh vegetables; market access; maximum residue limits; *Phaseolus vulgaris*; quality standards

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## 1. Introduction

Snap bean (*Phaseolus vulgaris)* production in Kenya is largely for the export to the European Union [1,2], and the produce accounts for one quarter by volume of Kenya's vegetable exports [3]. Production is mainly by smallholder farmers who are estimated to number about 50,000, while the sector employs about 60,000 people [2–4]. In 2017, about 4500 ha were under smallholder snap beans production [4]. Cropping of snap beans is favored by the suitable climatic conditions, which makes Kenya a counter-seasonal supplier for key European markets. The climatic conditions favoring production of snap beans in Kenya include well-distributed annual rainfall of between 900–1200 mm, well-drained soils with a pH range of 6.0–7.5, temperatures of 20–25 °C and the presence of pollinator bees [1,5].

The major exporters of fresh leguminous vegetables in Africa are Morocco, Egypt, Kenya, Tanzania, Senegal, Uganda, Rwanda, South Africa, Burkina Faso, Ethiopia, and Zimbabwe [6] (Figure 1). Kenya is the second-largest exporter of green beans to Europe [4] and its success is based on climatic and geographic competitive advantages, investments in certification schemes, value-adding through packaging, servicing niche markets, and investments in marketing. The major markets for the Kenyan snap beans are the European Union, the United States of America, South Africa, Brazil, Russia, India, and China [3,7,8]. However, Kenyan snap beans are exported in a highly regulated and pesticide-residue sensitive market. Maintaining high-quality standards is critical in achieving the set sanitary and phytosanitary standards. Kenyan snap beans producers are largely dependent on the EU market; for example, in 2018, Kenya exported leguminous vegetables to United Kingdom, German, France, and Sweden. Further, there was a decrease in the percentage of total value and volume of exported beans, peas, and lentils between 2010–2018, mainly due to restrictions imposed on Kenyan snap beans [9] (Figure 2). Kenya was also barred from exporting snap beans to the USA because of the failure to meet the set phytosanitary and technical quality requirements [10].

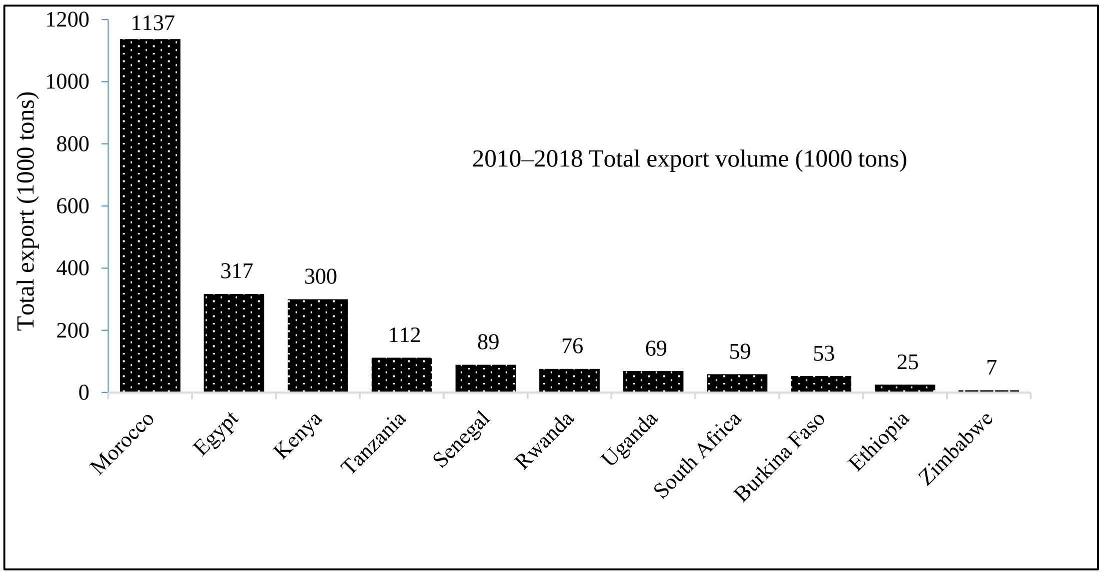


**Figure 1.** Total export volume of leguminous vegetables from African countries between 2010 and 2018 [6].

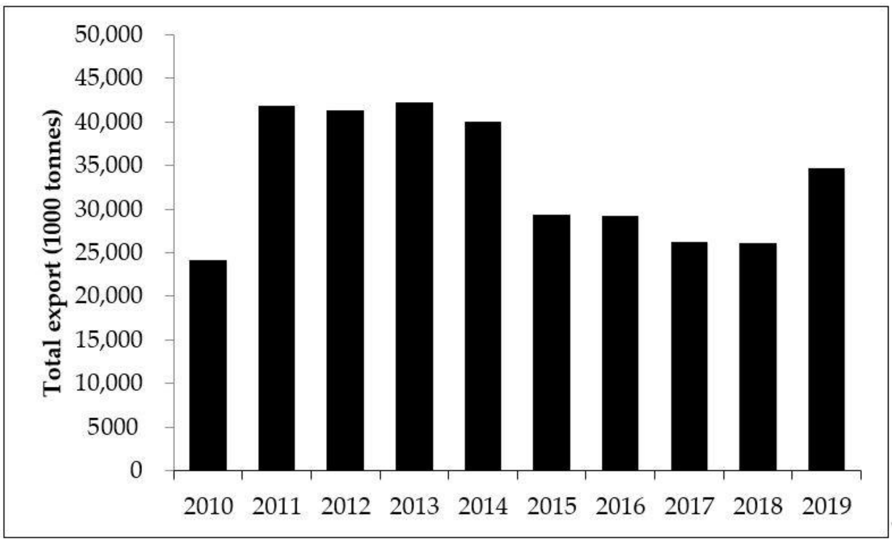


**Figure 2.** Yearly time series of Kenya's export volume of leguminous vegetables from 2010–2018 [6].

Management of pests is a key cross-cutting snap bean production challenge for the smallholder farmers and it dictates the quality of the export produce. Phytosanitary measures entail any legislation, regulation, or official procedure aimed at preventing the introduction or spread of quarantine and regulated pests into the importing country [11]. The notable quarantine pests in snap beans exported to the European Union are *Helicoverpa armigera*, *Bemisia tabaci*, and *Trialeurodes vaporariorum*, *Lyriomiza* spp. [12]. The technical measures to be adhered to in exporting snap beans are those that are aimed at protecting the health of consumers [13]. Examples of technical measures include maximum residue levels (MRLs), traceability, and product conformity [14]. The major contributor to the decline in snap bean export volume to the European markets was a result of noncompliance with pesticide MRLs [3]. The strict phytosanitary and technical regulations resulted in farmers and exporters incurring immense losses because of their snap bean pods being intercepted at the ports of entry in the EU. Therefore, stakeholders in fresh horticultural export produce have had to intensify their campaigns to address the chemical residues [10]. The continued noncompliance and resultant interceptions of Kenyan snap beans are attributed to the inadequate capacity for smallholder farmers and producer groups, unstructured stakeholder and institutional coordination, and relaxed enforcement mechanisms.

The value chain of snap beans in Kenya assumes a systems approach that looks into the causal relations of issues to do with economic, social, and environmental sustainability. For example, issues such as contract farming, market segments, certification schemes, and value addition give Kenya a competitive edge and, therefore, enable access to export markets amid stringent requirements [15]. The systems approach entails extensive field management measures, handling technologies, representative chemical analysis, and traceability that brings on board farmers, traders, institutions, and standards. Meeting phytosanitary and technical requirements is critical to the successful export of Kenyan snap beans [16,17]. This paper was borne out of how to address the quality issue plaguing snap beans destined for lucrative niche markets [10]. The value chain of fresh produce for international markets is prone to stringent food safety regulations that largely entail phytosanitary and pesticide residue requirements. Kenyan snap beans smallholder farmers have always continued to suffer blow after blow in failing to comply with stringent public and private standards because of compromised quality of fresh produce [15]. Up to date cases of snap bean rejections due to exceeding the set pesticide residue levels remain the major concern. In addressing noncompliance to phytosanitary and quality requirements, many researchers have published articles on sustainable vegetable production. Exporting of vegetables by smallholder farmers has always been hit by a myriad of challenges cutting across the value chain of resultant produce [15,16]. The purpose of this paper is to increase knowledge on implementing good practices across the value chain of fresh vegetables that would lead to improved quality and thereby meeting institutional requirements for the export market. Therefore, this review focuses on all the issues from production to marketing of snap beans as a model vegetable. Augmenting information on sustainable vegetable production and marketing, especially for lucrative markets, would enable all the stakeholders to see the need to work together. It is envisioned that the current work would cement the fresh vegetable supply chain as it addresses what, where, when, and how questions on stringent food safety regulations that over time have decimated the export volume of quality produce.

This review examines the phytosanitary and technical quality issues affecting fresh vegetables from sub-Saharan Africa, with snap beans as a model vegetable destined for export to the niche EU markets. The review also describes the potential approaches to enhance the quality of fresh horticultural produce in order to improve access to the lucrative export markets [18,19]. The review documents the export market requirements and the challenges faced by smallholder farmers in meeting these requirements. It also outlines the institutional framework for the enforcement of the phytosanitary and quality regulations and the sustainable integrated pest management (IPM) approaches in the production of fresh vegetables without compromising market standards. Amplifying the systems approach from production, trade, and consumption will enhance the adoption of good agricultural practices (GAP) [20,21] and interaction with stakeholders, enabling smallholder snap beans farmers to reap maximum economic benefits. The approaches may incorporate sustainable pest management regimes, capacity building, strengthening institutional coordination, standards enforcement mechanisms, and up-to-date government policy framework to upscale production and enhance the attainment of phytosanitary and technical requirements. Improved market access and export volumes of fresh vegetables would improve the livelihoods of smallholder farmers and contribute to the country's economic growth.

