

**PESTICIDE APPLICATORS' KNOWLEDGE, ATTITUDES AND
PRACTICES OF PESTICIDE USE AND EXPOSURE IN FLORICULTURE
FARMS IN NAIVASHA, KENYA**

BY

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DECLARATION

I declare that this is my original work and has not been presented to any university or institution for the award of a degree.

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DEDICATION

I dedicate this study to my wife Esther, daughter Stacey, friends, supervisors and the members of the Department of Epidemiology and Medical Statistics who have helped me morally and professionally throughout my studies.

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I extend my gratitude to Moi University's Department of Epidemiology and Medical Statistics for their help and advice throughout my academic journey. I am grateful to my supervisors, Prof. Diana Menya and Dr. Joseph Sitienei, for their commitment and guidance during all stages of implementing the study.

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ABSTRACT

Introduction: Pesticides are widely used in agriculture to boost yields and reduce pest-related losses. Global pesticide use has doubled since 1990, reaching 3.70 million tonnes in 2022, with Africa's usage rising by 185% over the same period. However, Africa saw a slight decline from 210,000 tonnes in 2021 to 209,000 tonnes in 2022, with most pesticides imported. In Kenya, use peaked at 6,228 tonnes in 2020 before falling to 5,083 in 2022. A study in Naivasha found 141 pesticides in 20 horticultural farms, 4.3% classified by WHO as highly hazardous (Mburu et al., 2013). These statistics highlight that pesticides are still in use, yet their usage poses significant health risks to pesticide applicators working in floriculture farms due to occupational exposure. Despite continued pesticide reliance and health risks for workers, little research explores knowledge, attitudes, and practices (KAP) related to pesticide exposure, particularly in Naivasha's floriculture industry.

Objective: The study aimed to identify pesticide applicators' knowledge of safe pesticide use and the potential health risks associated with exposure in floriculture farms. Secondly, it examined pesticide applicators' attitudes towards pesticide use, safety measures, and their perceived risks in floriculture farms. Thirdly, it evaluated the practices of pesticide applicators regarding protective measures, handling, and application of pesticides in floriculture farms.

Methods: A cross-sectional study conducted in May and June 2014 involving 168 pesticide applicators from floriculture farms in Naivasha, selected using multistage sampling. Data collection involved an interviewer-administered questionnaire. Ethical approval was obtained. Informed consent was secured from all participants prior to data collection. Data were analyzed using statistical methods: knowledge (0–23) was categorized using the Benjamin Bloom's scale, attitudes (0–39) as positive/negative, and risky behaviours (0–26) with scores above 15 indicating higher risk. Descriptive statistics summarized findings, while Mann-Whitney and Kruskal-Wallis tests examined socio-demographic associations ($p < 0.05$). The Kolmogorov-Smirnov test assessed the normality of KAP scores.

Results: All study participants were male, with an average age of 29; most (84.5%) were married, and half had attained post-primary education. Although 60.1% had high knowledge and 75% had positive attitudes toward safe pesticide use, 97.6% participated in risky practices. While higher knowledge ($\chi^2[2] = 14.539, p = 0.001$) and positive attitudes ($U = 3092, p = 0.023$) were significantly associated with reduced risky practices, they were not sufficient alone to ensure safe practices. Instead, the study found that older age ($U = 1676, p < 0.001$), being married ($U = 2731, p < 0.001$), higher educational levels ($U = 2280, p < 0.001$), and increased experience with pesticide usage ($U = 1760.5, p < 0.001$) were also significantly linked to safer behaviour.

Conclusion: Effective pesticide safety requires more than knowledge and positive attitudes. Addressing key demographic factors like age, education, and experience is crucial to reduce risky practices.

Recommendations: To improve pesticide safety in floriculture farms, stakeholders should provide training, raise awareness, and enforce protective measures. Educating pesticide applicators on health risks, promoting responsible attitudes, and ensuring proper equipment use will reduce hazardous exposure.

ABBREVIATIONS AND ACRONYMS

| | |
|-------------|---|
| AOR | Adjusted Odds Ratio |
| CAP | Common Agricultural Policy |
| CI | Confidence Interval |
| FAO | Food and Agriculture Organization |
| HBM | Health Belief Model |
| HHPs | Highly Hazardous Pesticides |
| IPM | Integrated Pest Management |
| IREC | Institutional Research and Ethics Committee |
| KAP | Knowledge, Attitude, and Practice |
| KFC | Kenya Flower Council |
| LNGG | Lake Naivasha Growers Group |
| OP | Organophosphorus |
| PCPB | Pest Control Products Board |
| PPE | Personal Protective Equipment |
| PVC | Polyvinyl Chloride |
| SD | Standard Deviation |
| SPSS | Statistical Package for Social Sciences |
| WHO | World Health Organization |

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CHAPTER ONE

1.0 Introduction

The chapter provides background information on pesticide applicators; their working environment; and potential health effects that may result from being exposed to pesticides. It covers the primary potential exposure routes dermal, inhalation, ingestion and the importance to be aware of these routes in order to minimize risk. The use of personal protective equipment (PPE) is also addressed as a significant strategy to lower exposure risks (gloves, masks, goggles, and protective clothing). The chapter also describes emergency first aid treatment for controlling pesticide exposure where accidents occur, emphasizing emergency measures when personnel accidentally come in contact with or are poisoned by pesticides. It ends with a problem statement, rationale for conducting the study, and outlines the study objectives.

1.1 Background

Pesticides are extensively used globally for various purposes, mainly as a control measure in public health programs and in agriculture (Tudi *et al.*, 2021). For public health, they are critical for the regulation of disease-carrying vectors (e.g. mosquitoes transmitting malaria, dengue, and other vector-borne diseases). Pesticides are indispensable in agriculture and forestry to boost food security and ensure the supply of forest products by controlling pests and avoiding damage of forest resources.

Pesticides are classified by the World Health Organization (WHO) according to the degree of hazard to human health. Pesticides of class Ia and class Ib are highly and extremely toxic, respectively. Both are extremely poisonous and require regulations on how they are handled and used. Class II pesticides are lower-hazardous pesticides but

still should be used with caution. Class III pesticides are low risk products, which can be used with minimal risk if used as directed. Finally, class IV comprises pesticides deemed to be relatively low-hazardous to humans (WHO, 2020b).

Global trends in pesticide use and trade

According to the Food and Agriculture Organization (FAO), some 3.70 million tonnes of pesticides were used by farmers globally in 2022 (FAO, 2024). This was 4% more than the previous year, 13% more than ten years ago, and twice the figure in 1990. The rise is a troubling reminder of how heavily agriculture still depends on pesticides to protect crops — and even more so as populations rise and climate conditions worsen. The volume of pesticides that were traded between countries was not greatly different in 2022, about 6.9 million tonnes of active ingredient in ready-to-use products (down 1% compared with 2021). But even as less by volume was traded, the value of pesticide exports overall grew by 13% to \$48.8 billion. These probably would have translated into higher prices over time, maybe because new products are more expensive, or the costs of production are higher. Looking at the longer range, 2013 to 2022, the amount of pesticide exports increased 50% and the value 53%. (FAO, 2024).

The use of pesticides has had significant variation over the past decades following changes in the agriculture pattern, high crop production, and pest control. The average pesticide used per cropland area was 2.38kg/ha in 2022 (FAO, 2024). This reflects a 3% increase from 2015, thus confirming the steady upward trend in chemical application to agricultural environments. Expressed relative to the value of agriculture, total pesticide use amounted to 0.90 kilograms per thousand international dollars (2% higher than the 2021 measurement). This modest increase suggests only a slight rise in

chemical input intensity relative to the additional value generated by the sector (FAO, 2024). The use of pesticides per person also rose by 2 per cent to 0.46kg per person. These figures highlight the complex interplay of population growth, consumer demand, and evolving agricultural practices and its reliance on pesticides.

When we examine pesticide trends from the long run perspective, since 1990, greater numbers of pesticides per hectare cropland are applied by an increase of 94% – input intensity has raised enormously almost definitely due to drive to raise even more yields, as well as of emerging pest pressure. The increase in pesticide use, however, relative to production value has been more modest at 5%, suggesting either productivity improvements or increased use of different types of crops (FAO, 2024).. The surge on a per capita basis is now 35 per cent – a telling sign of how growing global food demand and shifting diets have driven up the need for chemicals. These numbers highlight the delicate balance that hangs from the wire of boosting food security while grappling with pesticide-related environmental and health issues.

Regional trends in pesticide use

The Americas have the highest pesticide use and importation

Across different regions, pesticide use has varied significantly over time, owing to varying farming methods, crops, and regulation, as well as differing levels of economic development (FAO, 2024). Since the mid-1990s, the Americas have been using more pesticides than any other region in the world, predominantly due to large-scale industrial farming and dependence on chemical pest control. In 2021, the region used 1.71 million tonnes of pesticides—10% more than the year before—and this rose to 1.89 million tonnes in 2022 (FAO, 2024). This reflects ongoing dependence on

pesticides, especially for crops like soybeans, maize, and cotton in countries like Brazil, Argentina, and the United States.

The Americas are also the largest importers of pesticides, bringing in 1.2 million tonnes of formulated products in 2022, worth around \$10.8 billion (FAO, 2024). This highlights both the region's large-scale farming and its reliance on chemicals to protect crops and maintain agricultural value. The intensity of pesticide use per unit of land, agricultural production, and population was the highest in 2022. The average pesticide use was 3.06 kg/ha cropland, exceeding the world average. The same area used 1.51 kgs of pesticide for every \$1,000 of farm produce and 1.23 kg/ha, one of the highest rates in the world (FAO, 2024).

These numbers reflect the scale and intensity of farming in the region, which depends heavily on agrochemicals to manage pests and diseases. While this has boosted crop yields and exports, it has also raised serious concerns. Environmental problems like soil and water pollution, growing pest resistance, and health risks for farm workers and nearby communities are becoming more recognized. As a result, scientists, regulators, and advocacy groups are calling for stricter controls and more sustainable farming practices (FAO, 2024).

Asia a leading exporter but a moderate user of pesticides

In Asia, pesticide consumption reached 1.05 million tonnes in 2022, reflecting a slight 1% decline from the previous year. But even with this slight drop the trend over the decades is clearly one of steep increase – 76% more than in 1990 – reflecting the increased dependence on chemicals in crop protection in the region (FAO, 2024). The same year, Asia became the world's largest exporter of pesticides, sending out 3.5

million tonnes, worth \$21.7 billion in exports. Of these exports, 2.3 million tonnes, valued at \$15.3 billion, were traded with countries outside the region, illustrating Asia's leading position in the worldwide pesticide market and its close entanglement in international agricultural supply chains.

Nevertheless, pesticide use intensity in Asia continued to be low compared to global averages. The region used 1.60 kilograms of pesticides for each hectare of cropland, below the international average. Likewise, when normalized by agricultural output, Asia consumed 0.61 kilograms per 1,000 international dollars of agricultural production, and merely 0.22 kilograms per person "per capita". These lower levels of use may be due to more extensive, as opposed to intensive, agriculture in some countries, differences in climatic zones leading to differences in pest pressure or to different regulatory practices across the region (FAO, 2024).

Europe is declining in pesticide use and has strong regulations

Europe experienced a decline in agricultural pesticide use, dropping from 513,000 tonnes in 2021 to 480,000 tonnes in 2022, a 7% reduction (FAO, 2024). This current decline is a continuation of a longer-term trend; the region has reduced pesticide applications by 5% since 1990 and 7% since 2008. These decreases are a product of policy, market and behavioural changes that have occurred in European agricultural systems.

The decline in agricultural pesticide use in the region is in part due to the influence of the European Union's Common Agricultural Policy (CAP) (European Commission, 2025), which contains some of the world's most stringent pesticide legislation. These rules involve restrictions concerning certain active substances, compulsory integrated

pest management measures and support for environmentally friendly farming. One outcome of this set of policies that shaped the policy environment for pesticides for several decades is the decreasing use of insecticides, which in 2022 represented only 13 per cent of the total pesticide use in Europe, a proportion that was far less than in many other regions (FAO, 2024).

Consumer tastes also have been influential in determining how pesticides are used. The increasing demand for organic fruits & vegetables and foods with minimum pesticide residue have encouraged the farmers to opt for substitute for pest control and lower down the use of chemicals. Retailers and supply chains have reacted with increasingly stricter sourcing requirements also strengthening the push towards the use of less pesticides (FAO, 2024).

Despite the relatively low application rates (1.66 kilograms of pesticides per hectare in 2022), Europe has continued to be a big player in the global pesticide market, notably as an importer. A large part of this trade took place inside Europe, showing the presence of high intra-regional flows due to specialized production and distribution networks (FAO, 2024). This highlights the heterogeneity that characterizes agricultural input markets in Europe, despite its domestic use of pesticides having decreased, the continent still plays a significant part in the global flow of pesticides.

Oceania has low intensity but high per capita pesticide application

In Oceania, pesticide use remained stable between 2021 and 2022 at 67,000 tonnes, though overall consumption nearly tripled since 1990 (FAO, 2024). Although annual changes have been small over recent years, the overall trend is of a striking rise: total pesticide use in the region had almost tripled over thirty years, largely reflecting

changes in agriculture and the demand for crop protection (FAO, 2024). This increase could be associated with more intensified farming systems, more cropland, and more pest pressures in some regions, influenced by a changing climate and invasive species.

Trade in pesticides in Oceania was low in absolute terms and was largely limited to exchanges between neighbouring countries (e.g. between Australia and New Zealand) (FAO, 2024). In 2022, the total amount of pesticide imports reached 346,000 tonnes with an estimated market value was \$2 billion. Significantly, 70 per cent of pesticide exports were sold within the region, highlighting the oligopoly and self-containment of the agricultural input markets of Oceania and its dependence on intra-regional supply lines.

Notwithstanding the increasing use in general, application rates are low on a land use or commodity output basis in Oceania. In 2022, the region used, on average, 1.65 kilograms of pesticide for each hectare of cropland, just below the world mean, and 0.83 kilograms for every 1,000 international dollars of agricultural production (FAO, 2024). These numbers indicate that pesticides were used with relatively low intensity from the point of view of production efficiency.

But Oceania does have one of the highest rates of pesticide use per capita in the world, at 1.29 kilograms per person (FAO, 2024). This number is a result of both the relatively small population base in the region and the per capita, and the large area of commercial agriculture, with much of it in Australia and New Zealand, and much of the application of pesticides going to the high-output, export-oriented sectors of the economy, including grains, horticulture and viticulture. One interpretation of the high per- capita

usage is that farming requires relatively fewer labour inputs and more chemical inputs, compared to other labour-intensive means.

Africa has low consumption of pesticides on global scale but experience rapid growth over time

Africa had the lowest pesticide usage levels among all regions. Between 2021 and 2022, agricultural pesticide consumption decreased slightly from 210,000 tonnes to 209,000 tonnes (FAO, 2024). Despite this temporary drop, the long-term trend is that use of pesticides is swiftly rising. Africa's pesticide use grew 26% over the past decade, and by 185% between 1990 and 2022 in volume terms. However, despite this, between 2013 and 2022, Africa was responsible for only 5% of the world's overall pesticide consumption, indicating that the use of pesticides in the region is relatively low, on a global scale (FAO, 2024).

Despite such large-scale pesticide consumption, Africa depends on importation to sustain its agricultural requirement. The continent imported around 754,000 tonnes of pesticides in 2022, and 710,000 tonnes of these pesticides – nearly 94% – were imported from outside the continent (FAO, 2024). These imports were worth some \$3.6 billion in what was a large financial commitment for agricultural inputs. By contrast, exports of pesticides from Africa were marginal. In 2022 only about 12 000 tonnes of pesticides were exported from the continent, worth \$75 million, with most of the exports being traded regionally rather than internationally. On the other side of the coin, Africa experienced a reduction in the export volumes of pesticides by 19% and an 11% decline in imports in 2021. These changes may indicate the beginning of a trend of

increased domestic production of pesticides, but further evidence will be required to substantiate such a trend (FAO, 2024).