## 2. Agronomic Practices in Smallholder Snap Bean Production

Snap beans thrive in well-drained soils that are rich in organic matter and at temperatures of 18–30 °C with well-distributed rainfall of 900–1200 mm [22]. Supplementary irrigation is required where the crop is grown all the year-round as inadequate moisture may cause flower abortion and deformed pods. Snap beans area labor-intensive crop, especially for land preparation, planting, weed control, fertilizer, and pesticide application, harvesting, and postharvest handling [1,4]. Seeds are usually supplied by the contracting export companies and are dressed with fungicides such as lindane and thiram to curb the effects of bean stem maggot (*Ophiomyia* spp.) infestation and infection by root rot pathogens caused by various species of the genus *Fusarium, Rhizoctonia,* and *Pythium* [1]. Planting of snap beans is done at intervals of 2–3 weeks to ensure production all year round to meet the demands of the targeted market. The use of organic manure is recommended for soils that are deficient in nutrients, but chemical fertilizers are usually applied for optimal yield. Chemical fertilizers used include di-ammonium phosphate (DAP) at a rate of 200 kg/ha at planting and calcium ammonium nitrate (CAN) at a rate of 100kg/ha during the flowering stage [1,13]. Weeding is done after emergence.

The major pests are bean stem maggot, thrips, aphids, red spider mites, whiteflies, African bollworm, and cutworms, while the major diseases are rust, downy mildew, anthracnose, common bacterial blight, Fusarium wilt, damping off, angular leaf spot, powdery mildew, and bean common mosaic. Pests and diseases are managed through the frequent application of synthetic pesticides [23,24], but the use of specific pesticides is dictated by the need to meet the regulatory MRLs (Table 1).

**Table 1.** Regulatory maximum residue levels (MRLs) of pesticides are usually not recommended for use on vegetables.

| Pesticide | Status | MRLs (mg/Kg) |
|---|---|---|
| Acephate | Unauthorized | 0.01 |
| Carbendazim | Unauthorized | 0.2 |
| Chlorpyrifos | Not for foliar use | 0.05 |
| Dimethoate | Not for foliar use | 0.02 |
| Hezaconazole | Unauthorized | 0.01 |
| Lufenuron | Unauthorized | 0.02 |
| Methamidophos | Unauthorized | 0.01 |
| Omethoate | Not for foliar use | - |

Source [25,26].

Harvesting is done 6–8 weeks after planting, and it is done 2–3 times per week as per the market specifications. The pods are graded to remove the broken, twisted, damaged or blemished. Packaging is done as per the market specifications and the produce is immediately stored at 4 °C at a relative humidity of about 80%.

## 3. Phytosanitary and Technical Quality Issues in Snap Bean Production and Marketing

### *3.1. Phytosanitary Requirements for Export Snap Beans*

The International Plant Protection Convention (IPPC) stipulates the phytosanitary requirements that address plant health. The phytosanitary requirements are contained in the International Standards for Phytosanitary Measure 01, ISPM 01 (Phytosanitary principles for the protection of plants and the application of phytosanitary measures in international trade). ISPM 01 aims to prevent the introduction and spread of agricultural pests through plants and plant products during trade involving countries [14,27]. Fresh vegetables are subject to plant health inspections and require phytosanitary certificates prior to shipping. Fresh produce destined for the European niche markets must comply with the European Plant Health Directive 2000/29/EC for fresh fruits and vegetables [14].Fresh snap bean pods for the export market should be free from pests such as *Helicoverpa armigera*, *Bemisia tabaci*, and *Trialeurodes vaporariorum*, *Lyriomiza* spp., *Tetranychus* spp., *Megalurothrips sjostedti*, *Frankliniella schultzei*, and *F. occidentalis* [12]. *Helicoverpa armigera, Bemisia tabaci*, *Lyriomiza* spp., *Frankliniella occidentalis, Tetranychus* spp., and *Xanthomonas axonopodis* p.v. *phaseoli* are quarantine pests in the EU [28]. For example, the presence of only one caterpillar of *Helicoverpa armigera* in a consignment leads to the rejection of the produce [12]. Besides, the snap bean pods should be free from microbial hazards such as species of *Salmonella*, *Shigella*, *Campylobacter*, *Listeria*, and *Escherichia* and comply with European Regulation (EC) No. 2073/2005 for microbial hazards [10,14,29]. Fresh fruits and vegetables should be free from *Salmonella, Listeria monocytogenes,* and *Enterobacter sakazakii*, and Staphylococcal enterotoxins, and histamine as specific examples of toxins and metabolites, respectively. For example, the detection of *Campylobacter* sp. and *Shigella sonnei* in sugar snaps from Kenya to EU market in 2011 and 2020, respectively, were notified as information for attention [30]. The microbiological hygiene criteria are developed in line with the Codex Alimentarius food safety standards, Good Hygiene and Manufacturing Practices, and the Hazard Analysis Critical Control Point (HACCP) principles [14].

Hazard Analysis and Critical Control point (HACCP) is a systematic approach to the identification, evaluation, and control of food safety hazards. The HACCP system requires that potential food hazards are identified and controlled at specific points in the commodity value chain. Food safety certification requires the implementation of a HACCP-based food safety management system that is recognized by the Global Food Safety Initiative (GFSI) [14].

### *3.2. Phytosanitary Treatment for Fresh Fruits and Vegetables*

Exported fresh fruits and vegetables are normally subjected to phytosanitary treatments, as spelled out in ISPM 28 (Phytosanitary treatments for regulated pests), to prevent the introduction of harmful pests [31–33] (Table 2). However, the phytosanitary treatment deployed should not impact negatively on the quality of the fruit or vegetable [34]. The phytosanitary treatments are classified either as chemical or physical treatments. Examples of chemical treatments include fumigations, sprays, and dips while irradiation, cold, and heat treatments fall under physical treatments [32].

**Table 2.** Phytosanitary treatments for fresh fruits and vegetables.

| Type of Treatment | Type of Fruits and Vegetables | Target Pests | Pros and Cons | Reference | Comments |
|---|---|---|---|---|---|
| Radiation treatment 50–400 Gy to prevent egg hatching, development and emergence of adult pests | All fruits and vegetables | Fruit flies (*Anastrepha* sp., *Bactrocera* sp., *Ceratitis* sp.) Codling moth (*Cydia* sp. *Grapholita* sp.) Apple maggot fly (*Rhagoletis* sp.) Weevil (*Conotrachelus* sp., *Cylas* sp., *Euscepes* sp.) *Mealy bugs* (*Dysmicoccus* sp., *Planococcus* sp.), *Corn borer* (*Ostrinia* sp.) | High investment in irradiation facility Cost-effective over the long term Adequate throughput is required for profitability Reduces efficacy of Modified atmosphere packaging (MAP) and controlled atmosphere (CA) storage | [31,32,35,36] | Internationally approved Dosage depends on the target pest |
| Vapour Heat (TPT-VH) Temperature raised to 40–50 °C in a forced hot air chamber for 20–70 min Kills insect eggs and larvae | Papaya *(Carica papaya)* Caricaceae: Brassicales Melon *(Cucumis melo* var. *reticulatus),* Mango (*Mangifera indica*) | Melon fly (*Bactocera cucurbitae*) Fruit flies (*Bactrocera* sp.) | May cause internal and external damage to sensitive produce May accelerate color development | [31] | Internationally approved |
| Cold treatment temperature between 0 to 3 °C for 15–20 or more continuous days | Citrus (*Citrus limon)* sweet orange (*Citrus sinensis)* Tangerine (*Citrus reticulata*) Pomelo (*Citrus maxima)* Clementine *(Citrus clementina)* | Fruit flies (*Bactrocera* sp., *Ceratitis* sp.) | Environmentally friendly Safe for employers and consumers. Increase fresh plant product shelf life and quality Easy to apply | [31,36–38] | Internationally approved |
| Fumigation Ethylene dibromide (EDB) Methyl bromide *Ethanol* and *vinegar vapour* Hydrogen cyanide Fungicides (imazalil, thiabendazole, pyrimethanil, and fludioxonil) | Oranges, Grapefruit Tangerines Plums Mangoes Vegetables | *Fruit flies (Anastrepha* sp., *Ceratatitis* sp., Dacus sp., *Rhaqoletis* sp.) *Collectotrichum gloeosporioides Penicillium* sp. | Methyl bromide is stratospheric ozone-depleting and its uses are regulated and reduced Chemicals have adverse effects on humans | [39,40] | Chemical fumigation is usually avoided due to strict requirements by importing countries on pesticide residues |
| Hot water treatment Dip in water at 52–62 °C for 2–60 min Used for insect and disease control | Citrus Mango (*Mangifera indica*) | *Penicillium* spp. Fruit fly (*Ceratitis capitate, Bactrocera invadens*) *Anthracnose* (*Colletotrichum* sp.) | Loss of firmness and weight Uniform fruit-color and positively modify the pH Enhances fruit ripening | [40,41] | High temperatures may cause fruit damage May affect fruit color, appearance, and eating quality |

Phytosanitary irradiation of commercial fruits and vegetables has been shown to be the best alternative to fumigation, and it is also superior toother physical treatments [32,34,36]. Indeed, phytosanitary irradiation is effective against a wide range of pests including fruit flies (*Anastrepha* sp., *Bactrocera* sp., *Ceratitis* sp.), Codling moth (*Cydia* sp., *Grapholita* sp.), Apple maggot fly (*Rhagoletis* sp.), Weevil (*Conotrachelus* sp., *Cylas* sp., *Euscepes* sp.), *Mealy bugs* (*Dysmicoccus* sp., *Planococcus* sp.),Corn borer (*Ostrinia* sp.) and spider mites (*Tetranychus* spp.). In the case of fruits, irradiation treatment is reported to be effective in maintaining quality, inhibits decay and does not compromise the sensory attributes of strawberries under cold conditions [42]. However, fumigation treatment that requires exposure of strawberries to warm temperatures could compromise the quality of strawberries [43]. One typical example of hot water treatment is subjecting mangoes infested with *Ceratitis capitata.* It was found out that immersing the mangoes in water within a temperature range of 46.4 to 47 °C for 95 min, resulted in 99.9% mortality of *C. capitata*. Under the same conditions of hot water treatment, the quality of mangoes was not compromised [41]. Cold treatment is gaining popularity as a phytosanitary intervention in preserving the physical quality of fresh fruits and vegetables and further hinders insect pest infestation prompting sustained produce marketability [33].

### *3.3. Technical Quality Requirements for Export Snap Beans*

Snap beans destined for the export markets have to meet an array of legal and nonlegal technical quality requirements [44]. The legal requirements include MRLs for pesticides and contaminants, traceability, product conformity, product integrity, pod size specifications, labeling, and packaging [14,45]; the non-legal requirements address social and environmental compliance. The produce is subjected to official control to ensure food safety and compliance with the legal requirements, including documentary checks, identity checks, traceability, and conformity to the required market standards. The required documentation includes Bill of landing, phytosanitary certificate, Codex Alimentarius food safety standards certification, packing list, customs clearance, and a unique traceability code. In most cases, lot number or Global-GAP Number (GGN) are used as the traceability code.