Application rates are also the lowest in the world in Africa (FAO, 2024). The continent used 0.45 kilograms of pesticides per hectare of agricultural land — far less than any other region. The continent had the lowest pesticide application rates per hectare (0.45 kg/ha), per unit of agricultural output (0.43 kg/1,000 international dollars), and per capita (0.11 kg). These numbers highlight the fact that Africa does not use pesticides in line with its population, land area, and agricultural output, and they could result from various causes (liberal access to agricultural inputs, economic pressure, contrasting farming techniques and policy regulations) (FAO, 2024).

Leading countries in pesticide consumption globally

Of the individual countries, Brazil was the world's largest user of pesticides applying some 801,000 tonnes to agriculture in 2022 (FAO, 2024). This overwhelming figure showcases Brazil's heavy agricultural activity: large-scale production of soybeans, sugarcane, and corn, the biggest contributors to the country's export economy. Brazil's use of pesticides was more than 70 percent higher than that of the United States, the country with the second-largest volume, at 468,000 tonnes (FAO, 2024). Even with the increasing technological sophistication of U.S. agriculture, the U.S. applied much lower quantities, a disparity reflecting crop composition differences, regulatory context and Integrated Pest Management (IPM) practices.

Other top pesticide consumers were Indonesia (295,000 tonnes), Argentina (263,000 tonnes), and China (236,000 tonnes) — all of which depend significantly on agricultural sector as a main industry (FAO, 2024). In these countries, the high demand for

pesticides is associated to extensive staple and cash crops production like rice, oil palm and wheat. For example, Indonesia has the large extent of oil palm plantations which might account for the high consumption and Argentina has high soybean and maize (corn) production which may influence consumption.

Further down the list, Vietnam used 162,000 tonnes, again reflecting its densely planted rice-growing areas with a high prevalence of pest pressure. Canada and Russia came next, at 98,000 tonnes and 97,000 tonnes, respectively (FAO, 2024). These countries possess vast agricultural land but experience extreme cold leading to a possibly of fewer pests than tropical regions. Rounding out the top ten were Colombia (78,000 tonnes) and France (69,000 tonnes) (FAO, 2024), demonstrating how systemic pesticide dependence remains the norm even within countries with strict controls on environmental and health safeguards, and burgeoning consumer demand for sustainably produced food.

Use of pesticides in Kenya

In Kenya, chemical pesticides are the main mode of pest, plant disease and weed control in the agriculture sector which has become increasingly acute in the last decade (Route to Food Initiative, 2019). That this practice has intensified further into the 21st century indicates both the urgency of meeting global agricultural demands and the daunting task of defending crops from various threats faced by farmers. FAO reports that pesticide consumption increased drastically in Kenya from 2,758 tonnes in 2010 rising to its highest ever figure of pesticide consumption in 2019 with 6,587 tonnes, before dropping to 6,228 tonnes in 2020, 5,465 tonnes in 2021, and 5,083 tonnes in 2022 (FAO, 2025). This decrease might indicate a change in the trend, but the trend remains

notably high, casting doubt on the sustainability and even the safety of the current pest control practices.

Alarmingly, 76% of the pesticides applied in Kenya contain active ingredients classified as Highly Hazardous Pesticides (HHPs), representing acute or chronic risk to health or environment (Atlas, 2022). These have a potential of causing cancer and endocrine disruption or reproductive toxicity, as well as resistance to consistently degrading and accumulating in the environment. More concerning however is that over 44% of pesticides currently used within Kenya are banned in the European Union for being too dangerous but are cheap, readily available, and often heavily used in Kenyan agriculture (Atlas, 2022). This loophole is a gaping failure in supervision and a potential menace to farmers, consumers and the environment.

This risk to health and environment from the use of pesticides is also worsened by poor monitoring and regulation in Kenya (Atlas, 2022). There is no central or general government surveillance for residue levels of pesticides in food crops, and no understanding about what amounts of toxic residues consumers are taking in their meals. Furthermore, there are little, if any, available statistics on the environmental damages of using pesticides like the degradation of the soil, water pollution, loss of useful insects and of biodiversity. This information deficit can constrain evidence-based policies, but it also places risk management in a poor position.

With these facts in mind, there can be no better time for Kenya to adopt safer, more sustainable methods for pest control (including IPM, agroecology and non-chemical options) (Atlas, 2022). They emphasize prevention, environmental health, and in reducing the requirement for hazardous inputs. On the other hand, strengthening

national pesticide regulatory systems (and associated residue monitoring, environmental surveillance and public knowledge) is a condition for the sustained safety of food systems and farming communities and ecosystems in the medium and long-term. Should decisive action not be taken, reliance on dangerous chemicals will persist, which is likely to damage agricultural productivity as well as public health (Atlas, 2022).

In Naivasha, a region in Kenya's Rift Valley that is famous for its high levels of agricultural activity, pesticide application is particularly high within the horticultural sector. The region, enjoying favourable weather condition and water supply from Lake Naivasha, has become a major hotspot for large-scale agriculture. A study conducted in the area found a total of 141 pesticide active ingredients were in use in a sample of 20 farms, highlighting the extent of chemical use in the area's agricultural work (Mburu *et al.*, 2013). More alarmingly, six out of these pesticides—accounting for 4.3% of the pesticides—were categorized by the WHO as Class I pesticides, the most dangerous classification of pesticides which is characterized by acute toxicity (Mburu *et al.*, 2013).

These data not only point to grave concerns about environmental pollution, biodiversity decline and high health risks for the farm workers but also the surrounding communities.

This use of active substances has been amply documented to be hazardous. Farm workers, especially those who receive applications of these chemicals and anyone who works in sprayed fields soon after spraying, experience an increased risk of both acute and chronic health conditions, from skin and respiratory ailments to lasting neurological and reproductive effects (Kalyabina *et al.*, 2021). The situation becomes

even more worrying in areas in which prohibited compounds are actively used, or where the treatment of pesticides is not appropriate. Farm workers and smallholder farmers in many cases may not have the protective equipment or knowledge about the health consequences of pesticide exposure, making them even more vulnerable (Calista *et al.*, 2022).

In the Kenya's highly expanding horticultural industry, floriculture—in particular the production of cut flowers for export—has become a very important and dynamic sub-sector. The horticultural sector earned the country a total of KShs 154 billion (about \$US1.18 billion) in 2021, floriculture contributing KShs 110 billion (about \$US 0.84 billion), a staggering 71% of the total horticultural export earnings (Kenya News Agency, 2023). These statistics emphasize the importance of the industry to the Kenyan economy both in terms of foreign exchange returns and employment creation.

Into the recent past, Kenya has excelled in the flower market. In the first quarter of 2023, it had already earned the country 128 million USD from cut flower export alone making it one the leading flower exporting countries in the world (Kenya Flower Council, 2024). This success is based on growing a rich variety of ornamental crops such as roses, carnations, Alstroemeria, Gypsophila, lilies, Arabicum, Hypericum and statice, much of which is cultivated in greenhouses in the Naivasha basin. Floriculture is also a major employer, providing some 200,000 direct jobs to a mix of skilled and unskilled labour, with most workers living in rural areas. However, the employment in the sector which is essential for the welfare of many families comes with occupational risks, including exposure to pesticides (Kenya Flower Council, 2024).

Based on the demand of international markets for high aesthetic and phytosanitary standards, the floriculture industry has one of the highest application rates of pesticides compared to other agricultural activities. Ornamental plants – in particular cut flowers – are much more heavily managed for pests and diseases as compared to staple crops such as maize or wheat, and therefore chemical use per hectare is higher (Lan *et al.*, 2022; Pereira *et al.*, 2021; Yin *et al.*, 2023). Although these practices improve flower quality and market position, they have severe implications for human health. The level of health risk from pesticide applications will depend mainly on the type and amount of chemicals used, frequency of application and the access to protection and knowledge of farmworkers participating in the pesticide use process (Kaur *et al.*, 2024; Tudi *et al.*, 2022).

1.1.1 Pesticide applicators

Pesticide applicators are individuals who are responsible for spraying or applying the chemicals to control the pests, weeds and diseases in agricultural fields (Damalas & Koutroubas, 2016). They are generally responsible for the supervision and actual application of pesticide products and are integral to the farm labour force. However, these professionals are often subject to multiple occupational hazards related to the use of pesticides, which contribute to the maintenance and development of crop production (Moreira & da Silva, 2023).

Pesticide exposure can come in the form of breathing it in, absorbing it through the skin, or ingesting it accidentally, and the greatest risk is during the mixing, loading and applying practices. When pesticide applicators operate in conditions that lack safety features or in a poor infrastructure, potential risks would significantly be increased

(Moreira & da Silva, 2023). One such high-risk context is the greenhouse—inside an environment with controlled growing conditions but with poor ventilation. In this restricted space the concentration of the pesticide aerosol can be reached at a high level at the very beginning, and due to the limited ventilation, the risk for its inhalation and longer exposure is augmented. Applicators who work in greenhouses are at increased risk of acute and chronic health effects, particularly those without appropriate personal protective equipment and thoroughly installed ventilation systems.

As a result, pesticide applicators, particularly greenhouse applicators, need to be provided with protective measures of their occupational health (Moreira & da Silva, 2023). Such measures include access to personal protective equipment, routine health surveillance, and organizational measures that guarantee safe handling. Risks need to be understood and managed for the sake of their own health and the continued safety of the environment in which pesticides are used.

1.1.2 Pesticide Exposure

Pesticide exposure, as described by the WHO, is contact with chemical substances used for agricultural purposes (WHO, 2020a). Such exposure can happen at multiple points during the pesticide lifespan — when mixing and loading chemicals, applying or spraying chemicals, cleaning and repairing equipment, during spill clean-up and disposal of excess chemicals or containers, upon re-entering recently treated areas, and with sale, transportation and storage of chemicals. Such exposures, especially in the workplace, can represent substantial risks to health due to a lack of compliance with safety measures among workers exposed to pesticides (Tessema *et al.*, 2022; WHO, 2020a).

But pesticide hazards aren't just for those who handle them directly. Local residents who live near farming fields or industrial facilities that use, or store pesticides can also be significantly exposed to pesticides via environmental drift or polluting of air, soil, and water (Dereumeaux *et al.*, 2020; Friedman *et al.*, 2020). Pesticides are notoriously recalcitrant; they typically endure long retention in the environment, which raises prolonged threats to public health beyond the period of their use (Kalyabina *et al.*, 2021).

Misuse of pesticides increases the probability of exposure dramatically. These include non-compliance with manufacturer recommendations, absence or suboptimal use of PPE, and poor hygiene, as underscored by poor implementation of basic hygiene procedures—such as hand washing before meals and after pesticide applications—that reduce exposure risks (Alebachew *et al.*, 2023). In addition, pesticides may leach into groundwater, or they can run off into rivers and lakes, leading to environmental pollution and eventually passing through the human food chain. The contaminated water and food supplies pose risks to human health, especially among vulnerable groups.

Pesticide exposure can be broadly classified into two main classes: intentional and unintentional (Davies *et al.*, 2023). Intentional exposure constitutes quite often purposeful exposure, when someone intentionally ingests food or drink containing the pesticide, breathes in contaminated air, or takes a self-poisoning dose for suicidal or homicidal purposes. Unintentional exposure, in contrast, is exposure to pesticides that occurs that is not on purpose. This exposure scenario occurs in both occupational group

– like agricultural workers - and general populations, through residues on food or contaminated environments (WHO, 2019).

The data on pesticide poisoning are appalling. Globally intentional poisoning accounts for two-thirds while unintentional exposure for the remaining one-third of acute pesticide poisonings. Unintentional poisoning with pesticides accounts for an estimated 355, 000 fatalities per year globally, underscoring the scale of the public health problem (Anjala, 2017). For instance, in Kenya, unintentional poisoning led to a mortality rate of 24 per 100,000 individuals in 2019 (WHO, 2023).

Although developing countries contribute only about 20% of the world's pesticide consumption, their population suffers most from pesticide-induced health effects. Over 95% of all cases of acute pesticide poisoning are in farmers in these nations (Boedeker *et al.*, 2020). This difference highlights the shortcomings in pesticide legislation, occupational health and safety, public awareness, and health care infrastructure in low- and middle-income areas, where farmers and rural populations bear the brunt of the health impacts associated with pesticide exposure.

1.1.3 Routes of Pesticide Exposure

There are three primary routes of human exposure to pesticides which are dermal (skin contact), inhalation (breathing) and ingestion (swallowing) (Kalyabina *et al.*, 2021; Tudi *et al.*, 2022; WHO, 2020a). Of these, the dermal route of exposure is the most common, especially for workers in agriculture as well as pest control (Lari *et al.*, 2022). The skin can be a barrier and also a portal for pesticides to enter the body; and certain conditions such as skin cuts, abrasions, and sweating can also greatly enhance the rate of pesticide absorption. Workers that mix or prepare pesticides, especially if they are in

the form of concentrates, are at higher risk. That is because the concentration of active substances of the mixtures is rather high, raising the potential of toxic exposure (Kalyabina *et al.*, 2021). Furthermore, pesticide compositions which are acidic or caustic can cause skin irritations or burns, still further jeopardizing the integrity of the skin and providing access of toxic substances to deeper tissue.

Another significant exposure pathway for pesticides is through inhalation. It happens when pesticide grains, dust, small droplets, mists, or vapours blow into and are inhaled into the lungs. The risk of inhalation depends on the type of pesticide application. There is usually a low risk for this in low-pressure uses, since such droplets are too large to hang in the air for long and the aerosol cloud produced is quickly diluted. By contrast, high-pressure spraying, ultra-low volume and fogging applications generate droplets that are much finer and can remain in the air for a considerable length of time, greatly increasing the potential for respiratory exposure (Kalyabina *et al.*, 2021). The risk is even greater in confined or poorly ventilated spaces, like greenhouses or storage sheds, where airborne pesticides can build up to dangerous levels. Those working in these workplaces can be exposed for extended periods, resulting in acute or chronic health effects depending on the pesticide's toxicity.

Ingestion is among the least common of all means of exposure to pesticides but is considered the most lethal. It is often unintentional, with stored pesticides in unlabelled or incorrectly labelled containers, such as bottles or beverage containers, which are accidentally ingested. Occupational exposure may also lead to ingestion when workers eat, drink or smoke without cleaning their hands handling pesticides (Tudi *et al.*, 2022). The digestive tract is a highly efficient organ in the absorption of

chemicals, and even small quantities of ingested pesticides can result in serious toxic effects. Foodborne ingestion is a key public health concern alongside occupational exposure. Pesticides are regularly used in farming to safeguard crops against pests and disease but the residue is frequently left behind on the skin of fruits, vegetables, and other produce. For instance, residue analysis has revealed the presence of pesticide residues in commonly consumed crops such as tomatoes, kales, and French beans in Kenya (Marete *et al.*, 2020). Repeated consumption of such residues, particularly when regulation, monitoring and public information are ineffective can also be a long-term risk for health, including developmental, endocrine, neurological, or cancerogenic (cancer) effects.

1.1.4 Personal Protective Equipment (PPE)

Proper use of PPE is crucial for adequate protection against occupational exposure to contaminants, and particularly pesticides. PPE is particularly important for workers who are engaged in the application, the mixing, and the equipment cleaning activity, as the work activity involves a high possibility of dermal, respiratory, and ocular contact. Correct PPE usage is a very effective way to prevent acute poisoning and long-term health effects, such as respiratory issues, skin conditions, and even a few cancers caused by extended pesticide exposure (Garrigou *et al.*, 2020; Lari *et al.*, 2023).

Everyone involved in the handling of pesticides should have the appropriate PPE for the specific type of pesticide and for the task at hand. This is a responsibility that is squarely with the employer, who must ensure that PPE is available and kept clean and functional. No one should reuse contaminated PPE until it has been properly cleaned (Garrigou *et al.*, 2020; Lari *et al.*, 2023). Employers must accordingly adopt and

implement policies and procedures to safely store, clean, and replace used protective equipment. Workers should also be afforded the availability of spare outer protective clothing to minimize contact time with contaminated material, and in general, should be provided with at least one change of such clothing (Garrigou *et al.*, 2020; Lari *et al.*, 2023).