Maximum residue level (MRL) is the highest level of a pesticide residue or a contaminant that is legally tolerated in or on food or feed [46]. Contaminants include heavy metals such as cadmium, lead, mercury, and tin, which may contaminate the commodity during production, packaging, transportation, or storage. Regulation (EC) 1881/2006 sets the maximum residue limits for contaminants, with a limit of 0.10 mg/kg for most fresh fruits and vegetables [14]. The amounts of pesticide residues in or on food must be safe for consumers and must be as low as possible. The MRLs requirements dictate that the produce should not contain banned or higher amounts of agrochemical pesticide residues [44,47,48]. Pesticide residues in snap bean pods destined to the EU should not exceed the set legal MRLs (Figure 3; Table 3).

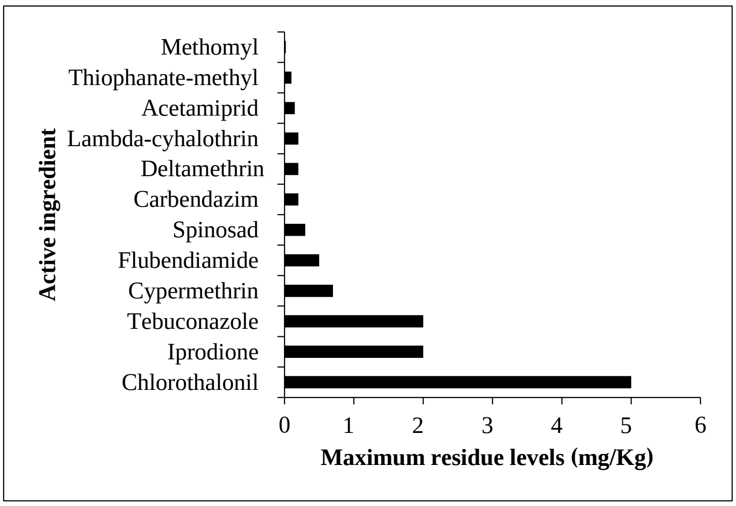


**Figure 3.** Maximum residue levels (mg/kg) in snap beans destined to the EU market. Source: [49].

**Table 3.** Maximum residue levels and postharvest interval (PHI) for selected synthetic pesticides used in snap beans production.

| Active Ingredient | Maximum Residue Levels (mg/Kg) | Post-Harvest Interval (PHI) (Days) |
|---|---|---|
| Abamectin | 0.01 | 7 |
| Acetamiprid | 0.06 | 7 |
| Alpha-cypermethrin | 0.01; 0.5 | 3, 7 |
| Azoxystrobin + difenoconazole | 1 | 7 |
| Permethrin | 1 | 7 |
| Carbendazim | 0.2 | 9 |
| Chlorantraniliprole | 0.1 | 3 |
| Bifenthrin | 0.5 | 7 |
| Tebucanozole | 0.14 | 14 |
| Imadacloprid | 2 | 8 |
| Emamectin | 0.01 | 7 |

Source: [47,49,50].

The European Commission directive 2009/128/EC gives a general default MRL of 0.01 mg/kg where a pesticide is not explicitly mentioned [46]. The EU's MRL harmonization advocates to improve access for countries like Kenya exporting snap beans to the trading block [51,52]. However, importers within EU member states like Germany and the United Kingdom apply stricter MRLs rules than those of the EU [53]. For example, the set MRLs by supermarket chains in the United Kingdom, Germany, the Netherlands, and Austria usually demand 33–70% of the legal MRL and upfront information on the commodity spray programs and pesticide application records. The non-uniform and always changing MRLs requirement in international markets is a challenge to Sub-Saharan countries like Kenya that exports fruits and vegetables. Data from the rapid alert system for food and feed (RASFF) shows Kenyan fruits and vegetables have been rejected at the ports of entry of the importing EU member countries [25] and the most affected vegetable due to border rejection are the fresh green beans (Table 4). Detection of dimethoate in fresh beans caused the highest number of border rejections in 2013 [25].

The labeling and packaging specifications for snap bean pods destined for the European Union markets require that the produce meets the specifications as per the legislation on food labeling [14]. The packaging materials should be new, clean, transparent, and should keep the pods intact without causing any damage [14,54]. Each package of freshly harvested pods should have a sticker label including the name and address of the packer, name and variety of the produce, country of origin, class and size, lot number, or the Global-GAP number (GGN) for traceability, and official control mark [14]. The premium quality requirements for snap beans include pods being fresh, intact, and free of any foreign matter and pests, aesthetically acceptable, free of strange smell and taste, free from abnormal external moisture, and free from parchment [55,56].

The market standards also set out the minimum quality and maturity of the commodity and spell out the characteristics of the various quality classes such as Extra Class, Class I, and Class II products, the different size codes, and the allowed tolerances in quality and size [14]. The produce must have a certificate of conformity with the commodity-specific standard. Fresh produce that is not covered by the particular standard must comply with the General Marketing Standards (GMS) of EU Regulation No. 543/2011 or the applicable UNECE standard [14,55]. Snap bean pods may be classified as extra class, class I, and class II, while pod size classes are extra-fine, fine, and bobby [12,55] (Table 5). Uniformity as a provision of snap bean presentation is paramount, and hence when packaging the pods should be from the same origin, variety, class, and size [55].

**Table 4.** Notifications on detection of pesticide residues in fruits and vegetables at ports of entry in the European Union market between 2015 and 2019.

| Year | Type of Notification | Chemical | Concentration (mg/kg-ppm) | Fruits and Vegetables |
|---|---|---|---|---|
| 2019 | Border rejection | methamidophos [u], acephate [u] | 0.6, 0.14, respectively | white beans |
| 2018 | Information for attention | carbofuran [u] | 0.015 | organic avocado |
| 2018 | Border rejection | carbofuran [u] | 0.14 | mangetout peas |
| 2016 | Border rejection | acephate [u] | 0.03 | snow peas |
| 2016 | Border rejection | carbofuran [u] | 0.14 | fresh snow peas |
| 2015 | Border rejection | carbendazim [u] | 1.5 | peas |
| 2015 | Border rejection | propamocarb, fluopicolide | 0.22, 0.034, respectively | peas |
| 2015 | Alert | carbofuran [u] | 0.018 | aubergines |
| 2015 | Border rejection | dimethoate | 0.18 | pea pods |
| 2015 | Border rejection | carbendazim [u] | 0.45 | fresh beans with pods |
| 2015 | Border rejection | methamidophos [u] | 0.3 | green beans |
| 2015 | Border rejection | methamidophos [u] | 0.067 | green beans with pods |
| 2015 | Border rejection | mandipropamid | 0.052 | fresh pea pods |
| 2015 | Border rejection | hexaconazole [u] | 0.021 | green beans |
| 2015 | Border rejection | carbendazim [u] | 1.2 | peas |
| 2015 | Border rejection | oxydemetun-methyl | 0.14 | fresh beans |
| 2015 | Border rejection | methomyl | 0.2 | green beans |
| 2015 | Border rejection | lufenuron | 0.089 | green beans |
| 2015 | border rejection | dimethoate, profenofos [u] | 0.049, 0.02, respectively | mangetout |
| 2015 | Border rejection | mataxyl | 0.29 | peas |

[u] unauthorized substance [30].

**Table 5.** Classification of snap bean pods, size, and their attributes and quality tolerances.

| | Quality | Attributes | Quality Tolerance |
|---|---|---|---|
| | | **Quality classes** | |
| Extra class | Superior quality | Turgid, quickly snapped, very tender, practically straight and stringless | 5% of class I |
| Class I | Good quality | Turgid, young and tender, practically stringless and slight defects in shape and color accepted | 10% of class II<br>No bean spot |
| Class II | Neither superior or good quality | Reasonably tender and meets minimum requirements | 10% of either class and or minimum requirements<br>No bean spot |
| **Size classes** | | | |
| Extra fine | | 6 mm | |
| Fine | | 9 mm | 10% not satisfying given size |
| Bobby/medium | | 12 mm | |

Source: [55].

Non legal requirements cover social and environmental compliance. The codes of conduct are myriad and depend on the particular export niche market. Examples of codes of social compliance include the Sustainable Agriculture Code, Ethical Trading Initiative (ETI), Business Social Compliance Initiative (BSCI) [14]. The demand for organically produced and processed food products among European consumers has been on the increase. Although organic products have a higher cost of production, they are better valued in the European market. For organic snap beans, the grower has to be reputed for using organic production methods for at least two years. Afterward, one has to be audited to have an organic logo on the export product [14]. Social and environmental compliance also entails record keeping of all farm operations, environmental standards, and welfare of farm workers [48].

## 4. Challenges Faced by Smallholder Farmers in Meeting Phytosanitary and Quality Requirements

The indicators of noncompliance with phytosanitary and technical regulations include decimating export volume of snap beans, rejections, and the high number of notifications. For example, as presented in Figure 2, Kenya's export volume of leguminous vegetables from 2013 to 2018 was on downward trajectory. The Figure points out clearly the documented data on rejections and the high number of notifications during marketing of snap beans. It is quite obvious that these are just a reflection of the true picture of the status of snap beans destined for export since they are reported at points of entry. To support this position taken by this review is the fact that substantial snap beans rejected for export are sold locally in supermarkets and open markets within the country and are estimated to be 9000 t. In addition, those rejected snap beans are also sold as animal feed and compost, each estimated to be 8000 t (15). Recently, a number of studies have highlighted the synthetic pesticides applied by smallholder farmers in key counties that produce and trade in snap beans (Table 6). From this Table it can be deduced that farmers are using chlorpyrifos and dimethoate that are not recommended for foliar use in vegetables and there are also cases of exceeding set MRLs by EU.

**Table 6.** Principal indicators used in the previous studies highlighting the synthetic pesticides applied by smallholder farmers.

| County | Pesticide | Finding | Reference |
|---|---|---|---|
| Meru | Azoxystrobin<br>Carbendazim and metalaxyl | MRLswere below that set by EU<br>MRLs exceeded that set by EU | [57] |
| Nairobi | Dimethoate<br>Chlorpyrifos and dimethoate | MRLswere below that set by EU<br>MRLs exceeded that set by EU | [58] |
| Murang'a and Kiambu | Imidacloprid, chlorantraniliprole, spirotetramat, indoxacarb and metalaxyl | MRLswere below that set by EU | [59] |
| Meru | Cabendazim, acetamiprid imidacloprid chlorpyrifos | MRLswere below that set by EU | [60] |

The problem of noncompliance is aggravated by overreliance on chemicals in pest management regimes where pesticides are overused, or deploying poorly designed regimes that compromise the quality of snap beans. Smallholder farmers most often are not fully conversant with EU requirements. Rejection of snap beans at the export market due to the presence of pests and pest damage on the pods are aspects of phytosanitary, while the presence of pesticide residues above the set MRLs is a technical requirement [61–63].