Employers should also provide changing rooms in the workplace to further promote proper hygiene and reduce the risk of cross-contamination. These should be the changing rooms with secure storage for clean clothes and contaminated work clothes. These would help in separating the clean clothes from the contaminated ones, thereby preventing cross-contamination and the overall sanitary environment (Garrigou *et al.*, 2020; Lari *et al.*, 2023).

PPE for pesticide-related tasks are diverse and consists of a number of essential items: nonpermeable gloves, rubber or PVC footwear, full-body coveralls, protective hoods or hats to protect overhead exposure, nonpermeable aprons, respirators that are specific for the formulation of the pesticide being handled, and eye protection that encompasses goggles, face shields, or safety glasses with side and brow guards. Material composition of PPE is also essential, since it should be impervious to chemicals applied in the process. These can be made of materials such as barrier laminate, polyvinyl chloride (PVC), neoprene, nitrile, and durable rubbers (Sureka *et al.*, 2021).

Correct donning and doffing are important to avoid self-contamination. For instance, gloves and boots should be washed before removal to prevent any pesticide residue from transferring to skin. PPE worn should be laundered separately from personal or family clothing and stored separately. Even in sweltering conditions, which can

contribute to discomfort while wearing PPE, continuous use is mandatory to safeguard health (Garrigou *et al.*, 2020).

Special attention should be given to wearing PPE appropriately for specific tasks. For instance, gloves must extend above the wrist to be effective. When spraying pesticides near the ground, sleeves should go over the gloves to prevent chemicals from dripping into them. Conversely, when spraying overhead (e.g., tree spraying or using boom sprayers), sleeves should be tucked into the gloves to avoid exposure (Garrigou *et al.*, 2020). Thick chemical-resistant aprons offer an added layer of defense, particularly for the chest and legs during high-risk tasks like loading, mixing, or cleaning, where splashing is more common.

Despite the proven effectiveness of PPE in preventing pesticide exposure, cost remains a significant barrier to their universal use. High-quality, chemical-resistant gear is often unaffordable, especially for smallholder farms or low-income agricultural operations. This financial pressure may lead to the unavailability of PPE or use of ineffective alternatives. Concerted efforts should be deployed to address this, such as subsidies for PPE, enforcing safety regulations, and the promotion of locally produced and affordable protective gear, to ensure the safety of workers is not compromised due to financial limitations (Garrigou *et al.*, 2020).

1.1.5 Emergency First Aid

Most pesticide labels have a specific section on emergency first aid. This is an important section that all pesticide users must familiarize themselves with before handling pesticides. Being well-versed with these instructions can mean the difference between a minor incident and a life-threatening emergency.

Sites at which pesticides are stored, used, or applied should have prearranged procedures established to deal with exposures that occur inadvertently. Minimum standards for such conditions include provision of basic personal hygiene items, such as soap, clean towels, changing attire, and an adequate supply of potable water. These are essential resources for decontamination and can prevent serious health outcomes to individuals that may accidentally get exposed to pesticides (Pandiyan *et al.*, 2023).

One should take immediate action when in contact with pesticides via skin or from contaminated clothing. Contaminated garments should be taken off immediately to minimize the risk of prolonged skin exposure. After pesticide exposure, the parts of the body that came in contact with the chemical should be thoroughly washed with large quantities of soap and water to take off pesticide residues. WHO recommends prompt and thorough washing following dermal exposure, to mitigate its resulting toxic effects (WHO, 2020a).

Inhalation of pesticide fumes or aerosols also constitutes a medical emergency. If an individual breathes in pesticide vapors, they should be moved immediately to an area with fresh air. Ensuring proper ventilation and avoiding further exposure are critical steps. The affected person should be encouraged to sit down and breathe normally, and medical assistance should be sought as soon as possible, particularly if symptoms such as dizziness, difficulty breathing, or nausea are present (WHO, 2020a).

If a person ingests a pesticide, they must follow the instructions in the first aid section on the product label. Some labels may advise inducing vomiting, while others may explicitly warn against it. This distinction is critical especially with corrosive substances since vomiting can cause additional harm by re-exposing the throat and

mouth to the poison. Misinterpreting these instructions can result in serious internal injury or increased toxicity (WHO, 2020a).

With proper planning and by carefully following first aid instructions on pesticide labels, users can reduce the risk of injury or adverse reactions. Cost-effective training and the availability of safety materials are key components of responsible pesticide use and occupational safety.

1.1.6 Regulatory framework for pesticide use and handling in Kenya

In Kenya the law enforcement authority responsible for regulation of pesticide registration and control is the Pest Control Products Board (PCPB), established under the Pest Control Products Act (Cap 346) (The National Council for Law Reporting, 2023). The PCPB is the national agency that registers, regulates and controls the quality of pesticides to ensure that they are safe, efficient, and of high quality for user, consumer and environment before they are made available for sale or used in agriculture, public health or in the home.

Central to this regulatory scheme is the requirement that all pesticides be registered. This procedure consists of the thorough chemical composition, use, and environmental and human health risk assessment of the product. The Kenyan government has listed which products have been given the go-ahead as a criterion for safety and efficacy in place for which products can be used in Kenya (PCPB, 2023). Rigorous labelling regulations require users to have access to important information such as safe handling practices, application procedures, dose, and first-aid in case of an accident.

Individuals who apply, distribute, or commercially use pesticides are required to have special licenses and/or certifications. This is to ensure that only qualified and experienced individuals handle these dangerous materials. Furthermore, pesticide applicators are required to participate in training programs that are specifically designed to ensure they possess the necessary knowledge and abilities to handle such chemicals safely and properly. These programs focus on pesticide storage, environmental considerations, PPE use, and how to dispose of pesticide containers (PCPB, 2023).

The controlling legislation also encompasses active and passive methods for protecting human health and the environment. These measures range from "no-spray" buffer zones around particular sensitive locations, such as in or near water, near schools, or in residential areas, in which pesticide use is restricted or disallowed. And such confinements minimize the chance of pesticide drift and environmental pollution (PCPB, 2023).

Pesticide users are also obliged to keep complete records of the category of pesticide, the amount applied, the dates applied, and the pests targeted. These logs provide traceability and accountability and are useful for regulatory audits. The PCPB, along with other regulatory bodies responds to disasters – usually twice annually – to check all installations are compliant with safety and operational guidelines (PCPB, 2023). Violation may subject the violator to arrest and to the penalties provided by law.

Kenya's policy conforms with global trends that promote sustainable agriculture, and in particular, supporting IPM practices. Through outreach, education, and policy enforcement the PCPB promotes the use of IPM programs which reduce the need to

use chemical pesticides and instead rely on nonchemical pest population management and control techniques, including pest eradication, pest exclusion, host eradication, cultural practices, biological control, host resistance, or other ecologically based pest management (PCPB, 2023).

The system of pesticide regulation in Kenya aims to achieve a balance between the requirement for effective pest control and the need to safeguard human health, and the environment and encourage the adoption of sustainable agricultural practices.

1.2 Problem statement

Occupational pesticide exposure remains a significant and intricate challenge to public health, particularly in low- and middle-income countries with limited regulatory and worker protection programs and public awareness (Ali, 2024; Desye *et al.*, 2024). The agricultural industry is considered one of the hubs of such exposures, while a wide spectrum of studies has documented various health hazards among farmworkers, including acute poisonings and chronic, long-term health effects such as neurological disorders, disruption in endocrine systems, and cancers. Workers in the floriculture industry represent a particularly vulnerable group within this high-risk landscape because their work involves intensive and frequent contact with a complex mixture of hazardous chemical agents.

This is particularly the case in Kenya. Floriculture is an important sector of the economy, especially in Naivasha, a region that is a centre of cut-flower production for export markets. Pesticides are typically used more in this sub-sector to ensure high flower quality and quantity. Application rates in floriculture are among the highest in

agriculture since ornamental plants are managed far more intensively than staple food crops.

Alarming, a large number of the pesticides used in Naivasha are Highly Hazardous Pesticides. A study by Mburu et al. (2013) identified 141 different active ingredients used in local farms, with 4.3% falling into WHO Class Ia/Ib, which can be categorized as extremely and highly hazardous, and 14.3% into Class II, which is moderately hazardous (Mburu *et al.*, 2013). Even more worrying is that more than 44% of the pesticides used in Kenya are banned in the European Union due to their proven dangers yet remain widely available in the local market. The documented health effects of exposure to such chemicals are serious and well-established in the growing scientific literature, including interference with the nervous and endocrine systems (Fagundes et al., 2023), birth defects (Jain et al., 2023), and carcinogenesis (Cavalier et al., 2023).

Yet, there is a critical and dangerous disconnect between what is known about the toxicity of these chemicals and an understanding of the human factors governing their use. In spite of the clear and present danger and this expanding industry, there is a substantial evidence gap regarding the Knowledge, Attitudes, and Practices (KAP) of pesticide applicators themselves-the frontline workers who are at greatest risk of daily, direct exposure. This is the core of the problem, which manifests in three critical ways:

First, there is an unquantified risk perception. Although the objective hazard of the chemicals is known, the subjective understanding of the applicators is not. It is not known whether they have sufficient knowledge regarding the particular health hazards of the pesticides they work with, understand the principal routes of exposure, namely dermal, inhalation, and ingestion, or are able to correctly identify the early symptoms

of both acute and chronic poisoning. The first link in this chain of possible unsafe behaviour is constituted by a knowledge deficit.

Second, this leads to potentially unsafe practices in a high-risk setting. In the floriculture environment, especially in the case of enclosed greenhouses with poor ventilation, pesticide aerosols can concentrate and greatly increase inhalation exposures. Without specific data regarding existing practices-such as frequency and appropriateness of PPE use, observance of re-entry intervals, hygiene after applications such as immediate bathing, and safe mixing, loading, and equipment cleaning-it is not possible to develop safety interventions that are effective, focused, and culturally appropriate. Specific risky behaviours, like eating without washing one's hands or blowing clogged nozzles with the mouth, may be common but have not been quantified.

Thirdly, such lack of data works as a severe impediment to effective policy and training. Evidence-based risk communication strategy formulation and appropriate safety training programs and impactful occupational health policies for the floriculture industry are critically hampered by the absence of localized KAP data. Policymakers and farm managers are left to operate on assumptions rather than evidence to develop generic interventions which may be unable to address the specific misconceptions, attitudinal barriers, and practical challenges faced by Naivasha's workforce.

While KAP studies are internationally recognized as important tools in the design of public health interventions and have successfully been applied in a number of agricultural contexts elsewhere (Abaineh *et al.*, 2023; Bhandari *et al.*, 2023; Monger *et al.*, 2023; Pandiyan *et al.*, 2023; Shahidullah *et al.*, 2023), this approach has been critically underutilized in the floriculture context of Kenya. Pesticide applicators in

Naivasha are thus operating in an objectively high-risk environment without the scientific evidence necessary to either guide or justify protective measures.

It is, therefore, important that this study be done to systematically assess the knowledge, attitudes, and practices of pesticide applicators in Naivasha floriculture farms. By investigating perceptions, beliefs, and behaviours, this study shall yield a very important evidence base. The findings will position stakeholders—including policymakers, industry representatives, public health professionals, and advocacy organizations beyond assumption to design tailored, effective, and sustainable interventions. The ultimate aim is to narrow the gap between known hazard and practical safety in order to improve occupational health, maintain the well-being of workers, and ensure long-term sustainability of this important economic sector.

1.3 Justification

Conducting a KAP study on pesticide exposure among pesticide applicators in floriculture farms is crucial due to the associated health risks. It has been shown across several studies that individuals involved in pesticides related work have an increased likelihood of suffering a variety of negative health effects, including respiratory, dermal, neurological and long term chronic diseases, when compared to those with no such exposure (de-Assis *et al.*, 2020; Negatu *et al.*, 2017; Pinto *et al.*, 2020). For instance, a study from Naivasha—a major floriculture hub of the Kenyan floriculture industry showed that flower farmworkers were more likely to report higher frequencies of symptoms that could be associated with pesticide exposure, such as headaches, dizziness, skin irritations, and respiratory problems, relative to individuals employed outside the flower industry (Tsimbiri *et al.*, 2015).

Despite the extensive use of pesticides in floriculture, literature shows there is a significant deficit regarding workers' level of awareness about possible health risks. For instance, Damalas & Koutroubas (2016) note in their review of farmers' pesticide use practices that "knowledge of pesticide usage among farmers is often inadequate, and attitude towards safe pesticide use is often negative." Specifically, regarding pesticide applicators, little is known on whether the persons handling, mixing, and applying these chemicals understand the specific risks involved or can recognize early signs of pesticide poisoning, a knowledge gap identified in a study of Ethiopian farmers where one common result was insufficient knowledge about pesticide risks (Endalew *et al.*, 2022). More importantly, previous research suggests that workers' attitudes may not correspond with the gravity of the risks, where certain symptoms are normalized or ignored-a situation that might impede compliance with safer practices (Moreira & da Silva, 2023; Mustapha *et al.*, 2017; Tessema *et al.*, 2022)

The other serious issue justifying this research is the documented problem related to inconsistent and often incorrect utilization of PPE among agricultural workers. PPE represents the first line of defense against pesticide exposure, but studies have shown that compliance is usually low, and correct use is not assured. A study in Ghana found that despite the high awareness of PPE, the use was consistently low due to factors like cost and discomfort (Ntow *et al.*, 2006). PPE is rendered ineffective in cases of underutilization or misuse, which is usually due to a lack of training and risk perception. The extreme consequence is poor protective gear and has also been reported in other developing countries (Garrigou *et al.*, 2020; Singh & Gupta, 2009). This gap is quite critical since it speaks to the direct influence on the level of protection that the workers

receive and may indicate the existence of profound barriers such as comfort, enforcement, or availability of protective wear. Thus, Mrema et al. (2017) have identified that "the use of PPE is oftentimes inadequate because of unavailability, affordability, discomfort, and impracticability under tropical climatic conditions."

Therefore, conducting a KAP study was essential to systematically determine the gaps in knowledge, attitude and practice of the floriculture workers with regards to pesticide exposure. The analyses in this three-dimensional space are aimed at helping identify where interventions are urgently needed. Results can help guide the development of tailored educational programs to enhance risk perception and safe conduct, help to develop workplace policies and implementation strategies regarding pesticide use, and underpin evidence-based public health and labour regulation in the floricultural sector. This research ultimately sought to inform academic and policy debate on occupational health in this area and set the foundation for pragmatic, intervention-based initiatives that can improve worker health and well-being in a high risk, national and global industry.

1.4 Objectives

1.4.1 Broad objective

To assess the knowledge, attitudes and practices among pesticide applicators on pesticide use and exposure in floriculture farms.

1.4.2 Specific objectives

- i. To identify pesticide applicators' knowledge of safe pesticide use and the potential health risks associated with exposure in floriculture farms.
- ii. To examine pesticide applicators' attitudes towards pesticide use, safety measures, and their perceived risks in floriculture farms.
- iii. To evaluate the practices of pesticide applicators regarding protective measures, handling, and application of pesticides in floriculture farms.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter contains a literature review on the health impacts of pesticide exposure, knowledge, attitudes, and practices regarding pesticide use, and the theoretical framework for the study which guided the development of the current research. The health effects of pesticides section discuss the documented effects of pesticides on human health, including acute and chronic conditions. The KAP studies review illustrates how people view, consider and handle pesticide use, and particularly on behaviours oriented toward exposure and risk. Finally, the chapter explains the conceptual framework of the research, pointing out the theoretical models, theoretical constructs and main variables which guide both the study design and the analysis.