Most smallholder fresh vegetable growers apply synthetic pesticides based on fixed calendar spray regimes, mostly twice a week, weekly, or once in two weeks, depending on the target pest [49]. The fixed calendar spray regimes lead to indiscriminate use of pesticides resulting in the development of resistance and resurgence of dangerous pest strains and also the accumulation of chemical residues on produce and the environment. In addition, awareness of the safe use of pesticides by smallholder growers is wanting, especially on product labels [64,65]. The chemical residues pose a risk to human health, nontarget organisms, beneficial insects and contamination of ground-water [62]. Consequently, the population of the beneficial insect and microbial species have been decimated and compromised the ecological balance and diversity. The presence of chemical residues on export snap beans has significantly contributed to interception and rejection of consignments due to noncompliance with the set legal MRLs [3,49,65–67]. The presence of chemical residues emanate from not observing the recommended preharvest intervals (PHI) and the application of restricted and banned pesticides. Several pesticide ingredients, including dimethoate, abamectin, beta-cyfluthrin, chlorpyrifos, cypermethrin, chlorpyriphos + beta-cyfluthrin, anddiazinon are now restricted or banned in the production of snap beans [50].

Produce that does not meet the set MRLs are subjected to hefty fines for each contaminated snap bean export consignment entering the European Union [68]. Consequently, snap bean exports are subjected to an increased sampling and inspection from 5 to 10% sampling resulting in delivery delays and increased costs of control measures [69,70]. Failure to meet the set MRL requirements results in the cancellation of an export license. For smallholder farmers to meet MRL requirements, it demands judicious use of pesticides, avoiding the use of banned pesticides, and use of safe and sustainable integrated pest management (IPM) approaches as per the Global-GAP certification standards [14,71,72].

Compliance with the set market standards implies that players in the snap beans value chain have to invest more in order to produce effectively, handle, grade, package, and transport snap bean pods without compromising on the quality of the produce [24,73,74]. However, Global-GAP certification is expensive for individual smallholder snap bean growers, who cannot meet the increased production costs. Restricted use of chemical pesticides and adherence to PHI ensures that the produce meets the required MRL requirements and the consumer demand for specific premium grades of fresh produce that is clean and aesthetically acceptable [7,24,75]. The European Commission directive 2009/128/EC gives guidelines on reducing pesticide residues through training of growers, pesticide distributors, an inspection of pesticide application equipment, limitation of pesticide use in sensitive areas, and awareness creation on the risks caused by pesticides [46]. In consideration of the type of pesticides used in managing pests in snap beans in Kenya, the majority belong to organophosphates and neonicotinoids that have environmental and toxicological consequences.

## 5. Enforcement and Facilitation of Phytosanitary and Quality Regulations

Governmental institutions that enforce phytosanitary and quality standards in fresh vegetables in Kenya include the Kenya Plant Health Inspectorate Services (KEPHIS), Horticultural Crops Directorate (HCD), Ministry of Agriculture, and Pest Control Products Board (PCPB). The Fresh Produce Exporters Association of Kenya (FPEAK) and Kenya-GAP (Table 7) are private institutions and standards that facilitate the implementation of phytosanitary and quality regulations. KEPHIS is the National Plant Protection Organization (NPPO) in Kenya, and it is mandated to enforce compliance with phytosanitary and quality requirements in the export of agricultural produce [76]. Harvested snap bean pods are subject to checks for pesticide residues at an accredited KEPHIS laboratory and inspection for the presence of pests at the port of exit [77]. KEPHIS, in collaboration with stakeholders in the horticultural sub-sector, ensures early detection of pests and pesticide residues and trains smallholder farmers on produce quality management and traceability [78]. KEPHIS is also responsible for the certification of fresh produce exporters to ensure compliance to phytosanitary and quality standards along the commodity value chain.

The PCPB is in charge of pesticide registration and training of farmers on the safe use of pesticides, including advising farmers on recommended pesticide rates, observance of PHI to minimize chemical residues in fresh vegetables [67].

**Table 7.** Institutions and standards involved in developing and enforcing phytosanitary and quality regulations of horticultural crops.

| Institutions/Standards | Roles | Reference |
|---|---|---|
| | **National regulatory institutions** | |
| Agriculture Food and Fisheries Authority (AFFA) | Promoting and regulating best practices from in production to marketing of produce. | [79] |
| Horticulture Competent Authority Coordinating Committee | Streamlining sanitary and phytosanitary measures to stop rejection of produce in the international market | [79] |
| KEPHIS | Phytosanitary certification, monitoring, and analyzing of pesticide residue | [79] |
| HCD | Regulating pack-houses and players in the vegetable value chain, including enforcement of export standards, registration exporters, produce traceability, and quarterly reporting by processors and exporters | [80,81] |
| PCPB | Registration, formulation analysis, and control of protection products. | [49] |
| Kenya Agricultural and Livestock Research Organization (KALRO) | Facilitating the use of up to date production technology and establishing feedback systems to improve export capacities in horticultural products. | [79] |
| | **National private institutions and standards** | |
| Fresh Produce Exporters Association of Kenya (FPEAK); Kenya GAP | Advocating for a favorable trading environment for fresh vegetable growers/exporters, supporting and enhancing members' ability to comply with international standards; promoting Kenyan products at international markets and providing members with market and technical information. | [82] |
| | Inter-governmental regulatory agencies | |
| International Plant Protection Convention (IPPC) | Setting the International Standards for Phytosanitary Measures (ISPMs); Ensuring that exported horticultural produce are compliant and allowed entry into markets | [80,83] |
| European and Mediterranean Plant Protection Organization (EPPO) | It is the regional plant protection organization for Europe responsible for cooperation in plant protection in the European and Mediterranean region. It develops regional standards for phytosanitary measures. | [4] |
| Codex Alimentarius Commission (CODEX) | Developing and encouraging the implementation of standards, codes of practice, guidelines, and recommendations on food safety | [84] |
| European Commission | Setting legislation on plant health to prevent the introduction and spread of organisms harmful to plants and plant products in the EU | [4] |
| Organization of Economic Cooperation and Development (OECD) | Providing a complete and internationally harmonized export quality inspection system for member countries | [85] |
| Hazard Analysis Critical Control Points (HACCP) | HACCP entails programs about the handling of snap beans and documenting | [86] |
| | International private standards | |
| Global Gap | Developing good agricultural practices for adoption across the value chain of fruits and vegetables | [54,72] |
| British Retail Consortium (BRC) | Specification of technical requirements that entails production, packaging, and distribution of produce | [87] |
| EU organic | Stipulating that the areas of cultivation of organic vegetables are reasonably synthetic agrochemicals free. | [88] |

The international inter-governmental agencies to which fresh vegetables must comply include the International Plant Protection Convention (IPPC), European and Mediterranean Plant Protection Organization (EPPO), Codex Alimentarius Commission (CODEX), the European Commission, Organisation of Economic Cooperation and Development (OECD) while the private standards include Global-GAP and British Retail Council (BRC). The IPPC Secretariat coordinates and facilitates the development of the International Standards for Phytosanitary Measures (ISPMs) and facilitates information exchange on import and export requirements, pest status, and regulated pest lists [27,83]. It also offers technical assistance to developing countries through their NPPOs on the implementation of the ISPMs. IPPC plays a key role in providing a platform for phytosanitary standard-setting and harmonization. In this context of the spread of plant product pests, its contribution to promoting appropriate measures undertaken by competent authorities in the EU and that of Kenya cannot be overemphasized [27,87]. The EU competent authorities obtain recommendations from EPPO as regional standards, ideally as a revision of the IPPC [27]. EU food law encompasses food safety, and enforcement is solely bestowed on member countries. Snap beans reaching entering EU niche markets that are found to be noncompliant to food safety are subjected to measures like destruction, special treatment, or re-dispatch undertaken by competent authorities. Kenyan competent authority, KEPHIS has been duly obligated in the issuance of a phytosanitary certificate that has to accompany snap beans to EU niche markets. The phytosanitary certificate issued by KEPHIS is modeled out with IPPC specifications, therefore, internationally acceptable. The issuance of a phytosanitary certificate by KEPHIS to an exporter of snap beans means that the produce has been inspected and found to be free from quarantine pests and meets all the quality attributes [79].

The United Nations Economic Commission for Europe (UNECE) standards are commercial quality standards for Europe whose big representation is the EU helps to facilitate trade as the focus is entirely on high-quality production and safeguard the health of consumers. Deployment of UNECE standards is for various crops, including fresh vegetables such as snap beans [55]. These standards are deployed across the value chain of snap beans and also used by international organizations during their involvement in the trade. OECD facilitates snap beans in international trade via the Fruit and Vegetables Scheme, dubbed the international standardization of fruit and vegetables for beans wholesomely about quality, sizing, and presentation. The Fruit and Vegetables Scheme is a valuable tool for inspection and enforcing standards. Key EU member states are members of OECD, of which Kenya is also a member [85]. Hazard Analysis Critical Control Points (HACCP) has already been described in detail as a mandatory requirement for exporting to the EU. Lastly, Global Gap, British Retail Consortium (BRC), and EU organic (Table 7) are corporate standards crucial for food safety in regard to European buyer's demands. For example, Global Gap is required by supermarkets as the EU one of the leading EU niche markets. Global Gap, as a common certification standard, emphasizes good agricultural practices during snap beans production until it is exported.

## 6. Alternative Pest Management Approaches to Overcome Phytosanitary and Quality Challenges

The available methods for managing pests in vegetables include the use of resistant varieties, cultural methods, biological control, and synthetic pesticides [12,62]. There has been an effort to develop alternative pest management approaches as opposed to calendar sprays of synthetic pesticides. The lauded alternative approaches in managing vegetable pests include the use of biopesticides, insecticidal soaps, seed dressing, the use of resistant varieties, and modified cropping systems [63]. Other approaches include the use of yellow sticky traps, scouting for early pest detection, seed dressing, and augmentation of predators, entomopathogens, parasitoids, and use of pheromones and kairomones [89,90].

The use of biopesticides has gained popularity all over the world and formulations are available in the market [91,92]. Biopesticides do not leave harmful chemical residues on produce, are renewable, less toxic to humans and nontarget organisms, have no adverse effect on the environment, and are compatible with other strategies. These attributes, coupled with being effective, have made biopesticides not only good alternatives to synthetic pesticides, but also reliable tool in sustainable crop protection [61,63,91,93]. Biopesticides can be sourced locally, and therefore, they do not lead to the development of resistance by pests [7,94]. Biopesticide-based products that have been commercialized include microbial antagonists, botanicals, parasitoids, pheromones, and kairomones (Table 8) [49].

**Table 8.** Registered and potentially active biocontrol agents and biopesticides for managing pests in horticultural crops.

| Active Substance | Target Pest | Source |
|---|---|---|
| **Microbial Pesticides** | | |
| *Verticillium lecanii* | *Bemisia tabaci* and *Trialeurodes vaporariorum* | [49] |
| *Bacillus thuringiensis* | *Helicoverpa armigera, Aphis craccivora, Tetranychus* spp. | [49,95] |
| *Paecilomyces lilacinus*, $1 \times 10^9$ cfu/mL | *Bemisia tabaci* and *Trialeurodes* Root-knot nematodes | [49] |
| *Beauveria bassiana*, $1.0 \times 10^8$ cfu/mL | *Megalurothrips sjostedti, Aphis craccivora, Tetranychus* spp. | [49,95] |
| *Trichoderma harzianum*, $8 \times 10^9$ spores/g | *Frankliniella schultzei*, and *F. occidentalis*, Soil-borne pathogens | [49] |
| *Trichoderma asperullum* | Soil-borne pathogens | [49] |
| **Botanical Pesticides** | | |
| Pyrthrins, 25% *w/w* | *Bemisia tabaci* and *Trialeurodes vaporariorum* | [49] |
| Azadirachtin | *Megalurothrips sjostedti*, *Frankliniella schultzei*, and *F. occidentalis* | [49] |
| Pyrethrin | *Megalurothrips sjostedti*, *Frankliniella schultzei* and *F. occidentalis* | [49] |
| Neem oil | *Bemisia tabaci* and *Trialeurodes vaporariorum* | [49] |
| **Predators** | | |
| *Chrysoperla carnae* | *Aphis craccivora, Tetranychus* spp. | [95] |
| *Coccinella* sp. | | [96] |
| **Parasitoids** | | |
| *Trichogramma* sp., *Trichogrammatoidea* sp., *Encarsia* sp., *Telenomus* sp. | *Trialeurodes vaporariorum, Ostrinia nubilalis, Aspidiotus destructor, Helopeltis antonii, Opisina arenosella, Helicoverpa armigera* | [97] |
| **Pheromones** | | |
| Kairomone capsule, | *Frankliniella occidentalis* | [98] |
| Methyl-isonicotinate | *Frankliniella* spp. | [99] |
| Pheromone traps (4-methyl-3,5-heptanedione) | *Aphis craccivora, Tetranychus* spp. | [95] |

Biopesticides hold a key spot in the integrated management of crop pests, and they are in tandem with the increasing awareness among fresh vegetable consumers who demand both safe food and environment [91,92,94].

Studies by Niassy et al. [100] and Muthomi et al. [101] showed that microbial antagonists and plant extracts were efficacious against harmful pests. Extracts from garlic, ginger, lemon, and turmeric were effective in reducing the population of whiteflies (*Bemisia tabaci* and *T. vaporariorum*) and thrips (*M. sjostedti*, *F. schultzei*, and *F. occidentalis*) on snap beans and compared well to the commercial formulations of neem (*Azadirachta indica*). Antagonistic *Trichoderma* spp. reduced severity of rust (*Uromyces appendiculatus* var. *appendiculatus*) and anthracnose (*Colletotrichum lindemuthianum*) and resulted in increased snap bean yields [101]. In a study of determining the efficiency of biogents and essential oils against bean rust, alternating of either *B. thuringiensis* or *T. viride* with thyme oil reduced the disease severity and at the same time increased green pod yield comparable to fungicide commonly used by farmers [102]. The efficacy of *Metarhizium anisopliae* against thrips (*M. sjostedti*, *F. schultzei*, and *F. occidentalis*) has been demonstrated on snap beans [103,104]. In the study, *M. anisopliae* was reported to possess semiochemical, Lurem-TR (methyl-isonicotinate).

Natural enemies and parasitoids, including *Neoseiulus cucumeris*, *Orius* spp., and *Ceranisus menes* are effective bio-agents for suppressing the population of thrips (*Megalurothrips sjostedti*, *Frankliniella schultzei*, and *F. occidentalis*) on vegetable crops, including snap beans [105,106]. The predatory mite, *Neoseiulus cucumeris* was tested for its efficacy against thrips (*M. sjostedti*, *F. schultzei*, and *F. occidentalis*) on snap bean pods in vivo and it significantly reduced the population of adult and larvae resulting in a reduction in yield losses by up to 25% [107].

Potassium salts of fatty acids (insecticidal soaps) have been demonstrated to manage soft-bodied insect pests such as whiteflies (*B. tabaci* and *T. vaporariorum*) and aphids (*Aphis fabae*) by washing away the cuticle and disrupting the insect's physiology [108]. They are reputed for their knockdown effect on the insects, leave no residues, are user friendly, and have no MRL or pre-harvest interval (PHI) requirements [109]. Studies by Wafula [110] and Wafula et al. [111] showed that foliar sprays of potassium salts of fatty acids reduced the population of thrips (*M. sjostedti*, *F. schultzei*, and *F. occidentalis*) and whitefly (*B. tabaci* and *T. vaporariorum*) in snap beans by up to 69% and reduced pest damage on pods by up to 83%, thereby increasing marketable pod yield by up to 151%.

The use of resistant snap bean cultivars with desired export quality attributes is a cost-effective and sustainable approach that could help the growers to access niche markets [112]. Wahome et al. [2] reported the development of high-yielding snap bean varieties with resistance to rust (*Uromyces appendiculatus* var. *appendiculatus*) and anthracnose (*Colletotrichum lindemuthianum*). The five lines of snap beans were resistant to rust while one line was resistant to anthracnose and these were crossed with commercial varieties that were high yielding and produced pods that meet the classification of either fine, extra fine, and bobby [2].

Modification of the cropping system to manage pests in the vegetable is easily adaptable by smallholder growers due to extra benefits accrued from the companion or intercrop crops. Modification of the cropping system encompasses growing snap bean together with another crop in the form of companion crops, intercropping, border crop, and use of mulch [113–116]. Companion crops and intercropping work by repelling the pests and favors the proliferation of natural enemies [105,115]. Kasina et al. [105] reported a significant reduction in the population of flower thrips (*M. sjostedti*, *F. schultzei*, and *F. occidentalis*) when snap beans were intercropped with African marigold (*Tagetes erecta*) and coriander (*Coriandrum sativum*). Intercropping snap beans with maize (*Zea mays*) reduced the population of adult thrips (*M. sjostedti*, *F. schultzei*, and *F. occidentalis*) [115]. Intercropping snap beans with maize also resulted in a higher population of *Orius* spp., which are natural enemies of thrips, and increased marketable pods yield.

The different pest management options are combined in the development of integrated pest management (IPM) programs. Integrated pest management (IPM) aims at reducing synthetic pesticide sprays by integrating eco-friendly options, including biopesticides, seed dressers, manipulation of cropping systems, use of natural enemies, good agricultural practices, and judicious use of safe pesticides [61,95,110]. The approach focuses on early detection and prevention of pests before the build-up of their population. Integrated pest management (IPM) approaches are safe, simple, sustainable, economical, and environmentally sound [63,93]. Pest management approaches combining cultural practices, chemical, physical, and biological, have been observed to suppress pests below the economic threshold as opposed to calendar chemical spray regimes and increase the number of predators [95]. Otim and colleagues [61] found that seed dressing or soil drenching plus the timely foliar application of pesticide reduces insect pest infestation and therefore can be tools to be integrated with snap bean's pest management with consideration of lower cost to enable smallholder farmers to make a profit. Additional studies by Wafula [108] and Muthomi et al. [117] showed that integrating seed dressing, intercropping snap bean with maize, pyrethrin, and neem sprays was effective in managing whiteflies and thrips on snap beans. Snap bean seeds were dressed with a systemic insecticide (imidacloprid 233 g/L+ pencycuron 50 g/L + thiram 107 g/L) before planting, followed by two to three pyrethroid (Pesthrin 6% EC) sprays until flowering and neem (azadirachtin 0.03%) sprays after flowering. The integrated approach reduced the population of whiteflies (*B. tabaci* and *T. vaporariorum*) and thrips (*M. sjostedti*, *F. schultzei*, and *F. occidentalis*) by up to 60%.

## 7. Conclusions and Recommendations

The challenges faced by smallholder farmers in complying with the phytosanitary and quality requirements are contributed largely by non optimal agronomic practices, limited market information, less supported producer groups, and lack of coordination among the stakeholders along the snap bean value chain. This review reports the continuous use of synthetic pesticides by smallholder farmers, which aggravates attaining the full potential of exported snap beans despite the cry by stakeholders to have this paradigm-shifting to integrated pest management coupled with good agricultural practices. There is a need for continued research to develop new pest management technologies to match the dynamic phytosanitary and quality regulations and stringent consumer demands while maintaining the environment and safeguarding the economic viability of smallholder vegetable growers. For successful application of integrated pest management (IPM) systems, the development of new technologies is required for mass production of natural enemies, entomopathogens, and microbial antagonists, in addition to bio-prospecting and formulation of new biopesticides. IPM is part of Global-GAP certification and strict adherence to the IPM principles will reduce the usage of synthetic pesticides. In consideration of the diverse alternative pest management approaches, advocacy for the adoption of IPM programs that are accessible to the smallholder farmers and suited to local conditions is required.

In addition, the formulation of supportive policies will spur innovation, safeguard local biodiversity in the bio-prospecting for biopesticides, and intellectual property rights for the new products. Structured capacity building on international phytosanitary and quality standards would result in a reduced number of interceptions and rejection of fresh vegetables at the export market. This would entail training of the farmers on the market accepted pesticide's active ingredients, their rates of application, good agricultural practices, and the available alternative sustainable and environmentally-friendly IPM programs. This requires collaboration and partnerships among the various stakeholders in the snap bean value chain, including growers, local authorities, exporters, research institutions, governmental regulatory institutions, and private actors in providing solutions to smallholder snap bean producers. Awareness creation and promotion of new technologies will help in the increased adoption of new agronomic and pest management practices by the growers, thus boosting the quality of snap beans destined for the niche markets.