2.1 Health Effects of Pesticides

Pesticides have a number of health effects that depend on the level of exposure, the type of pesticide, and the duration and frequency of exposure. Although some health effects may be temporary and are resolved once the exposure is discontinued, others may prolong or result in chronic conditions, especially for individuals who are regularly or occupationally exposed. Chronic pesticide exposure poses concerns about cumulative and irreversible adverse health outcomes, such as chronic diseases and neurotoxicity. Pesticide poisoning is generally classified as mild, moderate or severe according to standardized grading of signs and symptoms. Very low acetylcholinesterase activity, an enzyme important to the nervous system, is a significant clinical indication of severity (Tosetto *et al.*, 2021; Wicaksono *et al.*, 2023).

Mild pesticide poisoning usually presents with non-specific symptoms of nasal, throat, eye or skin irritation. Affected individuals may experience headaches, dizziness, decreased appetite, increased thirst, nausea, diarrhea, excessive sweating, generalized weakness, fatigue, restlessness, mood fluctuations, nervousness, and sleep disturbances like insomnia (Somboon *et al.*, 2022).

Moderate poisoning presents more intensified symptoms. In addition to those experienced in mild cases, individuals may suffer from vomiting, hypersalivation, persistent coughing, a choking sensation or tightness in the throat and chest, abdominal cramping, blurred or double vision, rapid heart rate, heavy sweating, profound weakness, tremors, poor coordination, and mental confusion (Somboon *et al.*, 2022). These are signs of more widespread disturbance to the body's systems and require medical attention.

Severe poisoning with high dose of pesticide is potentially fatal and immediate action is needed. In extreme cases, it can cause the following: airway obstruction by mucus or phlegm and respiratory failure, miosis (or pinpoint pupils), chemical burns to the skin, hyperthermia, tachypnea, coma, uncontrolled muscle twitching (fasciculations), reflexes suppression, and death (Dos Santos *et al.*, 2023; Somboon *et al.*, 2022).

In addition to acute poisoning, cases of chronic pesticide exposure have been linked to various chronic health conditions. These conditions include skin problems, such as contact dermatitis, exacerbation of pre-existing respiratory illnesses (de Barros Rodrigues *et al.*, 2022; Tarmure *et al.*, 2020) and neurotoxic effects such as sensory peripheral neuropathy, motor coordination deficiency and long-term neurobehavioral dysfunctions (Thammachai & Sapbamrer, 2020). Moreover, people with prolonged

exposure to pesticides experience cognitive impairments like verbal and non-verbal abstraction, attention span, memory and mood disorders like anxiety and depression have also been reported (Aloizou *et al.*, 2020).

The toxicity of pesticides varies widely by chemical class and formulation. The level of health threat they pose is determined by several important factors. First, the kind of pesticide makes a big difference—one of the reasons being that certain groups (like organophosphates and carbamates) are themselves more poisonous than others. Second, the quantity and toxicity of the pesticide that an individual is exposed to will determine the severity of possible health outcomes. Third, the duration of exposure is important. The longer and more frequent the exposure, especially in occupational environment, the more the risk. Fourth, it matters how the pesticide enters the body; it can be inhaled, ingested, or absorbed through the skin, all of which have health implications. Finally, the addition of other compounds in the pesticide formulation may lead to enhanced toxicity especially with the synergy of chemicals that may enhance the deleterious effects (WHO, 2020a). Consequently, the risk of illness increases as the pesticide concentration, exposure duration, and strength rise.

2.2 KAP Studies on Pesticide Use and Exposure

It is critical to comprehend the KAPs of individuals toward pesticide exposure to inform context specific interventions. Such insights provide an understanding about the current misconceptions, cultural beliefs, and behaviour which may contribute to the unsafe use of pesticides. By examining the descriptive profiles of people's awareness, attitude, and practices towards pesticide handling and exposure, public health professionals, policymakers, and educators can develop specific communication

strategies and intervention programs. These targeted interventions are more likely to provide a meaningful message to certain communities that promote safer precautions, elevate protective behaviours and reduce risks in the long term to health and the environment inherent to the use of pesticides.

2.2.1 Knowledge of pesticides and their use

The knowledge related to pesticide use and potential exposure is broad and multidimensional throughout a complex network of closely related information. These include the classes of pesticides applied, the mode and duration of exposure (inhalation, dermal, and ingestion), the ease of access to PPE, the education levels and awareness of users, their economic standing, financial status, and the extent of local and national regulation. Full knowledge about these dimensions is important not just to promote the safe handling of pesticides, but for protecting the health of human beings, especially those most at risk like farm workers, and for mitigating the larger ecological impacts of toxic exposure to pesticides.

The importance of such knowledge is made more apparent in the context of studies that have shown that substantial differences in knowledge and knowledge-based practices exist among various demographic and occupational groups. Several studies have shown differences in knowledge and behavior, in particular between rural and urban, all levels of education, and gender groups. These disparities emphasise the need for strategic education-based interventions and policy reform to address the knowledge gap and to provide health equity.

A cross-sectional study was conducted in Nakhon Sawan province, Thailand, to assess knowledge, attitudes and practices towards pesticide use among farmers and to

determine the prevalence of acute pesticide-related illness. The results were worrisome: a large number of farmworkers had very low knowledge about the health risks of pesticide exposure. Notably, only 37.9% of the participants demonstrated a high level of knowledge of the risk of pesticides (Kangkhetkron & Juntarawijit, 2021). This lack of knowledge also applied to long-range health impacts, as most participants were unaware of pesticides being linked to diabetes, asthma, and neurodegenerative illnesses such as Alzheimer's and Parkinson's.

A KAP survey in Brazil with 112 farm workers from two rural communities, identified a considerable level of awareness in agricultural workers on the possible health risks from pesticides (Pasiani *et al.*, 2012). Most respondents (87.5%) agreed that pesticides could be harmful to human health. Even among those concerned about pesticides (more than 95% of the respondents), there was an overwhelming awareness that pesticides are essential for agriculture productivity and pest control. But with this understanding came substantial worries: 77.7% of respondents were concerned about the potential impact of their fieldwork on their own personal health.

Furthermore, nearly 90% of the farmers explicitly viewed pesticides as harmful substances, particularly for individuals directly involved in their application (81.3%) or in general farm activities (70.5%) (Pasiani *et al.*, 2012). The study also found a statistically significant correlation ($p < 0.01$) between those who perceived their work as harmful and those who regarded pesticides as a health risk, highlighting a nuanced understanding among farmers of the occupational dangers associated with pesticide exposure. Moreover, another 67% believed that pesticide residues were left in food after pesticides application, while about 40% understood that concurrent compliance

with withholding periods could bring such residues down, indicating a partial but important recognition of concerns about food safety in the context of pesticides use.

Similarly, a study in Bangladesh's Narsingdi District explored the knowledge level and practices of pesticide use in vegetable cultivation (Barau *et al.*, 2020). However, the results generally presented a less encouraging picture, as 57.3% of the farmers showed moderate level of knowledge, and 42.7% had little knowledge about pesticide use protocols. Importantly, none of the participants displayed a high level of knowledge, thus indicating that comprehensive ignorance exists that could potentially be hazardous as regards human health and environmental safety.

The research showed a slightly positive and significant correlation ($r = 0.32$) between farmers' access to information sources with their knowledge of pesticides (Barau *et al.*, 2020). This result highlights the need for quality methods of spreading information. Therefore, the authors called for immediate government intervention to bolster education and enforcement. By increasing accessibility and quality of information related to safe use of pesticides, through the extension services, public campaigns and training of farmers, authorities can contribute to safe agricultural practices and a better health of the rural population.

A research done by Jambari and *et al.* (2020) assessed the KAP regarding pesticide exposure in 144 farmers in Kelantan, Malaysia. The results revealed a poor knowledge gap; 7.6% of the farmers had high knowledge of pesticide use, most (61.1%) of the farmers had a moderate level of knowledge (Jambari *et al.*, 2020). This implies that the majority of farmers may not have in-depth knowledge of the risks and safe handling

of pesticides. Although education programs have been developed and implemented to improve knowledge, the overall levels of knowledge were still low.

Surprisingly, over 52.8% of the respondents have attended pesticide handling training programs (Jambari *et al.*, 2020). These training were offered by the Ministry of Agriculture (26.4%) and the State Farmer's Organization Authority (26.4%). Nevertheless, the weak effect seen in this training implies that the content, implementation, length, or access to the training could be inadequate. There was also a significant association between educational level and the knowledge score ($b = 0.926$, $p = 0.030$). This shows that the higher the education, the better the knowledge on pesticide use. However, educational level accounted for only a small fraction (3.3%) of the variance in knowledge levels, suggesting that additional unmeasured factors may also be influential in forming farmers' understanding of pesticide safety.

Another study in Kabudrahang County, Iran, examined KAP of agricultural workers towards pesticide use (Rostami *et al.*, 2019). The study was carried out to evaluate the knowledge of the farmers regarding pesticide hazards and the use of personal protection when handling pesticides. The results showed poor knowledge among the respondents. Only 195 (74.4%) farmers out of 262 farmers interviewed knew the mechanisms of pesticides entry into the human body (through inhalation, skin absorption and ingestion).

Although most farmers were aware of some safety practices, such as the proper storage of pesticides (231, 88.2%) and self- protection measures (189, 72.1%), the practical knowledge on correct pesticide usage was considerably limited (Rostami *et al.*, 2019). Only 100 (38.2%) respondents reported knowing how to apply pesticides properly,

implying that a high proportion of the farm workers were at risk of unsafe practices and exposure. These results highlighted the pressing need for specific training programs, educational efforts, and capacity-building activities to enhance the safety of pesticides and the health of farmers.

In South India, a cross-sectional survey of 100 agricultural workers was undertaken to investigate knowledge and practices regarding pesticides use and health and environmental risks (Mohanty *et al.*, 2013). Results revealed significant discrepancy between knowledge and practice among participants. Although a considerable proportion of the workers (70%) were aware about the effect of pesticide spraying on human health, only 40% knew about the potential environmental impacts of pesticides, including soil degradation, water pollution, and damage to non-target organisms.

With regard to pathway of exposure, two-thirds of respondents knew that pesticides could enter the body through inhalation via the nose. But there was a marked deficiency in knowledge with respect to the other major routes of exposure including dermal exposure through the skin and ingestion through contaminated food and water (Mohanty *et al.*, 2013). In general, only 42% of the farmers had good knowledge about the safety and risk of pesticide. While there was some awareness, real protective behaviour was absent. Forty to seventy percent of the farmers surveyed reported not always using PPE, such as masks, gloves and or goggles, during pesticide application, and thus were at higher risk for pesticide acute and chronic disease. The results indicate the urgent requirement for improved education/training and the stricter enforcement of safety regulations in order to close the knowledge-practice gap and protect the health of agricultural workers and the environment.

In a study by Weng and Black (2015) in Taiwan, 77 farmers in fruit-growing farms were surveyed for their knowledge, attitude, behavior and clothing practices while working with pesticides. The objective of the study was to assess the knowledge of workers both about pesticide health risks and the practical barriers they encounter in using protective measures. Study results indicated that respondents generally had a good knowledge of the risk of pesticides to human health. A large number of workers also reported some symptoms suggestive of pesticide poisoning (headache, dizziness, skin irritation and respiratory discomfort) showing not only the high exposure but also the awareness about possible risks to health. However, pesticides continued to be perceived by the workers as indispensable means for pest control, presuming a well-calculated pragmatic approach from agricultural productivity requirements.

Key barriers identified in the study included infrequent use of PPE, which primarily resulted from existing uncomfortable clothes not originally tailored to be adaptive to Taiwan humid and hot weather (Weng & Black, 2015). Wearing bulky or non-breathable PPE was challenging for workers carrying out physically intensive duties in high temperature, and therefore this interfered with its use. The study highlighted the necessity of incorporating preventive measures in daily agricultural activities and stressed that the use of PPE could play a pivotal role in reducing health risks. The findings of the study underscored the need to engage preventive measures in routine agricultural practices, where use of PPE may emerge as an important factor to reduce health risks. The study proposed the development and dissemination of climate-appropriate protective gear, and the strengthening of occupational health education

programs – keeping workers informed about, as well as supplied with, what they need to protect their health as they apply pesticides.

Mergia et al. (2021) assessed the knowledge, attitude and practice (KAP) of small-scale vegetable farmers toward pesticide use in Ethiopia with a specific emphasis on those farmers located along the Lake Ziway watershed. Results of the survey indicated a worrisome knowledge deficit among the respondents: just ten farmers (fewer than 5%) were considered to have “good knowledge” of pesticide use, 200 of the farmers were shown to have poor knowledge. This is an alarming lack of knowledge on safety in pesticide handling and risk involved. The study identified that up to 17% of the farmers surveyed said that they did not know about potential paths of pesticide exposure in the human body, like inhaling, touching the skin, or swallowing. This lack of general knowledge is particularly alarming in the context of health and safety for these farmers and their communities. It was a matter of serious concern that as high as 92.4% of the respondents were also not aware of any pesticides which have been officially prohibited/restricted, indicating gross inadequacy in information about the regulations. And just a tiny percentage, 7.6%, were able to identify any pesticides that have been banned or restricted.

Of the few who knew of such regulations, 56% attributed the banning or restricting of the pesticides to high toxicity (Mergia *et al.*, 2021). Yet even this knowledgeable group harbored significant misunderstandings and lack of knowledge. For example, 19% of such farmers understood that the banned pesticides were simply ineffective, 13% believed these pesticides were prohibited because of their high cost, whilst a further 13% confessed not knowing why these were prohibited. These findings highlight not

just lack of information, but also inaccuracy and misinterpretation of pesticide use guidelines. Furthermore, a significant correlation was observed between the knowledge level and the education level of the farmers. There was a strong association between educational level and knowledge level about pesticide use ($\chi^2 = 77.82, p < 0.01$), which also means that as the educational level of farmers increases the odds of good knowledge also increased significantly. This indicates the role of education in shaping safe agricultural practices and suggests targeted training and awareness-raising efforts, especially for the less educated farming community.

2.2.2. Attitudes and perception on pesticide use and exposure

Attitudes concerning the use of and exposure to pesticides play a key role in shaping the behaviour of farmers, policy-making processes, and public discourse on environmental and health-related issues. Such attitudes are shaped by multiple interacting socio-cultural, socio-economic, educational and occupational variables which vary considerably across communities and between stakeholders. Previous studies have demonstrated broad disagreement about pesticide exposure and response across different segments of the population, such as farm workers, rural communities, consumers, policy makers, and advocacy organizations.

A study done in Ethiopia on synthetic chemicals application by farmers and possible pesticide residues on fish (Agmas & Adugna, 2020) reported a serious problem concerning the awareness and attitude of the farmers towards pesticide application. About 80.16% of the farmers were found to have negative attitudes towards the safe and responsible use of pesticides. Although a significant proportion of respondents were aware of the adverse effects of pesticides on human (62.65%) and animal health

(39.48%), the gap in awareness with respect to the aquatic ecosystem was evident, with only 15.13% considered run-off and residues of pesticides to be harmful to fish populations. This suggests limited ecological consciousness or a general unawareness on what agricultural poisons might do to larger ecological systems. Even though there were concerns about adverse health effects associated with the pesticides, 69.98% of the farmers still felt strongly that pesticides were very important for obtaining high harvest, a manifestation of the high reliance on chemicals for productivity.

A similar trend was reported in a study conducted among 334 vegetable farmers in Bangladesh (Shahidullah *et al.*, 2023). The study emphasized the dependence on pesticides and the conservatism of farming attitudes. Over half of the respondents were not inclined to give up the use of pesticides entirely simply on the assumption that it would be impossible to farm vegetables without the assistance of pesticides. Nonetheless, a large majority—approximately 73%—expressed a willingness to reduce the amount and frequency of pesticide application, suggesting an openness to partial behavioral change if viable alternatives or support mechanisms were introduced.

When it came to safety compliance, however, the study found low levels of proactive engagement: only about 26% of farmers indicated an intention to adopt safer pesticide application methods, while 16% remained uncertain, and a significant 58% planned to maintain their current practices, essentially continuing "business as usual." The farmers were about equally divided in their sense of whether there might be adoption of organic pesticides in the future, ranging from curiosity to scepticism as to options of such a switch over (Shahidullah *et al.*, 2023). On a brighter side, the research indicated a great interest in spreading information and public awareness. Approximately 84% of farmers

were interested to learn about the safe practice on safe use of pesticides and its health risk by means of mass media, particularly radio and television. This study result indicates that well-planned awareness campaigns through mass media could be a viable means to educate farmers for better agricultural practices and also to sensitise them to the wider health and environmental impact of pesticide application.

In a research from the Philippines, farmers had a negative attitude on the use of pesticide (Lu, 2022). The most common fallacy was the misconception that pesticide application is necessary in order to obtain higher crop production. Most farmers (58.7%) agreed with the sentence "Pesticide use yields more crops than any other methods," and less than 7.8% correctly disagreed. Additionally, 32.0% disagreed with the statement "Pesticide use can be harmful to crops", while 23.8% correctly agreed. Lastly, the majority of farmers (30.5%) agreed that "Pesticides are necessary if one wants to feed the growing world population with quality good food," compared to 27.9% who correctly disagreed. The total scores of practices, attitudes, and knowledge were positively correlated. The highest relationship was found between knowledge and attitudes ($r = 0.651$); implying that as the knowledge score increases, so do the attitude scores. Practices and knowledge ($r = 0.631$) and practices and attitudes ($r = 0.402$) were also moderately correlated.

A study conducted among 2100 farmers from Turkey (Cevik et al., 2020) showed that almost half of the farmers had inappropriate attitudes towards pesticide use. Though a large proportion (86.8%) believed that pesticides are useful in increasing agricultural productivity, considerable number of participants (22.0%) were worried that pesticides could potentially harm human health. Moreover, 83.0% of farmers advocated for the

preference of cheaper pesticides. The consideration of protective clothing, such as masks and special overalls, during pesticide application was limited among the farmers. Regarding empty pesticide containers, 62.0% believed they should be buried in the ground, while 57.9% thought they could be left in the environment, and 35.1% suggested leaving them in outdoor garbage cans. Several variables increased the likelihood of obtaining a low score on the Attitude Index: advanced age (2.7 times), being unmarried (35.7 times), lack of formal education (30.1 times), living in a non-crowded household (2.1 times), and low income (≤ 2000 Turkish liras per month, equivalent to $\leq \$357$ as of April 2019 exchange rates) (3.1 times).

A study conducted in Egypt (Shaheen *et al.*, 2016) sought to evaluate the effectiveness of a health education program in enhancing knowledge, attitudes, and practices regarding organophosphorus (OP) pesticide use among women residing in rural communities. The study revealed several important baseline perceptions and the positive influence of the intervention. A substantial proportion of participants had some knowledge of the risks of OP pesticides before the educational intervention. In particular 62.5% of the women knew that pesticides are toxic, revealing a very basic level of understanding of the threat for their health. Also, 72.5% of the respondents recognized that it was important to read the label on a pesticide container and understand the directions, indicating a minimum level of awareness for safe handling.

After the implementation of a health education program, there was a statistically significant increase in the scores of all attitude-related parameters towards OP poisoning in farm workers ($p < 0.05$) (Shaheen *et al.*, 2016). This implies that the

intervention was successful in enhancing participants' beliefs and intention to engage into safe pesticide practices. The mean attitude score increased from 10.65 (± 3.01) before the educational intervention to 11.15 (± 2.23) after the intervention, which was statistically significant ($p < 0.05$).

Monger et. al. conducted a cross-sectional survey of selected areas in Bhutan to determine the exposure of farmers to pesticides and determine their knowledge, attitudes, and practices with respect to safe pesticide handling (Monger *et al.*, 2023). The investigation gives an important account of farmers attitudes and practice in direct relation with pesticides in the course of their agricultural operation. Results elicited a varying level of perception and concern among the respondents. There was fair level of concern for pesticide exposure in the majority of households (63%, $n = 188$), which shows some awareness for related health risks; however, compared to these, a substantial percentage (37%, $n = 112$) was found to exhibit less degree of concern, possibly indicative of complacency or lack of grasp about the harms from pesticide use. This gap illustrates the disparity in risk perceptions among the farmers and indicates the need for targeted education intervention to address their perceptions.

Furthermore, the study (Monger *et al.*, 2023) found concerning beliefs concerning personal protective equipment with respect to individual protective actions. Only 15% ($n = 44$) strongly agreed and 19% ($n = 58$) agreed that the use of cloth to cover the mouth and nose was enough to protect themselves when they sprayed pesticides. This suggests that a large number of farmers may lack access to the appropriate equipment and were unaware of the limitations of such rudimentary methods of protection.

A study done in 2017 assessed the knowledge, attitude and practice of horticultural farmers towards pesticides use in the communities of Banjulinding and Lamin of the Gambia (Idowu *et al.*, 2017). The objective was to estimate farmers' knowledge on pesticide-related health hazards and to what extent farmers applied safe-handling and personal protective measures during their day-to-day farm activities. Results showed that the level of knowledge of participants about the health hazards of pesticides was relatively high. A high percentage (93.94%; $n = 62$) of them knew that human body is being exposed to pesticides through various exposure pathways including inhalation, dermal contact, and ingestion. This indicates that the majority of the farmers knew the basic dangers of pesticide use, a good indication for potential behavioural change with appropriate training and availability of resources.

But the research also revealed pockets of misinformation or misunderstanding (Idowu *et al.*, 2017). Of concern was the 10.61% ($n = 7$) of the participants who thought one could build up immunity to pesticides over time. This perception is mistaken, and it can be dangerous since multiple chemical exposure not only yields cumulative toxic impact, instead of resistance, but it also increases the potential for chronic diseases like respiratory problems, neurological harm and cancer. Significantly, all the respondents (100%) agreed on the importance of taking a bath after using pesticides, which would indicate a common practice associated with reduction of dermal exposure. Such behaviour indicates some dedication to hygiene and sanitation but is not enough in absence of other preventive measures such as PPEs. Also, one farmer reported to gradually lose smell sensitivity to pesticide which they attributed to the long-term exposure and absence of protective material.

A research appraised the knowledge, awareness and practice of farmers with respect to pesticide application in farmlands in the Northern Nigeria (Nwadike *et al.*, 2021). A major finding was that farmers' attitude to pesticide use is highly affected by the aspiration to increase agricultural productivity. Particularly, 35.4% strongly believed that use of pesticide is essential to increase crop production. There was also a high level of consciousness about the health hazards of pesticide exposure and the need for prevention. Most (62.7%) of the farmers strongly agreed that utilization of PPE like gloves, masks, boots, and overalls may dramatically minimise the occurrence of pesticide poisoning.

The study also investigated hazardous practices in the pesticide application stage where the level of perceived risk was inconsistent. For example, 52.7% respondents strongly believed that eating/drinking during pesticide application are dangerous practices which may increase exposure (Nwadike *et al.*, 2021). Although this suggests an elementary-level awareness that oral ingestion is a potential mechanism of pesticide entry into the body, it also suggests that about half of subjects may not have adequate understanding or may not consistently engage in these practices to avoid such hazardous behaviors. Even more encouraging was that both smokers and non-smokers reported knowledge of the hazards of smoking while applying pesticides. A large majority, 80.7% of the respondents agreed or strongly agreed that smoking while working with pesticides is a severe risk to health. This is important given that smoking is a possible source of pesticides from contact via the hand to mouth and increase hazardous fume exposure.

2.2.3 Pesticide application practices

It is very important to improve pesticide safety behavior for the protection of human health, environmental conservation and stable food supply. Pesticides are important for increased crop yield and ensuring food security, but their misuse can result in risks to health, environment and safety. Research in a variety of farming populations worldwide highlights the imperative of encouraging safe pesticide practice through education, training, and policy. Understanding the complexities and unique issues faced by farmers around the world would help develop appropriate strategies to ensure pesticide safety and manage the associated risks.

In Ghana, a research was conducted on the prevalent use of pesticides in yam farming (Wumbei *et al.*, 2019). The study, which included interviews with 100 farmers, showed that herbicides were the most common family of pesticides used. Although farmers were aware of the pesticide risks, most over applied and paid less attention to using PPE. A significant proportion (20–40%) never used the PPEs, and more than 44% sprayed glyphosate, a non-selective herbicide above the recommended rate, which resulted in an average exposure above acceptable safety limits. The investigation suggested government involvement including: a training of pesticide dealers, farmer education, law enforcement, and support for protective measures.

In Rwanda, Ndayambaje *et al.* (2019) investigated a pesticide use practice and knowledge among 206 small-holder rice farmers to determine possible health and environmental risks of pesticide use in the rural areas. The results suggested a general lack in adherence to basic safety requirements: more than 95% of farmers did not at all comply with the minimum safety requirements for pesticide application and handling.

Disturbingly, 80% of the women stored pesticides in their homes without security measures (locked cabinets or proper storage). This posed a serious risk of accidental or unintended contact, especially for children and other susceptible household residents. In addition, 90% of participants indicated that they had personally suffered some type of medical problem, including headache, dizziness, respiratory difficulty, and skin rash or itching, that they associated with being exposed to pesticides (Ndayambaje *et al.*, 2019). The study also recorded domestic animal abnormal behaviour leading to shared concerns that the surrounding water sources used by both the people and animals were contaminated with pesticides. These results may imply a wider area of environmental influence, and not necessarily only within the farm periphery.

Atreya *et al.* (2012) in Nepal, sought to characterize the knowledge, attitudes and practices concerning pesticide application among farmers, as well as the effects of pesticide use on their health, including measurement of acetylcholinesterase activity. The research showed a troubling deficiency in safety practices as many farm workers were not aware of the hazards of pesticide use and did not receive proper training; many did not use the appropriate protective equipment. The study showed that exposure to organophosphate pesticides in the region was significantly depressing acetylcholinesterase activity, a well-established biomarker for exposure to cholinesterase-inhibiting chemicals. While the decrease in enzyme activity was clear biochemical evidence of exposure, it did not commonly lead to the manifestation of acute clinical signs of poisoning, implying subclinical toxicity that would be associated with a potential long-term health threat.

Similarly, the study found that exposure also is associated with some other major classes of pesticides commonly used (cholinesterase-inhibiting insecticides and fungicides) (Atreya *et al.*, 2012). The organochlorines, in contrast, were associated with both the incidence of illness symptoms in farm workers (headaches, dizziness, skin irritation, and respiratory problems) and more frequent acute poisoning effects. These results indicate that while organophosphates' impacts are more modest but potentially more biologically relevant, pyrethroids and fungicides are associated with immediate and observable health effects. The research emphasizes the critical need for enhanced safety training, more robust regulatory monitoring and access to personal protective equipment to ease the health impact of harmful pesticide exposure in farming communities.

Among 300 Ethiopian floriculture workers included in a study by Endalew *et al.* (2022), 61.3% practiced good pesticide handling. It is interesting to note that PPE was never used by 37.7%, and of PPE users, 59.3% used gowns, 37.7% gloves, 14.0% boots and 5.0% facemasks during pesticide application. A substantial percentage (65.7%) did not follow the instructions on the pesticide label, while 64.7% ate and drank at work. Four determinants of pesticide-handling practices emerged from multivariable regression analysis: knowledge on pesticide impact on the environment (AOR, 0.54), awareness of pesticide health problems (AOR, 0.36), willingness to wear and invest in PPE (AOR, 0.53), and PPE supply (AOR, 0.29) (Endalew *et al.*, 2022).

In another Ethiopian study, an assessment was conducted on the knowledge, attitudes, and practices of peasant association members regarding the safe use of pesticide management (Karunamoorthi *et al.*, 2011). The findings indicated that peasant farmers

were not aware of the dangers inherent in pesticides and did not handle them in a secure way. A large proportion of the respondents did not use personal protective equipment when applying pesticides and a high proportion of them utilized empty pesticide containers for drinking and storage of food. Of interest, 20.0% of the farmers used pesticides inappropriately by sweeping with plant leaves.

In Kuwait, 59% of 250 surveyed farmers were found storing pesticides safely, while 15% were stored unsafely (Jallow, Awadh, Albaho, Devi, & Thomas, 2017). Leftover solutions were often used on crops (82%); just 18% mixed only the amount used. Most (58%) did not use any PPE during pesticide work. Reasons for non-use included not being available (35%), uncomfortable in hot weather (90%), too expensive (65%) and perceived decreasing speed of performance (29%). Of PPE users (<5%), gloves (61%), hats (42%), and glasses/goggles (48%) were frequently used, but users often omitted respirators (70%), coveralls (68%), or boots (54%). Younger and more educated farmers were more likely to use PPE, but no association was observed with years of farming. Years of farming experience was related to safe storage and disposal of pesticides.

A research study examined pesticide knowledge, attitudes, and practices among small-scale Hmong farmers from California's San Joaquin Valley (Thao *et al.*, 2019). Findings showed that respondents often practiced protective ways to handle the pesticide, such as using protective clothing (e.g., gloves, long-sleeves, pants, hats, goggles, and mask). Most did not eat, drink and/or smoke during application, worked in calm weather, and observed re-entry periods. But even with these measures, a large proportion of farmers had direct body contact with pesticides, especially on their

hands. Although many participants changed their clothing after the application, a substantial percentage of them did not shower immediately after the application.

A study investigated pesticide management activities of 260 pesticide applicators from the Autonomous Province of Trento, Italy (Ricco *et al.*, 2018). Most of the participants were found to be experienced in pesticide applications as 74% had more than 5 years of work experience. 63.5% used pesticides more than or equal to three times monthly, during the crop season. Although 92.7% of them routinely read pesticide labels, for some the information on the label was complicated. Pesticide resellers were the most frequent source of information (33.8%), followed by experience acquired on their own (23.1%) and professional courses (17.7%). Storage practices were generally safe with 90.8% of respondents storing pesticides outside the house and 93.5% bringing empty containers back for disposal. Almost all participants used PPE (92.7% gloves, 91.2% face masks) during disposal. After disposal, there were widespread hygiene behaviours such as hand washing (94.6%) and showering (86.2%), but some risky behaviours such as smoking (18.5%) or using chewing gum (10.8%).

2.3 Conceptual Framework

The conceptual framework (**Figure 2.1**) illustrates potential factors that could influence pesticide applicators' behaviours and risk profiles. This diagram shows how the socio-demographic profiles, including age, sex, education, years of work, and training, may play both direct and indirect influence on multiple aspects of pesticide handling. This includes an applicator's knowledge of how pesticides should be used and the risks posed to health, attitudes about pesticide safety and exposure, and actual behaviours involved in pesticide preparation, application, and disposal.

Additionally, the framework indicates that these three domains are not isolated but rather interact dynamically. For example, more exposure to the hazards of pesticides and protection measures might result in more cautious or protective attitudes. In turn, these perceptions could influence more careful and responsible practices of pesticides application. On the other hand, poor or negative safety protocols may lead in turn to unsafe practices. Hence, the framework is not only emphasizing the role of socio-demographic factors in determining pesticide-related behaviours, but also emphasizes the interdependence among knowledge, attitudes, and practices that collectively determine the level of pesticide exposure and associated health risks among applicators.