The government should increase support to snap beans smallholder farmers, especially the youth and women, by facilitating them to form producer groups that will enable them to access finances in terms of credit and grants. This study was limited by a lack of data on the fate of synthetic pesticides in the Kenyan context. Therefore, future research on the assessment of the impact of organophosphates and neonicotinoids largely used in snap beans in Kenya on humans and the environment should be carried out. The resulting findings then should be extended to smallholder farmers. Further, KEPHIS should also be able to carry dimethoate risk assessment in the snap bean potential counties.

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## References

1. National Farmers Information Service (NAFIS). French Beans Value Chain Development Murang'a County. Available online: http://www.nafis.go.ke/vegetables/ (accessed on 20 June 2016).
2. Wahome, S.W.; Kimani, P.M.; Muthomi, J.W.; Narla, R.D. Quality and yield of snap bean lines locally develop din Kenya. *Int. J. Agron. Agric. Res.* **2013**, *3*, 1–10. [CrossRef]
3. United States Agency for International Development-Kenya Horticulture Competitiveness Project (USAID-KHCP). *Global Competitiveness Study: Benchmarking Kenya's Horticulture Sector for Enhanced Export Competitiveness*; Fintrac. Inc.: Nairobi, Kenya, 2015.
4. Kok, M.G.; Osena, E.; Snel, H. *Food Loss in the French Bean Supply Chain of VEGPRO-Group Kenya*; Analysis of the French bean pilot; Report WCDI-19-085/WFBR-1999; Wageningen University & Research: Wageningen, The Netherlands, 2019.

5. Masiga, R.; Kasina, M.; Mbugi, J.; Odhiambo, C.; Kinuthia, W.; Gemmill-Herren, B.; Vaissièr, B.E. Do French beans (*Phaseolus vulgaris*) grown inproximity to Mt. Kenya forestin Kenya experience pollination deficit? *J. Pollinat. Ecol.* **2014**, *14*, 255–260. [CrossRef]
6. Trad Map. Trade Statistics for International Business Development; Monthly, Quarterly and Yearly TradeData. *Importand Export Values, Volumes, Growth Rates, Market Shares, etc.* Available online: https://www.trademap.org/cbi/Country_SelProduct_TS.aspx?nvpm=1%7c%7c%7c%7c%7c070820%7c%7c%7c6%7c1%7c1%7c2%7c2%7c1%7c2%7c2%7c1 (accessed on 12 April 2020).
7. Okello, J.J.; Swinton, S.M. International food safety standards and the use of pesticides infresh export vegetable productionindeveloping countries: Implications for farmer health and the environment. In *Pesticides—Formulations, Effects, Fate*; Stoytcheva, M., Ed.; IntechOpen: London, UK, 2011. [CrossRef]
8. Horticultural Crop Development Authority (HCDA). Vegetables, French Beans. Available online: http://www.hcda.or.ke/?page_id=1054 (accessed on 22 December 2014).
9. Kenya National Bureauof Statistics (KNBS). *Statistical Abstract*; Kenya National Bureau of Statistics: Nairobi, Kenya, 2019; ISBN 978-9966-102-10-2.
10. Hortnews. United States Opens Market for Kenyan French-Beans. Available online: http://www.hortinews.co.ke/2016/01/28/united-states-opens-market-for-kenyan-french-beans/ (accessed on 18 February 2018).
11. Kuehn, J. Glossary of Phytosanitary Terms. National Standard for Phytosanitor Measures. 2015. Available online: https://pflanzengesundheit.julius-kuehn.de/dokumente/upload/e3aff_np3-glossary_phytosanitary_terms2015_en.pdf (accessed on 18 October 2016).
12. Infonet-Biovision. Crops. Available online: http://www.infonet-biovision.org/default/ct/118/crops (accessed on 27 June 2016).
13. Jong-Woo, K.; Dorothea, R. Impact of Sanitary and Phytosanitary Measures and TechnicalBarriersonInternationalTrade.MunichPersonalRePEcArchive. MPRA Paper No. 82352. 2017. Available online: https://mpra.ub.uni-muenchen.de/82352/ (accessed on 30 December 2019).
14. Centre for the Promotion of Imports from Developing Countries (CBI). What Requirements Should Fresh Fruitsor Vegetables Comply with to be Allowed on the European Market. Available online: https://www.cbi.eu/market-information/fresh-fruit-vegetables/buyer-requirements/ (accessed on 10 February 2018).
15. Value Chain Analysis for Development (VCAD). *Green Beans Value Chain Analysis in Kenya*; Directorate General International Cooperation and Development—Europe Aid, Directorate Sustainable Growth and Development: Nairobi, Kenya, 2018.
16. Shingal, A.; Malte, E. *Trade Effect of MRL Harmonization in the EU: Improved Access for Non-EU Partners*; European University Institute: Florence, Italy, 2018.
17. European Union (EU). New EU Plant Health Rules: Regulation (EU) 2016/2031 on Protective Measures against Plant Pests ("Plant Health Law"). Available online: https://ec.europa.eu/food/plant/plant_health_biosecurity/legislation/new_eu_rules_en (accessed on 15 July 2020).
18. MFarm. Growing French Beansin Kenya. 2014. Available online: https://www.mfarm.co.ke/blog/post/growing-french-beans-in-kenya (accessed on 18 October 2016).
19. Wamucii, S. Why French Beans Have Become a Top Horticultural Choice in New Regions of Kenya. Available online: https://www.selinawamucii.com/why-french-beans-have-become-a-top-horticultural-choice-in-new-regions-of-kenya/ (accessed on 7 October 2020).
20. Fanelli, R.M. The (un)sustainability of the land use practice sand agricultural production in EU countries. *Int. J. Environ. Stud.* **2019**, 1–22. [CrossRef]
21. Fanelli, R.M. The spatial land temporal variability of the effects of agricultural practices on the environment. *Environments* **2020**, *7*, 33. [CrossRef]
22. Green life Crop Protection Africa. French Beans. Available online: https://www.greenlife.co.ke/french-beans/ (accessed on 25 October 2018).
23. Nyasetia, D.M.S. Antifungal Activity of Selected Crude Plant Extracts on Bean Rust (*Uromycesappendiculatus*) and Their Effectson Physiological Activities of French Beans. Master's Thesis, Jomo Kenyatta University of Agriculture and Technology, Juja, Kenya, 2011.
24. Okello, J.J. Exit, voice and loyalty in Kenya's French bean industry: What lessons can we learn from small holder farmers' past response to international food safety standards? *Afr. J. Food Agric. Nutr. Dev.* **2011**, *11*, 4460–4475. [CrossRef]
25. Pesticide Residues in Food (PRF). The Expert Committee on Pesticide Residues in Food. Annual Report; 2016. Available online: https://www.gov.uk/government/publications/pesticide-residues-in-food-quarterly-monitoring-results-for-2016 (accessed on 1 October 2017).
26. Pest Control Products Board (PCPB). *Pest Control Products Registered for Use in Kenya. Fully Registered Pest Control Products*, 10th ed.; Pest Control Products Board: Nairobi, Kenya, 2015.
27. IPPC. Adopted International Standards for Phytosanitary Measures (ISPMs). *International Plant Protection Convention*. 2017. Available online: https://www.ippc.int/en/core-activities/standards-setting/ispms/#publications (accessed on 2 June 2018).
28. European and Mediterranean Plant Protection Organization (EPPO). Quarantine List A1. 2017. Available online: https://www.eppo.int/QUARANTINE/listA1.htm (accessed on 2 March 2018).
29. Gathura, G. Fresh Produce Processing Factories Risking Kenya's Export Market through Unhygienic Practices. 2017. Available online: www.rocketscience.co.ke (accessed on 23 July 2018.).