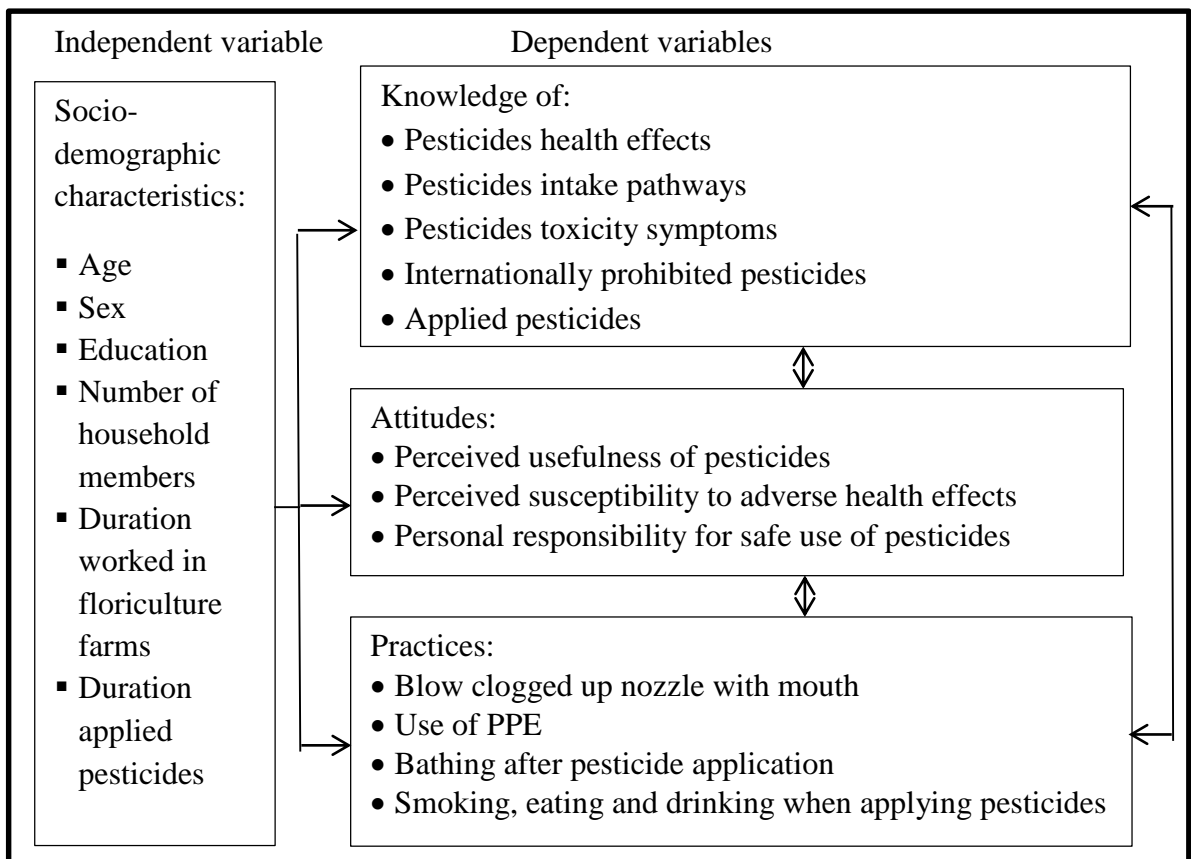


Figure 2. 1: Conceptual framework, Source: Author's construct

According to this conceptual framework, socio-demographic profiles play the role of independent variables which may influence, either directly or indirectly, several elements of pesticide handling practices.

Selection of these particular socio-demographic independent variables is justified for the following reasons:

- Age: Older applicators may have more experience, which could translate into better safety practices, or vice versa, entrenched bad habits. The younger workers may be more receptive to training but also have a higher risk perception.
- Sex: This is a key social determinant of health. For that reason, in mixed-gender settings, it might impact assignment of tasks, for example, mixing versus applying, given access to training opportunities, risk perception, and health outcomes for biological and social reasons.
- Number of household members: This can also be considered a proxy for economic pressure and social responsibility. The more dependents one has, the greater the urge to focus on speed and productivity rather than safety (increase risk) or, vice-versa, one may be motivated to avoid health risks in order to continue providing for the family (decrease risk).

These socio-demographic factors thus represent the foundational characteristics needed to shape an applicator's reality with regard to access to information, risk perceptions, and resulting safety practices.

2.4 Theoretical Framework

While the conceptual framework outlines the key variables and their presumed relationships, this study is guided by the health belief model (HBM) (Alyafei & Easton-Carr, 2024) for explaining and predicting the health-related behaviours of pesticide applicators. The HBM is a psychological framework that suggests an individual's likelihood of adopting a health-protective behaviour is determined by their perceptions of the following constructs:

- i. Perceived susceptibility: The belief in one's personal vulnerability to a health threat. For instance, "How likely am I to get poisoned by pesticides?"
- ii. Perceived severity: The belief about the seriousness of the health threat and its consequences. Examples include "How bad would pesticide poisoning be for me and my family?"
- iii. Perceived benefits: The belief in the efficacy of the advised action to reduce the threat (e.g., "Will using PPE effectively protect me from exposure?").
- iv. Perceived barriers: The perception of the tangible and psychological costs of the advised action. For example: "Is PPE too expensive, uncomfortable or inconvenient to use?"
- v. Cues to action: Strategies or events that trigger readiness to change, such as training, seeing a colleague fall ill, warning labels.
- vi. Self-efficacy: The confidence in one's ability to successfully execute the required behaviour. For example, "I am confident I can correctly wear and use a respirator".

Application to the current study:

In this context, the "health-protective behaviour" refers to a steady practice of safe pesticide handling. The study variables map directly onto the HBM constructs:

- Knowledge influences perceived susceptibility and severity: knowledge of health risks makes the risks more realistic and serious.
- Attitudes are influenced by the relative considerations of perceived benefits. For instance, the belief that pesticides improve crop yield-and the associated perceived barriers, such as discomfort from PPE and cost.
- Socio-demographic factors, such as education, may modify these perceptions and also act as Cues to Action.
- Practices are the final result, which comes from weighing these perceived threats, benefits, and barriers by the applicator, moderated by their Self-Efficacy.

By using the HBM, this study extends its analysis beyond a mere descriptive account of Knowledge, Attitudes, and Practices toward a theoretical explanation of why pesticide applicators in Naivasha may engage in risky behaviours.

CHAPTER THREE

RESEARCH METHODOLOGY

3.0 Introduction

This chapter outlines the method deployed in the study. It includes the study setting, the study population, the definition of the sampling method, the research tool, data collection, data entry and analysis. It also gives a view of what was done and methodology used to meet the aim of the study.

3.1 Study Design

This was a cross-sectional study in which data were collected at one point in time from study participants. In cross-sectional research the exposure of interest is measured at one point in time. This design was selected because of its appropriateness for simultaneous comparison of multiple variables. It is relatively inexpensive, permits collection of a large sample of data, and can be completed in a relatively short period of time. However, it's important to note that cross-sectional studies may not provide conclusive insights into cause-and-effect relationships. These studies provide a snapshot of a single moment, lacking consideration for events preceding or following the moment captured.

3.2 Study Population

The population for the study consists of pesticide applicators in the floriculture farms under the Lake Naivasha Growers Group (LNGG). Based on communications with farm managers, the total number of applicators across all member farms is estimated to be approximately 1400-1600. These workers' responsibilities include pesticide mixing, loading and application to the cut-flowers grown in the open and closed fields. Workers

spend their working time in direct contact with pesticides. Given the nature of their occupation, these workers face occupational exposure to pesticides.

3.3 Eligibility Criteria

The study aimed to recruit pesticide applicators in floriculture farms with significant occupational exposure to pesticides. Their eligibility in the study was determined as follows:

3.3.1 Inclusion Criteria

Individuals were considered for inclusion in the study if they had held the position of pesticide applicators in floriculture farms for a duration exceeding one month. Subsequently, only those who willingly provided their consent were enrolled in the study.

3.3.2 Exclusion Criteria

Individuals were excluded from the study if they were employed as pesticide applicators for less than a month. Furthermore, those holding a supervisory or administrative position were excluded from the study as their roles were characterised by minimal or no direct pesticide use. Also, those unwilling to provide informed consent were excluded.

3.4 Study Area

The study was carried out in the floriculture farms located in Naivasha in Nakuru County. This specific region was selected because the use of pesticides in the cultivation of flowers is high. According to Kenya Flower Council (2012), the major areas where flowers are grown in Kenya are around Lake Naivasha. The Naivasha basin (**Figure 3.1**) accounts for nearly 70% of Kenya's cut flower exports (WWF,

2012). Other parts of the country where flower growing takes place include Mt. Kenya region, Nairobi, Athi River, Kitale and Kericho.

Naivasha has a lot of land under cut flower production with approximately 1,900 hectares used for this purpose. Almost two-thirds of the land area is shelved in greenhouses for cut flower farming. Pesticides are routinely applied in the area as well, where up to about 75% of floriculture firms apply pesticides on approximately 90% of the farmland (Mburu *et al.*, 2013). These farms grow a range of ornamental flowers for cut flowers, including roses, carnations, Alstromeria, Gypsophilla, Lilies, Arabicum, Hypericum, and Statice.

The administrative and commercial key centre in Naivasha is Naivasha town, which is about 90.6kms north-west of the Kenyan capital, Nairobi. The main economic activities are farming, particularly floriculture, and fishing in Lake Naivasha. It is also a known tourist area.

There are several dispensaries and health centres for the floriculture farm workers in the Naivasha area. Health services are provided at Rocco dispensary for worker communities from north of Lake Naivasha and in facilities like South Lake Medical Centre and Naivasha AIC Health Centre for the workers from south of Lake Naivasha. For more complicated health challenges that cannot be managed at these centres, patients are referred to Naivasha County Referral Hospital, a level five facility located at along Kenyatta Avenue in Naivasha Town.

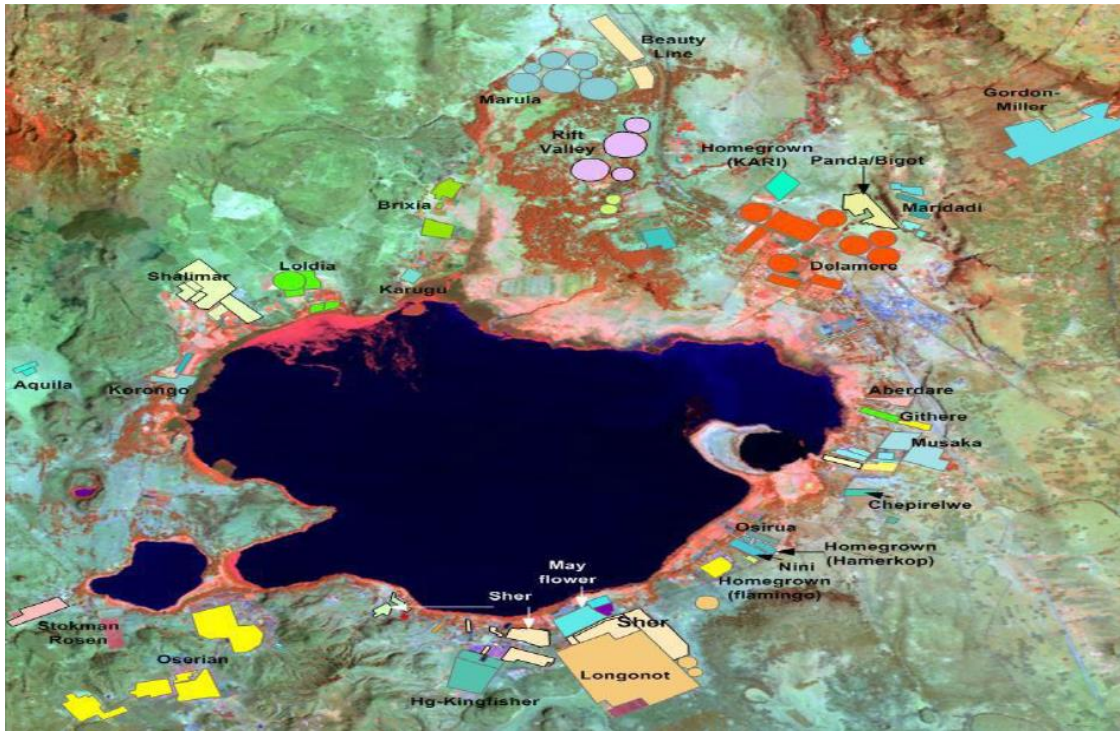


Figure 3. 1: Farms around Lake Naivasha, Source: (Mekonnen & Hoekstra, 2010)

3.5 Sample Size Determination

The sample size for the study was determined using Daniel's Formula for sample size computation (Daniel & Cross, 2018):

$$n = \frac{Z^2PQ}{d^2}$$

Where: n is the sample size; Z(1.96) is the standard normal deviation corresponding to 95% confidence interval; P is the proportion of farmers that acknowledge that pesticide use has potential harm to their health (87.5%) as determined by Pasioni *et al* (2012); Q= 1-P; and d is the precision of the study (5%).

Therefore:

$$n = \frac{1.96^2 \times 0.875 \times 0.125}{0.05^2} = 168$$

The sample size calculation using the formula resulted in 168 pesticide applicators.

3.6 Sampling Technique

A multistage sampling approach was employed in the study, with floriculture farms forming the primary sampling frame. Due to budget constraints, four out of the nineteen Lake Naivasha Growers Group (LNGG) member farms (Appendix B) were randomly chosen for inclusion in the study (Lake Naivasha Growers Group, 2013). This process involved each floriculture farm being given a number and the preparation of cards for each number. These cards were put in a container and the researcher randomly selected four cards. The drawn cards were for Shalimar, Longonot, Oserian Development Company, and Nini, which were selected for the study.

The number of pesticide applicators in the four selected farms was 301 (Table 1.1) and the total required sample size in the study was 168 pesticide applicators. To ensure a proportional representation, the number of pesticide applicators selected from each farm was determined using proportionate sampling, as illustrated in the following formula:

$$\frac{\text{Number of pesticide applicators in a farm}}{301} \times 168$$

The distribution of the pesticide applicators based on the farms was as follows:

Table 1. 1: Sample size in each farm

| Farm | Target population | Sample size |
|----------|-------------------|-------------|
| Oserian | 126 | 70 |
| Longonot | 79 | 44 |
| Nini | 57 | 32 |
| Shalimar | 39 | 22 |
| Total | 301 | 168 |

At the farm level, systematic sampling was employed to choose the pesticide applicators who took part in the study. A roster of pesticide applicators in each of the

selected farms served as the basis for sampling. Every 2nd pesticide applicator in the list from each farm was included in the study.

3.7 Study Variables

The dependent variables of the study consisted of the knowledge, attitudes and practices of the pesticide applicators regarding the pesticide usage and exposure. While the independent variables were socio-demographic factors of the pesticide applicators, which include age, marital status, education, and the number of people in the household.

3.8 Research Instruments

Interviewer administered questionnaire (Appendix A), which had four-section structures, was employed to collect data. Section one was used to collect information on socio-demographic variables which included age, gender, marital status, level of education, household size, as well as number of years of pesticide application and work in the floriculture farms. Section two contained questions aimed at assessing the participants' knowledge regarding pesticide use and exposure effects. This included inquiries about the respondents' understanding of the impact of pesticides on human health, pesticide intake pathways, toxicity symptoms, the presence of pesticide residues, internationally prohibited pesticides, and alternative pest control methods.

Section three focused on the pesticide applicators' attitudes, gathering information about their beliefs regarding personal susceptibility to health effects from pesticides, their sense of responsibility for safe pesticide use, and their opinions on the usefulness of pesticides. Section four was related to practices and included the use PPE, hand washing before meals after application, post-spraying bathing, and equipment cleaning. Before the study, the questionnaire was pre-tested on 10 pesticide applicators

from Bilashaka Flowers and modifications were done to the instrument after considering their feedback.

3.9 Execution of the study

The study was conducted within the premises of floriculture farms in Naivasha in May and June 2014. To assist in data collection, three research assistants were appointed as interviewers. These interviewers underwent training in research ethics and the methods for administering questionnaires.

At the beginning of the study, the investigator, together with the interviewers, met with the human resources managers on the farms. After explaining the study objectives, the human resource managers introduced the pest management departments in the farms. The heads of the pest management sections then ushered the investigator and interviewers to the pesticide applicators, presented the purpose of the study, and requested participation.

The study participants were selected from the pesticide applicators lists provided by the heads of pest management departments, upon fulfilling inclusion criteria. Once identified, the interviewers conducted the interviews in dedicated and comfortable rooms within each farm. Before the respondents were approached for the data collection, the interviewer explained the aim of the study and that their participation was voluntary. Then the interviewer obtained informed consent from the participants.