30. Webgate, E.C. Rapid Alert System for Food and Feed (RASFF); Notifications. Available online: https://ec.europa.eu/food/safety/rasff_en (accessed on 13 April 2020).
31. Hennessey, M.K.; Jeffers, L.; Nendick, D.; Ken, G.; Floyd, L.; Hansen, J.D.; Bailey, W.D.; Winborne, I.; Bartels, D.; Ramsey, C.; et al. Phytosanitary Treatments. In *The Handbook of Plant Biosecurity*; Gordh, G., McKirdy, S., Eds.; Springer: Dordrecht, The Netherlands, 2014.
32. Hallman, G.J. Process control in phytosanitary irradiation of fresh fruits and vegetables as a model for other phytosanitary treatment processes. *Food Control* **2017**, *72*, 372–377. [CrossRef]
33. Saeed, N.; Tonina, L.; Battisti, A.; Mori, N. Postharvestshortcoldtemperaturetreatmenttopreservefruitqualityafter *Drosophila suzukii* damage. *Int. J. Pest Manag.* **2020**, *66*, 23–30. [CrossRef]
34. Nicholas, A.; Lidbetter, F.; Eagleton, N.; Spohr, L.; Harris, A.; Barchia, I. Phytosanitary irradiation of three species of spider mites (Trombidiformes: Tetranychidae). *Austral Entomol.* **2018**. [CrossRef]
35. Follett, P.A.; Neven, L.G. Phytosanitary irradiation: Does modified atmosphere packaging or controlled atmosphere storage creating allow oxygen environment threaten treatment efficacy? *Radiat. Phys. Chem.* **2020**, 108874. [CrossRef]
36. Bustos-Griffin, E.; Hallman, G.J.; Griffin, R.L. Phytosanitary irradiation in ports of entry: A practical solution for developing countries. *Int. J. Food Sci. Technol.* **2015**, *50*, 249–255. [CrossRef]
37. Dias, V.S.; Hallman, G.J.; Cardoso, A.S.; Hurtado, N.V.; CMaxwell, F.R.; Cáceres-Barrios, C.E.; Vreysen, M.J.B.; Myers, S.W. Relative Tolerance of three Morphotypes of the *Anastrepha fraterculus* complex (Diptera:Tephritidae) to Cold Phytosanitary Treatment. *J. Econ. Entomol.* **2020**, *113*, 1176–1182. [CrossRef] [PubMed]
38. Dohino, T.; Suzuki, N.; Miyazaki, I.; Tanno, M.; Yoshinaga, M.; Shukuya, T. Comparison of Cold Tolerance of egg sand larvae of *Bactrocera dorsalis* (Diptera: Tephritidae) among citrus fruits. *Res. Bull. Pl. Prot. Jpn.* **2019**, *55*, 1–10.
39. Suwapanich, R.; Krusong, W.; Thompson, A.K. Postharvest control of anthracnose in mangoes by fumigation with vinegar and ethanol vapours. *Int. J. Postharv. Technol. Innov.* **2019**, *6*, 179–191. [CrossRef]
40. Papoutsisa, K.; Mathioudakisc, M.M.; Hasperuéd, J.H.; Ziogas, V. Non-chemical treatments for preventing the postharvest fungal rotting of citrus caused by Penicillium digitatum (green mold) and Penicillium italicum. *Trends Food Sci. Technol.* **2019**, *86*, 479–491. [CrossRef]
41. Hernández, E.; Rivera, P.; Bravo, B.; Toledo, J.; Caro-Corrales, J.; Montoya, P. Hot-water phytosanitary treatment against *Ceratitis capitate* (Diptera: Tephritidae) in "Ataulfo" mangoes. *J. Econ. Entomol.* **2012**, *105*, 1940–1953. [CrossRef]
42. Yoon, Y.-S.; Ameer, K.; Song, B.-S.; Kim, J.-K.; Park, H.-Y.; Lee, K.-C.; Eun, J.-B.; Park, J.-H. Effects of X-ray irradiation on the postharvest quality characteristics of 'Maehyang' strawberry (*Fragaria* × *ananassa*). *Food Chem.* **2020**. [CrossRef]
43. Serapian, T.; Prakash, A. Comparative evaluation of the effect of methyl bromide fumigation and phytosanitary irradiation on the quality of fresh strawberries. *Sci. Hortic.* **2016**, *201*, 109–117. [CrossRef]
44. Centre for the Promotion of Imports from Developing Countries (CBI). Buyer Requirements: Fresh Fruit and Vegetables. CBI Market Intelligence. Available online: www.cbi.eu/market-information (accessed on 23 June 2016).
45. Centre for the Promotion of Imports from Developing Countries (CBI). *Product Factsheet Fresh Beans, Peas, and Other Leguminous Vegetables in Europe*; CBI Ministry of Foreign Affairs: The Haque, The Netherlands, 2015.
46. European Commission. The European Commission Directive 2009/128/EC on Maximum Residue Levels. 2009. Available online: https://ec.europa.eu/food/plant/pesticides/max_residue_levels_en (accessed on 15 April 2017).
47. Pesticide Residues in Food (PRF): The Expert Committee on Pesticide Residues in Food (PRF) Report on the Pesticide Residues Monitoring Programme: Quarter 3 2019. Available online: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/879216/prif-monitoring-2019-quarter3.pdf (accessed on 30 September 2020).
48. CUTS. Standards and Market Access: Opportunities and Challenges for East African Exports into European Union. 2009. Available online: http://www.cuts-international.org/ARC/Nairobi/BIEAC/PDF/BIEAC-Standards_and_Market_Access.pdf (accessed on 30 July 2017).
49. Pest Control Products Board (PCPB). *Pest Control Products Registered for Use in Kenya. Fully Registered Pest Control Products, Version 1_2018*; Pest Control Products Board: Nairobi, Kenya, 2019.
50. USAID-Kenya Agricultural Value Chain Enterprises (USAID-KAVES) Project. *Initial Environmental Examination, Amendment Pesticide Evaluation Report and Safer Use Action Plan (PERSUAP) for USAID/Kenya's Kenya Agricultural Value Chain Enterprises (KAVES) Project*; Fintrac. Inc.: Nairobi, Kenya, 2014.
51. Shingal, A.; Ehrich, M. Trade Effects of Standards Harmonization in the EU: Improved Access for Non-EU Partners. ©Indian Council for Research on International Economic Relations. 2019. Available online: http://hdl.handle.net/11540/9984 (accessed on 13 May 2020).
52. European Union (EU). EU Legislation on MRLs. Available online: https://ec.europa.eu/food/plant/pesticides/max_residue_levels/eu_rules_en (accessed on 14 April 2020).
53. CBI. *Practical Market Insights for Your Product: Fresh Beans and Pulses in Germany*; The Haque, The Netherlands, 2015. Available online: https://www.importpromotiondesk.de/fileadmin/user_upload/Publikationen/factsheet/obst_gemuese/Beans___Pulses_160331_eng.pdf (accessed on 14 May 2020).
54. United States Agency for International Development-Kenya Horticulture Competitiveness Project (USAID-KHCP). The EU Market for Green Beans. 2011. Available online: www.GrowKenya.org\T1\textbar{}khcp@fintrac.com\T1\textbar{}www.fintrac.com\T1\textbar{}MarketSurvey#03 (accessed on 14 December 2018).

55. United Nations Economic Commission for Europe (UNECE). *ENECE Standard FFV-06 Concerning the Marketing and Commercial Quality Control of Beans*; United Nations: Geneva, Switzerland, 2017.
56. Kenya Plant Health Inspectorate Service (KEPHIS). EU Requirements. Available online: www.kephis.org (accessed on 21 June 2017).
57. Marete, G.M.; Shikuku, V.O.; Lalah Mputhia, J.O.; Wekesa, V.W. Occurrence of pesticides residues in French beans, tomatoes, and kale in Kenya, and their human health risk in dicators. *Environ. Monit. Assess.* **2020**, *192*, 692. [CrossRef]
58. Inonda, R.; Njage, E.; Ngeranwa, J.; Mutai, C. Determination of pesticide residues in locally consumed vegetables in Kenya. *Afr. J. Pharm.* **2015**, *4*, 1–6.
59. Kipkemoi, E.; Andayi, W.A.; Njagi, E.C.; Ptoton, B. Analysis of Pesticide Residues in Tomatoes and French Beans from Murang'a and Kiambu Counties, Kenya. *Eur. J. Nutrit. Food Saf.* **2020**, *12*, 121–132. [CrossRef]
60. Marete, M.; Lalah, J.O.; Mputhia, J.; Wekesa, W.V. Determination of level so for *organophosphorus* pesticide residue sin kales, tomatoes and French beans from Meru County, *Kenya by GC*-MS. *Afric. J. Emerg. Issues* **2019**, *1*, 20–29.
61. Otim, M.; Kasina, M.; Nderitu, J.; Katafiire, M.; Mcharo, M.; Kaburu, M.; GBwire, J.B.; Cheminingw'a, G.; Olubayo, F.; Ugen, M. Effectiveness and profitability of insecticide formulations used for managing snap bean pests. *Ugan. J. Agric. Sci.* **2016**, *17*, 111–124. [CrossRef]
62. Nyakundi, W.O.; Magma, G.; Ochoa, J.; Nene, A.B. A survey of pesticide use and application patterns among farmers: A case study from selected horticultural farms in Rift Valley and Central Provinces, Kenya. *OJS Sci. Conf. Proc.* **2012**, *686*, 618–630.
63. Pretty, J.; Pervez, B.Z. Integrated pest management for sustainable intensification of agriculture in Asia and Africa. *Insects* **2015**, *6*, 152–182. [CrossRef]
64. Macharia, I. Pesticides and Health in Vegetable Production in Kenya. *BioMed Res. Int.* **2015**. [CrossRef]
65. European Commission. *Final Report of an Audit Carried out in Kenya from 12 to 19 November 2013 in order to Evaluate Controls of Pesticides in Food of Plant Origin Intended for Export to the European Union*; DG (SANCO) 2013-6692-MR FINAL; European Commission: Brussels, Belgium, 2014.
66. Fening, K.O.; Adama, I.; Tegbe, R.E. On-farm evaluation of homemade pepper extract in the management of pests of cabbage, *Brassica oleraceae* L., and French beans, *Phaseolus vulgaris* L., in two agro-ecological zones in Ghana. *Afr. Entomol.* **2014**, *22*, 552–560. [CrossRef]
67. Koigi, B. Digital traceability: Reigniting Kenya's International Trade. The Technical Centre for Agricultural and Rural Cooperation (CTA). 2018. Available online: http://spore.cta.int/en/research/reigniting-kenyas-international-trade.html (accessed on 13 October 2018).
68. Business Daily Africa. EU Forces Pesticide Chemical Banning. 2012. Available online: https://www.freshplaza.com/article/2092322/kenya-eu-forces-pesticide-chemical-banning/ (accessed on 22 January 2015).
69. Andae, G. Fresh Exports Get Boost as KEPHIS to Monitor EU Sales. Business Daily. Available online: http://www.businessdailyafrica.com/Fresh-exports-get-boost-as-Kephis-to-monitor-EU-sales/-/539552/3048684/-/13dhxpsz/-/index.html (accessed on 24 June 2016).
70. Hortfresh. EU Lifts Ban on Kenya's Beans. *Hortfresh J.* Available online: http://hortfreshjournal.com/eu-lifts-ban-on-kenyas-beans/ (accessed on 23 June 2016).
71. Infonet-Biovision. Export Requirements for Fruits and Vegetables in Kenya. Available online: https://www.infonet-biovision.org/EnvironmentalHealth/Basic-Export-Requirements-FruitVegetable-Kenya (accessed on 21 July 2020).
72. Global-GAP. What We Do. Available online: https://www.globalgap.org/uk_en/what-we-do/ (accessed on 20 October 2017).
73. Wahome, S.W.; Kimani, P.M.; Muthomi, J.W.; Narla, R.D.; Buruchara, R. Multiple disease resistance in snap bean genotypes in Kenya. *Afr. Crop Sci. J.* **2011**, *4*, 289–302.
74. Odhiambo, O. D.Competitiveness of Small holder Snap Bean Production in Kirinyaga County, Kenya. Master's Thesis, University of Nairobi, Nairobi, Kenya, 2012.
75. Research Solutions Africa (RSA) Ltd. *Report of a Study on Fresh Vegetables Market in Kenya. Desk Review*; Research Solutions Africa (RSA) Ltd.: Nairobi, Kenya, 2015.
76. Kenya Plant Health Inspectorate Service (KEPHIS). Phytosanitary Services. Available online: https://www.kephis.org/index.php/import-requirements/2014-09-19-08-11-21 (accessed on 24 January 2020).
77. Nassilah, S. Kenya Plant Health Inspectorate Service (KEPHIS) 2016 Annual Report. Available online: https://issuu.com/nassilah/docs/2017_annual_report_24.04.2017_12.37 (accessed on 5 October 2018).
78. Kleih, U.; Allen, C.; Basset-Mens, C.; Edewa, A. *Green Beans Value Chain Analysis in Kenya*; Report for the European Commission; Value Chain Analysis for Development Project (VCA4D CTR 2016/375-804), + annexes; DG-DEVCO: Brussels, Belgium, 2017; 171p.
79. United States Agency for International Development-Kenya Agricultural Value Chain Enterprises (USAID-KAVES). *French Bean Value Chain Analysis*; Fintrac. Inc.: Nairobi, Kenya, 2015.
80. Otieno, G.A. Standards and Development: Perspectives from Kenya's Horticultural Export Industry. Ph.D. Thesis, Erasmus University Rotterdam, Rotterdam, The Netherlands, 2016.
81. Agriculture and Food Authority (AFA). Horticultural Crops Directorate (HCD). 2018. Available online: https://horticulture.agricultureauthority.go.ke/?page_id=20 (accessed on 4 June 2018).