As a safety measure, no interviews took place while the pesticide applicators were in the process of applying pesticides, to avoid the possibility of exposing the interviewers to harmful chemicals. Each interview lasted an average of one hour per person. Privacy

was strictly protected; the names of the study participants were not captured in the questionnaires and in the procedures of the analysis phase

3.10 Data Processing and Analysis

The collected data were entered, cleaned, and analyzed using Statistical Package for Social Sciences (SPSS) version 22.0 by the researcher. Composite scores for knowledge, attitudes, and practices were computed as follows:

Variable scoring and categorization

Knowledge

The 23 knowledge questions were each assigned a score of 1 for correct answers and 0 for incorrect responses. This resulted in a continuous knowledge score ranging from 0 to 23. The continuous knowledge score was then categorized according to the Benjamin Bloom scale as follows: over 80% (19–23) indicating 'High knowledge,' 60% - 80% (14–18) indicating 'Moderate knowledge,' and below 60% (0–13) indicating 'Low knowledge.'

Attitude

Attitude was measured quantitatively by using a 13-item, structured Likert scale. Respondents indicated their level of agreement with each item using a 4-point scale that ranged from 0 (Strongly Disagree) to 3 (Strongly Agree). Negative statements were reverse-scored so that a higher score consistently reflected a more positive or safety-conscious attitude. The scale was designed to measure three distinct domains of attitude:

- Beliefs about the usefulness of pesticides (3 items, score range 0-9)
- Beliefs regarding personal susceptibility to health effects (6 items, score range: 0-18)
- Beliefs about personal responsibility for safe use (4 items, score range: 0-12)

Total continuous attitude scores were obtained by summing the scores for all individual responses, giving a range from 0 to 39. The higher the score, the more positive and safety-oriented the attitude. The sample median was used to dichotomize the continuous attitude score into 'positive' (20–39) and 'negative' (0–19) attitudes.

Practices

The self-reported "risky behaviours" of the pesticide applicators were utilized to assess their practices. Behaviours known or associated with pesticide exposure were assigned a score of 1, while those not associated with exposure were given a score of 0. A continuous practice score was computed by summing the scores from the 26 practice questions, yielding a score ranging from 0 to 26. Practice scores greater than 15 were categorized as indicating 'more risky behaviours,' whereas scores of 15 and below indicated 'few risky behaviours.'

Statistical methods

To summarize the data, descriptive statistics were used. Categorical variables were analyzed as percentages, while continuous variables were summarized as means and standard deviations. The Kolmogorov-Smirnov test revealed that continuous KAP scores violate normality (Table 7.1). Thus, non-parametric tests are utilized in this inferential analysis. In comparing two independent groups in terms of KAP scores, the Mann-Whitney U test was used, and for three or more groups, the Kruskal-Wallis H test was conducted. The level of significance is less than 0.05. Analysis was made of unadjusted associations between all the collected socio-demographic variables and the KAP scores. Only those which proved to be statistically significant ($p < 0.05$) are presented herein.

3.11 Limitations

The study faced limitations due to constraints in both time and resources, leading to the selection of only four floriculture farms located within a single district in Kenya. The questionnaire employed for data collection primarily featured closed-ended questions, which had the effect of limiting the depth of responses. It's worth noting that for a more comprehensive assessment of KAP, open-ended questions could have been more suitable, offering participants greater flexibility in their responses compared to the leading questions with restricted answer options utilized in the study.

Furthermore, it's important to acknowledge that the study lacked a direct method for measuring pesticide exposure and relied instead on information provided by the respondents and were subject to recall bias. In practice, risky behaviours may be presumed to lead to potential exposure, which was the assumption made in this study. The validation of this assumption would require actual exposure measurements.

3.12 Ethical Considerations

Ethical approval for the research was granted by the Moi University Institutional Research and Ethics Committee (IREC) with the approval number FAN: IREC 1140 (**Appendix D**). Furthermore, prior to conducting the study, permission was sought and obtained from the management of the selected farms. Informed consent was diligently obtained from all study participants before any data collection procedures were initiated.

The study participants were provided with a comprehensive explanation regarding the study, emphasizing aspects such as confidentiality and the voluntary nature of participation. Data collected from the participants was handled with the utmost care, ensuring privacy and safe storage.

CHAPTER FOUR

RESULTS

4.0 Introduction

The study findings are presented in this chapter, which is divided into three sections. First, the demographic profiles of the respondents are presented. It is followed by an analysis of knowledge attitudes and practices of the study participants. The third section explores the relationship between knowledge, attitude, and practice scores.

4.1 Socio-demographic characteristics

The study was carried out in four floriculture farms in Naivasha from May to June 2014 and comprised of 168 male respondents. The mean age of these participants was 29 ± 4.7 (Mean \pm SD) years. Notably, only 25.6% ($n = 43$) of the respondents were over 30 years old (Table 4.1). A significant majority, 84.5% ($n = 142$), were married, and while 80.4% ($n = 135$) were literate, only half (50%, $n = 84$) had achieved education beyond the post-primary level.

More than half of the respondents, specifically 52.4% ($n = 88$), reported having one to three household members. The average duration the respondents had worked in floriculture farms and applied pesticides was 5.9 ± 3.3 (Mean \pm SD) and 3.1 ± 2.0 (Mean \pm SD) years, respectively. Only 35.7% ($n = 60$) of the respondents had worked in floriculture farms for more than six years, and approximately a third (33.1%, $n = 54$) had applied pesticides for more than three years.

Table 4. 1: Socio-demographics factors in relation to KAP scores

| Variable | n (%) | Knowledge 18.51 ± 3.57 (M ± SD) | p | Attitude 22.76 ± 4.21 (M ± SD) | p | Practice 3.54 ± 1.62 (M ± SD) | P |
|---|-----------|---------------------------------------|--------------|--------------------------------------|--------------|-------------------------------------|--------------|
| Age (29.4 ± 4.7) | | | 0.000 | | 0.128 | | 0.000 |
| ≤ 30 | 125(74.4) | 66.08 | | 81.16 | | 92.59 | |
| > 30 | 43(25.6) | 135.14 | | 94.20 | | 60.98 | |
| Marital Status | | | 0.000 | | 0.112 | | 0.000 |
| Married | 142(84.5) | 92.89 | | 87.05 | | 78.27 | |
| Not Married | 26(15.5) | 38.69 | | 70.60 | | 118.54 | |
| Literate | | | 0.000 | | 0.375 | | 0.135 |
| Yes | 135(80.4) | 96.53 | | 86.14 | | 81.79 | |
| No | 33(19.6) | 35.30 | | 77.79 | | 95.61 | |
| Education | | | 0.000 | | 0.082 | | 0.000 |
| Primary | 84(50.0) | 52.56 | | 77.99 | | 99.35 | |
| Post-primary | 84(50.0) | 116.44 | | 91.01 | | 69.65 | |
| No. of household members (3.6 ± 1.5) | | | 0.225 | | 0.599 | | 0.341 |
| 1 – 3 | 88(52.4) | 80.19 | | 82.62 | | 87.89 | |
| > 3 | 80(47.6) | 89.24 | | 86.56 | | 80.83 | |
| Years worked in Floriculture Farms (5.9 ± 3.3) | | | 0.043 | | 0.415 | | 0.119 |
| ≤ 6 | 108(64.3) | 78.90 | | 86.77 | | 88.76 | |
| > 6 | 60(35.7) | 94.58 | | 80.41 | | 76.82 | |
| Years Applied Pesticides (3.1 ± 2.0) | | | 0.000 | | 0.008 | | 0.000 |
| ≤ 3 | 114(67.9) | 71.97 | | 77.70 | | 96.06 | |
| > 3 | 54(33.1) | 110.95 | | 98.85 | | 60.10 | |

Statistical test: Independent samples Mann-Whitney U Test

4.2 Knowledge of pesticide use and exposure

The respondents exhibited an average knowledge score of 18.51 ± 3.57 (Mean \pm SD), ranging from 6 to 23. According to Bloom's classification, the majority of respondents, specifically 60.1% (n = 101), were classified as having 'high' knowledge, while 27.4% (n = 46) were categorized as having 'moderate' knowledge, and only 12.5% (n = 21) were identified as having 'low' knowledge. It's noteworthy that all study participants possessed knowledge regarding the adverse health impact of pesticide exposure, although 36.9% (n = 62) believed that all pesticides had the same adverse health effects.

Participants demonstrated a strong understanding of the ways pesticides can enter the body. The most familiar routes of entry were skin absorption (91.9%, n = 153), inhalation (78.6%, n = 132), and swallowing (78%, n = 131). They also indicated various symptoms that result from pesticide poisoning: abdominal pain (97%, n= 163), skin rash (95.2%, n = 160), nausea (95.2%, n = 160), great tiredness (95.2%, n = 160), excessive salivation (83.9%, n = 141), chest pain (84.5%, n = 142), sore eyes (73.8%, n = 124), headache (72%, n = 121), and heart attack (69.6%, n = 117).

Regarding pesticide residue, 93.5% (n = 157) of the respondents believed it could exist in the soil, 70.8% (n = 119) on fruits, seeds, or plant leaves, and 60.7% (n = 102) in groundwater. However, only 4.8% (n = 8) of the respondents thought that pesticide residue might be present in the air. A majority, 95.8% (n = 161), were aware of internationally prohibited pesticides, and 89.3% (n = 150) acknowledged the existence of alternative pest control methods, including natural (83.9%, n = 141) and biological (81.5%, n = 137) approaches. About 86.9% (n = 146) of the respondents were able to name the pesticides they used.

The Kolmogorov-Smirnov test revealed that knowledge scores ($D[168] = 0.156$, $p < 0.001$) did not follow a normal distribution (**Appendix B**). Therefore, the Mann-Whitney test was conducted to examine the relationship between respondents' socio-demographics and their knowledge (**Table 2**). The analysis indicated that respondents with higher knowledge were more likely to be older ($U = 4865$, $p < 0.001$), married ($U = 655$, $p < 0.001$), literate ($U = 604$, $p < 0.001$), had higher levels of education ($U = 6211$, $p < 0.001$), had worked for a longer duration in floriculture farms ($U = 3845$, $p = 0.043$), and had applied pesticides for a longer period ($U = 4506$, $p < 0.001$). However,

no statistical difference was observed in knowledge based on the number of household members.

4.3 Attitude towards pesticide use and exposure

The overall mean attitude was 22.76 ± 4.21 (Mean \pm SD) with a minimum score of 14 and a maximum score of 34. The respondents' attitude regarding pesticide use and exposure was described as follows: the three-quarters of the respondents, 75% (n=126), demonstrating "positive attitudes", and the remaining 25% (n=168) categorized as "negative attitudes".

The mean attitude of the usefulness of pesticide use was 1.12 ± 1.02 (Mean \pm SD) and the range from 0 to 4. The majority, 80.4% (n=135), "strongly agreed" that pesticide must be applied during cut flowers cultivation. More than two-thirds, 67.3% (n=113), "strongly agreed" that a pesticide that is made up of several chemicals increases its quality, and nearly 72.6% (n=122) "strongly agreed" that when pests' attack is on the rise, the quantity and concentration of pesticides should be increased.

The mean attitude on personal susceptibility to the health effect of pesticide use was 13.75 ± 2.66 (Mean \pm SD) with a minimum of 7 and a maximum of 18. More than half of the respondents (55.4%, n=93) "strongly agreed" that the use of pesticides had the ability to cause health problems to humans and destroy the environment. Furthermore, a majority strongly agreed with the necessity to stop spraying immediately when it becomes windy (57.7%, n = 97), and that all workers should undergo medical check-ups for pesticide exposure at least once a year (59.5%, n = 100).

Majority of the respondents “strongly disagreed” that one should stand at the direction of the wind, 57.1% (n=96) and smoking, drinking, and eating are allowed during the pesticide application, 51.2% (n=86). However, only 39.3% (n=66) “strongly agreed” that exposure to pesticides could imply having signs such as headache, tiredness, and nausea.

The mean attitude of personal responsibility for the safety of the pesticide application was 0.89 ± 2.03 (Mean \pm SD) ranging from 3 to 12. Over half the participants “strongly disagreed” that they could get immunity after using pesticides over an extended period, 53.6% (n=90); and that a spraying tank should be cleaned in a pond or river without damaging the fish or marine animals, 62.5% (n=105). However, only 22.6% (n=38) “strongly agreed” that anyone applying the pesticide is responsible for its safety and 31.0% (n=52) “strongly disagreed” that one should not wear protective clothing thoroughly when spraying pesticides.

The application of the Kolmogorov-Smirnov test indicated that the attitude scores ($D(168) = 0.090$, $p=0.002$) were not normally distributed (**Appendix B**). Therefore, the Mann-Whitney test was applied to identify the relationship between the socio-demographic and the attitude scores (**Table 2**). None of the listed socio-demographic characteristics was associated with the attitude scores, except for the duration at which the respondent has been applying the pesticide. Respondents who had applied pesticides for a longer duration were more likely to have positive attitudes ($U = 4506$, $p = 0.008$).

4.4 Practice with regards to pesticide use and exposure

The average practice score was 3.54 ± 1.62 (Mean \pm SD), varying between zero to eight. The majority, 71.4% (n = 120), respondents reported few risky behaviours (1 – 4) while 26.2% (n = 44) reported more risky behaviours (4 – 8), and only 2.4% (n = 4) reported no risky behaviours. All the respondents used pesticides through spraying, and all farms had an assigned first aid area.

However, almost all the respondents reported safe practices, such as not blowing a clogged nozzle with the mouth 96.4% (n = 162) and wearing proper PPE 86.9% (n = 146). Most of the respondents took a bath before a meal 92.3% (n = 155) and 89.2% (n = 150) were not smoking, drinking, eating, or chewing gum while spraying. Nevertheless, 64.9% (n = 109) never stopped spraying during windy conditions, while others 50.6% (n = 85) were spraying against the wind. Still, most of the respondents 86.3% (n = 145) continued spraying when their clothes were wet with pesticide and 61.3% (n = 103) washed these clothes with other dirty ones. Other unsafe practices included 55.4% (n = 93) who did not bath immediately after a spray.

Appendix B shows that a Kolmogorov-Smirnov test showed non-normal distribution of the practice score; thus, the Mann-Whitney test was used to assess the relationship between socio-demographic characteristics and practice scores. The results revealed that older respondents (U = 1676, p < 0.001), married (U = 2731, p < 0.001), those with higher levels of education (U = 2280, p < 0.001), and those who applied pesticides for a long time (U = 1760.5, p < 0.001) reported fewer risky behaviours in their practice. However, there was no statistical difference with practice scores based on literacy, number of household members, or years the applicators had worked in the floriculture farm.

4.5 Association of KAP

As per the results of the Mann-Whitney U and Kruskal Wallis tests, knowledge was significantly associated with both attitude and practice. Higher knowledge was significantly associated with positive attitudes ($\chi^2[2] = 7.029$, $p = 0.030$) (**Table 4.2**).

In particular, greater knowledge was significantly linked to the belief in the usefulness of pesticides ($\chi^2[2] = 15.529$, $p < 0.001$) and the acceptance of personal responsibility for the safe use of pesticides ($\chi^2[2] = 6.881$, $p = 0.032$).

Concerning pesticide application practices, higher knowledge was significantly associated with the adoption of less risky behaviours ($\chi^2[2] = 14.539$, $p = 0.001$).

Furthermore, the practice of less risky behaviours was significantly associated with positive attitudes ($U = 3092$, $p = 0.023$). Specifically, adopting fewer risky behaviours was significantly linked to the belief in personal responsibility for the safe use of pesticides ($U = 3044$, $p = 0.014$).