82. Fresh Produce Exporters Association of Kenya (FPEAK). Making Kenyan Horticulture the Global Choice. 2018. Available online: http://fpeak.org/ (accessed on 4 June 2018).
83. Food and Agriculture Organization of the United Nations (FAO). International Plant Protection Convention. Available online: https://www.ippc.int/en/ (accessed on 18 March 2018).
84. Food and Agriculture Organization of the United Nations (FAO). Codex Alimentarius International Food Standards. Available online: http://www.fao.org/fao-who-codexalimentarius/en/ (accessed on 18 March 2018).
85. Organisation for Economic Co-operation and Development (OECD). About Fruit and Vegetables. Available online: http://www.oecd.org/tad/code/aboutfruitandvegetables.htm (accessed on 5 October 2018).
86. Export Development Authority and Green Trade Initiative. Green Beans Market Overview in France. 2018. Available online: https://eda-gti.org/wp-content/uploads/2018/08/green-beans-market-overview-in-France.pdf (accessed on 18 January 2021).
87. BRC Global Standards. British Retail Consortium (BRC) Global Standards. Available online: https://www.brcglobalstandards.com/ (accessed on 12 March 2018).
88. European Commission. What is Organic Farming and Organic Certification? Available online: https://ec.europa.eu/agriculture/organic/organic-farming/what-is-organic-farming/organic-certification (accessed on 13 February 2018).
89. Sharmah, D.; Rahman, S. Management of the major pests of French bean through development and validation of certain IPM modules, Assam. *India J. Appl. Nat. Sci.* **2017**, *9*, 674–679. [CrossRef]
90. Murali-Baskaran, R.K.; Sharma, K.C.; Kaushal, P.; Kumar, J.; Parthiban, P.; Senthil-Nathan, S.; Mankin, R.W. Role of *kairomones in* biological control of crop pests-Review. *Physiol. Mol. Plant Pathol.* **2017**, 1–13. [CrossRef]
91. Chandler, D.; Bailey, A.S.; Tatchell, G.M.; Davidson, G.; Greaves, J.; Grant, W.P. The development, regulation and use of biopesticides for integrated pest management. *Philos. Trans. R. Soc. Lond. B Biol. Sci.* **2011**, *366*, 1987–1998. [CrossRef]
92. Krishan, J. *Global Trends in the Development and Use of Biopesticides. Regional Experts Workshop on Development, Regulation and Use of Biopesticides in East Africa*; Nairobi, Kenya, 2014; Available online: https://www.slideshare.net/ILRI/bioinnovate-jindal-may2014 (accessed on 21 December 2017).
93. Croplife. Integrated Pest Management. Available online: https://croplife.org/wp-content/uploads/pdf_files/Integrated-pest-management.pdf (accessed on 12 February 2018).
94. Kimani, V. Biopesticides Development, Use and Regulation in Kenya. Regional Experts Workshop on Development, Regulation and Use of Biopesticide in East Africa Slide Share 2014. Available online: https://www.slideshare.net/ILRI/bioinnovate-kimani-may2014 (accessed on 21 December 2017).
95. Mondal, A.; Shankar, U.; Abrol, D.P.; Singh, I.; Norboo, T. Evaluation of pest management strategies against sucking insect-pests for the safety of beneficial insects in vegetable French bean (*Phaseolus vulgaris*). *Int. J. Curr. Microbiol. App. Sci.* **2017**, *6*, 1441–1448. [CrossRef]
96. Sushil, S.N.; Singh, J.P.; Ghosh, P.K.; Akhtar, M. *Integrated Pest Management (IPM) in French Beans (Phaseolus Vulgaris) for Export Purpose*; Plant Protection Advisor, Directorate of Plant Protection, Quarantine and Storage: Faridabad, India, 2018.
97. Fathipour, Y.; Maleknia, B. *Ecofriendly Pest Management for Food Security*; Omkar, Ed.; Elsevier Inc.: Amsterdam, The Netherlands, 2016; pp. 329–366. [CrossRef]
98. Harbi, A.; Elimem, M.; Chermiti, B. Use of *synthetic* kairomone to control Frankliniella occidentalis. Pergande (thysanoptera: Thripidae) in protected *pepper in* Tunisia. *Afr. J. Plant Sci. Biotechnol.* **2013**, *7*, 42–47.
99. Muvea, A.M.; Kutima, H.L.; Lagat, S.O.; Waiganjo, M.; Subramanian, S. Evaluation of coloured traps with kairomones attractant for monitoring thrips population dynamics on tomato crops in East Africa. *Int. J. Trop. Insect Sci.* **2017**, *37*, 89–97. [CrossRef]
100. Niassy, S.; Maniania, N.K.; Subramanian, S.; Gitonga, M.L.; Maranga, R.; Obonyo, A.B.; Ekesi, S. Compatibility of Metarhizium anisopliae isolate ICIPE69 with agrochemical used French bean production. *Int. J. Pest Manag.* **2012**, *58*, 131–137. [CrossRef]
101. Muthomi, J.W.; Fulano, A.M.; Wagacha, J.M.; Mwang'ombe, A.W. Management of snap bean insect pests and diseases by use of antagonist stick fungi and plant extracts. *Sustain. Agric. Res.* **2017**, *6*, 52–63. [CrossRef]
102. Zyton, M.A.; Ahmed, G.A. Management of bean rust by some bioagents and essential plant oils. *Egypt. J. Phytopathol.* **2019**, *44*, 167–186. [CrossRef]
103. Niassy, S.; Maniania, N.K.; Subramanian, S.; Gitonga, L.M.; Ekesi, S. Performance of a semiochemical-baited auto inoculation device treated with Metarhizium anisopliae for control of Frankliniella occidentalis on French bean in field cages. *Entomol. Exp. Appl.* **2012**, *142*, 97–103. [CrossRef]
104. Kuboka, M.N. Effect of Temperature on the Efficacy of Metarhizium Anisopliae in Management of Western Flower Thrips in French Beans. Master's Thesis, University of Nairobi, Nairobi, Kenya, 2013.
105. Kasina, J.M.; Nderitu, J.H.; Nyamasyo, G.H.N.; Olubayo, F.; Waturu, C.N.; Obudho, E. Evaluation of companioncrops for thrips (Thysanoptera: Thripidae) management in French beans (*Phaseolus vulgaris*) L. *Int. J. Trop. Insect Sci.* **2006**, *26*, 121–125. [CrossRef]
106. Zilahi-balogh, G.M.G.; Shipp, J.L.; Cloutier, C.; Brodeur, J. Predation by Neoseiulus cucumeris on western flower thrips, and its oviposition on greenhouse cucumber under winter vs. summer conditions in atemperate climate. *Biol. Control* **2007**, *40*, 160–167. [CrossRef]
107. Nyasani, J.O.; Subramanian, S.; Poehling, H.M.; Maniania, N.K.; Ekesi, S.; Meyhöfer, R. Optimizing Western Flower Thrips Management on French Beans by Combined Use of Beneficials and Imidacloprid. *Insects* **2015**, *6*, 279–296. [CrossRef]
108. Mohammed, A. An Overview of Distribution, Biology and the Management of Common Bean Anthracnose. *J. Plant Pathol. Microb.* **2013**, *4*, 193. [CrossRef]

109. Dheeraj, J.; Susan, V.P.; Nisha, S. Fatty Acid Metallic Salts and Pyrethroids-Environmental friendly Pesticides. *Int. J. Sci. Res. Rev.* **2013**, *2*, 43–51.
110. Wafula, G.O. Potential of Potassium Salts and Integrated Pest Management Strategies in Management of Snap Bean Pests. Master's Thesis, University of Nairobi, Nairobi, Kenya, 2014.
111. Wafula, G.O.; Muthomi, J.W.; Nderitu, J.H.; Chemining'wa, G.N. Efficacy of potassium salts of fatty acids in the management of thrips and whitefly on snap beans. *Sustain. Agric. Res.* **2017**, *6*, 45–54. [CrossRef]
112. Monda, E.O.; Munene, S.; Ndegwa, A. Snap bean production constraints in Kenya. *Afr. Crop Sci. Conf. Proc.* **2003**, *6*, 683–687.
113. Muthomi, J.W.; Kinyungu, T.N.; Nderitu, J.H.; Olubayo, F.M. Spatial arrangement of maize as border crop to manage aphids and aphid-transmitted viruses in potato. *East Afr. Agric. For. J.* **2010**, *76*, 21–29.
114. Muthomi, J.W.; Kinyungu, T.N.; Nderitu, J.H.; Olubayo, F.M. Incidence of aphid-transmitted viruses in farmer-produced seed potato tubers in Kenya. *Afr. J. Hort. Sci.* **2011**, *5*, 18–25. [CrossRef]
115. Nderitu, J.; Mwangi, F.; Nyamasyo, G.; Kasina, A.M. Evaluation of cropping systems as a strategy for managing snap beanflower thrips in Kenya. *Int. J. Sustain. Crop Prod.* **2009**, *4*, 22–25.
116. Waiganjo, M.M.; Muriuki, J.; Mbugua, G.W. Potential of indigenous leafy vegetables as companion crops for pest management of high-value legumes: Acase study of *Gynandropsis gynandra* in Kenya. *Acta Hort (ISHS)* **2007**, *752*, 319–321. [CrossRef]
117. Muthomi, J.W.; Wafula, G.O.; Nderitu, J.H.; Chemining'wa, G.N. Integration of seed dressing, bio-pesticides and intercropping to reduce pesticide use in snap bean production. *Int. J. Agric. Sci. Nat. Resour.* **2018**, *5*, 12–20.