Table 4. 2: Associations of knowledge with attitudes and practices

| Variable | Knowledge* | | | Chi-Square | df | P | Risky behaviours | | Mann-Whitney U | P |
|--|------------|----------|--------|------------|----|--------------|------------------|-------|----------------|--------------|
| | High | Moderate | Low | | | | A few | More | | |
| Usefulness attitude mean rank | 92.85 | 82.28 | 49.21 | 15.529 | 2 | 0.000 | 87.10 | 77.18 | 2406 | 0.223 |
| Personal susceptibility attitude mean rank | 87.65 | 82.41 | 73.93 | 1.523 | 2 | 0.467 | 87.56 | 75.86 | 2348 | 0.167 |
| Personal responsibility attitude mean rank | 92.43 | 72.43 | 72.81 | 6.881 | 2 | 0.032 | 89.94 | 69.18 | 2054 | 0.014 |
| Overall attitude mean rank | 91.94 | 77.43 | 64.21 | 7.029 | 2 | 0.030 | 89.55 | 70.27 | 2102 | 0.023 |
| Risky behaviours mean rank | 73.39 | 97.86 | 108.67 | 14.539 | 2 | 0.001 | N/A | N/A | N/A | N/A |
| Knowledge mean rank | N/A | N/A | N/A | N/A | | N/A | 93.40 | 59.41 | 1624 | 0.000 |

*Kruskal Wallis Test

CHAPTER FIVE

DISCUSSION

5.0 Introduction

This chapter contains a discussion of the main findings of a study of workers involved in pesticide application in floriculture farms. It is organized into sections that address three key aspects of worker behaviour and experience: knowledge, attitudes and practices around use of pesticides and exposure. In addition to each of these dimensions, the chapter also highlights the associations between knowledge, attitudes, and practices.

5.1 Knowledge of pesticide applicators regarding pesticide use and potential exposure

The high level of knowledge regarding pesticide use and associated exposure reported in the study with 60% of applicators classified as having 'high' knowledge according to Bloom's classification (Section 4.2)—aligns with a recent cross-sectional study conducted in Nepal (Paudel *et al.*, 2024). Furthermore, all participants were aware of the adverse health effects related to pesticides, confirming results from previous studies (Keleb *et al.*, 2024; Satya Sai *et al.*, 2019). This increased awareness can be linked to their direct participation in pesticide application activities and their vast experience in managing pesticides. Their years of experience with pesticide-work have presumably increased their awareness of pesticide safety through learned experiences and hands-on training.

Pesticides are classified into four categories depending upon the risk they pose for human, and the Class I pesticides are of highest risk (WHO, 2020b). As the toxicity of pesticides rises, more stringent protective measures and handling procedures are

required (Ahmad *et al.*, 2024; Damalas & Koutroubas, 2016). However, the study's results revealed that not all participants acknowledged the distinctions in pesticide toxicity, indicating a knowledge gap concerning pesticide hazards. Such gaps have also been noticed in Kuwait (Mustapha *et al.*, 2017), where there was a great deal of awareness about the risks of pesticides, yet specific knowledge of different toxicity levels was insufficient among the applicators. There might be misunderstanding caused by lack of training, on-the-job training without formal education, or inefficient communication of risk. Likewise, research conducted in Greece (Damalas *et al.*, 2019) demonstrated that many pesticide users perceive all chemicals as equally dangerous, resulting in careless handling practices that increase exposure risks. Such gaps in understanding can increase susceptibility to health dangers, especially when dealing with highly toxic pesticides. This observation agrees with the idea that the adverse effects of pesticides are related with their intrinsic toxicity as well as exposure levels (Van Straalen *et al.*, 2022).

The high awareness of pesticide entry routes—skin absorption (91.9%), inhalation (78.6%), and ingestion (78%)—among applicators aligns with prior studies conducted in Argentina (Raimondo *et al.*, 2022) and Malaysia (Mustafa Udin *et al.*, 2017), which indicated that dermal exposure is the main concern due to the direct contact pesticide handlers have with these chemicals. However, the limited awareness among some applicators regarding ingestion as a potential exposure route reveals a knowledge gap that may result in an underestimation of its associated risks. A comparable pattern was observed in Kuwait, where Jallow *et al.* (2017) found that although pesticide users were well-informed about dermal and inhalation exposure, their understanding of ingestion

risks especially from contaminated hands, food, or water was insufficient. This deficiency in knowledge raises the risk of accidental exposure, especially in environments where the use of PPE is not consistent. It is crucial to address this gap through enhanced safety training and better risk communication to mitigate pesticide-related health threats.

Pesticide residues in agricultural environments continue to be a major concern due to their potential impact on human health and the ecosystem. The study indicated that most participants were aware that pesticide residues could linger in the soil, cling to fruits, seeds, or plant leaves, and pollute groundwater. These findings are consistent with well-established scientific studies. Evidence indicates that pesticide build-up in soil may be long-lasting, contaminating the soil microbiota (Goulson, 2013). In addition, pesticide residues on the grains and on the seed have also been previously reported, and these residues have often used to pose a potential human dietary risk (Fantke & Juraske, 2013). Moreover, it has been confirmed that the pesticides may leach into groundwater, especially in regions of intensive agriculture and high-permeability soils (Cossu *et al.*, 2024).

An important finding of this study is that only 4.8% of the participants recognised the presence of pesticide residues in the air. This suggests potential unawareness, as airborne pesticide drift is a well-documented phenomenon. Pesticides can be released into the air via volatilization, as well as in other ways (spray drift), having the potential to cause environmental contamination and accidental exposure in non-target areas (Tudi *et al.*, 2022; Zaller *et al.*, 2022). Studies have identified pesticide residues in the atmosphere, especially in areas with high levels of pesticide use (Materu *et al.*, 2021).

The dispersion of pesticides into the atmosphere poses risks to surrounding communities and ecosystems, especially when applied in aerial spraying or in conditions that promote volatilization (Boonupara *et al.*, 2023).

The results of the study showed knowledge levels were significantly influenced by various socio-demographic characteristics, including age, marital status, literacy, education level, duration of employment in floriculture, and the time spent handling pesticides. These factors influence individuals' understanding, perceptions, and practices concerning pesticide usage and safety protocols. Studies have shown that older individuals tend to have greater practical experience with pesticides, yet they may not always have formal training or up-to-date knowledge on modern pesticide safety regulations (Jambari *et al.*, 2020; Kangavari *et al.*, 2024). Marital status can also influence awareness, as married individuals may be more concerned about the long-term health risks of pesticide exposure for their families, prompting greater precautionary behaviour (Tham-Agyekum *et al.*, 2023).

Literacy and education level significantly influence an individual's understanding. Typically, those with higher education have a greater awareness of the dangers associated with pesticide use, appropriate handling methods, and applicable regulatory standards (Jallow, Awadh, Albaho, Devi, & Thomas, 2017). Conversely, people with lower literacy levels may depend more on informal knowledge, which can sometimes result in unsafe practices when applying pesticides (Mubushar *et al.*, 2019).

The duration of employment in floriculture and the time spent handling pesticides are also important factors affecting knowledge. Workers with more experience might acquire hands-on expertise in pesticide application; however, their understanding may

not consistently reflect best practices unless they engage in ongoing training (Onwona Kwakye *et al.*, 2019). Additionally, prolonged exposure to pesticides without adequate education and safety measures can elevate health hazards (Mrema *et al.*, 2017; Shekhar *et al.*, 2024).

5.2 Attitudes of pesticide applicators towards pesticide handling

The perceptions and attitudes of pesticide applicators regarding pesticide usage and exposure are crucial for maintaining occupational health and safety. Overall, three-quarters of the pesticide applicators had positive attitudes towards pesticide application, appreciating its advantages for agricultural productivity and pest management, which aligns with findings from research conducted on farmers in Bhutan (Monger *et al.*, 2023). Also, 55.4% of the pesticide applicators expressed concerns on potential negative health effects associated with working with pesticides, which aligns with the findings of a study conducted in Brazil (Pasiani *et al.*, 2012), demonstrating an increased awareness of the dangers associated with pesticide use.

A concerning finding is that merely around 20% of the participants felt that each person applying pesticides should take accountability for their safe usage. This perceived absence of individual responsibility may stem from various reasons, such as dependence on regulatory systems, the responsibilities of employers, and restricted access to training on pesticide safety. A previous study highlight that many applicators believe that safety measures should be enforced by government agencies or employers rather than being an individual duty (Utyasheva *et al.*, 2024). Additionally, some applicators may underestimate their personal risk due to long-term exposure without

immediate adverse health effects, leading to complacency in adopting protective behaviours.

Four-fifths of the pesticide applicators believed that applying pesticides is as an indispensable practice in every instance of cultivation. This perspective is largely driven by the necessity of producing high-quality flowers that are free from insect damage, which is vital for financial prosperity and visual appeal. Furthermore, 72.6% pesticide applicators believed that the best way to deal with pest issues is to increase the quantity and concentration of pesticides during outbreaks. Although pesticide usage is prevalent in flower farming, applying them excessively during outbreaks can lead to serious consequences, including environmental harm (Ahmad *et al.*, 2024), health hazards (Kalyabina *et al.*, 2021; Pathak *et al.*, 2022) and the development of pesticide resistance (Siddiqui *et al.*, 2022). Hence, the adoption of sustainable pest management practices like IPM is vital for sustaining flower farming in the long run and minimizing the hazards posed to ecosystems and human health.

5.3 Practices of pesticide applicators when working with pesticide

The findings highlight that pesticide application practices pose real and major threats to health and the environment. For example, 64.9% of the applicators did not stop spraying when it was windy, resulting in a greater probability for pesticide drift and unwanted exposure to the applicator or nearby people (Damalas & Koutroubas, 2016; Kasner *et al.*, 2021). Furthermore, 50.6% of the respondents sprayed both upwind and downwind, aligning with findings from a study conducted in Ethiopia (Endalew *et al.*, 2022). This practice increases inhalation risks since pesticides can be transported by air currents over significant distances (Boonupara *et al.*, 2023).

Additionally, 86.3% of the pesticide applicators said they kept spraying even after their clothes were soaked in pesticides, which increased the risk of dermal absorption—the primary method of pesticide absorption and a risk factor for negative health outcomes like systemic toxicity and skin irritation (Tudi et al., 2022). In addition, 61.3% of the applicators reported washing pesticide-contaminated clothing with other garments, a risky practice which may lead to long-term exposure to toxic chemicals and cross-contamination (Licina et al., 2021).

Good personal hygiene is key to lower chances of pesticide contamination. Pesticide applicators should immediately shower and change into clean clothes after handling pesticides. However, it is the finding of this study that over half of the pesticide applicators did not follow this guideline, which heightens their risk of systemic toxicity due to extended dermal exposure. Pesticides such as organophosphates and pyrethroids can infiltrate the skin, resulting in immediate symptoms like dizziness and nausea, as well as long-term consequences, including neurological disorders and cancer (Adeyinka *et al.*, 2023; Ore *et al.*, 2023). Research indicates that washing right away significantly decreases pesticide residues (Salvatore *et al.*, 2008), yet many workers postpone showering due to insufficient facilities, fatigue, or the false belief that wearing protective gear negates the necessity of washing after application (Mrema *et al.*, 2017; Rostami *et al.*, 2019). Epidemiological studies show that delayed hygiene activity was related to elevated levels of pesticides metabolites and elevated health risks (Arcury *et al.*, 2007; Coronado *et al.*, 2011; Yuan *et al.*, 2022).

While risky behaviours remain prevalent, this study also revealed some good practices which applicators do which may contribute towards minimizing the risk of developing

health hazards. A major result of this study was that 96.4% of pesticide applicators did not clean obstructed nozzles by blowing with their mouths. This represents important safety behaviour because studies have shown that direct oral contact with pesticide residue induce acute poisoning and chronic health problems (Ahmad et al., 2024; Damalas & Koutroubas, 2016). Furthermore, 86.9% of the pesticide applicators reported to consistently using PPE, a very good practice as it at least reduces exposure to harmful chemicals (Garrigou et al., 2020; Nguyen & Tsai, 2024).

The study also found that 92.3% of pesticide applicators washed before eating post pesticide application. This aligns with WHO recommendations, which emphasizes thorough washing after handling pesticides to reduce dermal absorption and prevent ingestion (WHO, 2020a). Furthermore, avoiding behaviours such as smoking, drinking, eating, or chewing gum while spraying pesticides is crucial, as these activities significantly increase the risk of ingesting toxic residues (Rostami *et al.*, 2019; Walton *et al.*, 2016). Pesticide applicators should be encouraged to maintain these commendable practices to reduce exposure risks.

It is the finding of this study that demographic factors significantly influence pesticide application practices. Specifically, older individuals, those who are married, and those with higher education levels tend to exhibit fewer risky behaviours when handling pesticides. Additionally, experience in pesticide application appears to enhance safety practices.

Age is an important determinant of pesticide application behaviours. Older individuals may adopt safer practices due to accumulated experience and increased risk awareness. Previous research supports this notion, suggesting that younger pesticide applicators

engage in riskier behaviours, such as improper handling and lack of protective equipment use (Damalas & Hashemi, 2010; Kearney *et al.*, 2015; Rohlman *et al.*, 2020). This is perhaps due to a lower perception of risk and a greater emphasis on efficiency over safety (Lekei *et al.*, 2014). In contrast, older individuals may have experienced the long-term health consequences of pesticide exposure, making them more cautious.

Marital status appears to be a protective factor against risky pesticide use. Married individuals often exhibit more responsible behaviours, possibly due to increased household responsibilities and awareness of the potential consequences of pesticide exposure on family members. Married individuals have been documented to be more likely to adopt health-protective behaviours in various occupational settings, including farming and pesticide application (Borau *et al.*, 2022; Guner *et al.*, 2018; Long & Liu, 2020). Having dependants may prompt individuals to adopt safer practices to minimize the risk of exposing their households to harmful substances.

Higher education levels correlate with reduced risky behaviours as it enhances an individual's ability to access, interpret, and apply information regarding pesticide safety (Damalas & Koutroubas, 2016). Also, farmers with formal education have been documented to be more likely to follow recommended guidelines for pesticide handling, storage, and disposal (Oshingbade *et al.*, 2025). Moreover, literate individuals may have greater exposure to training programs and written safety instructions, improving compliance with best practices.

The study also found that those with longer experience in pesticide application engaged in fewer risky behaviours. Experience in handling pesticides may lead to better adherence to safety guidelines due to repeated exposure to training and personal

observations of unsafe practices leading to adverse outcomes. It has been documented that inexperienced pesticide applicators are more likely to misuse pesticides when compared to the experienced ones (Damalas & Koutroubas, 2016; Khan & Damalas, 2015). This highlights the importance of on-the-job learning and knowledge accumulation in improving pesticide safety practices (Damalas & Koutroubas, 2016).

In summary, the findings highlight that demographic and experiential factors significantly influence safety practices. The study specifically identified older age, married, higher educational levels, and increased experience with pesticide usage as crucial factors in minimizing risky behaviours. Thus, these factors should be factored in when designing appropriate interventions for improving workplace safety in the agricultural sector.

5.4 The correlation between the knowledge, attitudes, and practices of pesticide applicator

The research findings highlight the important connections between knowledge, attitudes, and practices related to pesticide use and exposure. Specifically, an increase in knowledge correlates with more positive attitudes and safer pesticide application methods. This is consistent with the findings of earlier research, highlighting the importance of education and knowledge in minimising pesticide risks (Ahmadipour & Nakhei, 2024; Damalas & Koutroubas, 2016). There is increasing evidence to show that good knowledge about the hazards related to pesticides and the safe practices related to their handling could help users to use the chemicals in a safer and protective manner (Jallow, Awadh, Albaho, Devi, & Ahmad, 2017). For example, Damalas and Koutroubas (2016) reported that formally trained farmers in pesticide application were more likely to wear PPE and followed the recommended application procedures.

Similarly, our findings also indicate that an increase in knowledge contributes to a better attitude in pesticide safety and further, this is conducive to the safe handling of pesticides.

Moreover, our results revealed that positive attitudes were significantly associated with reduced engagement in risky behaviours. This is in line with the health belief model, which suggests that individuals who feel more vulnerable to health threats are more inclined to adopt preventative measures (Ahmadipour & Nakhei, 2024; Ghanbari *et al.*, 2018). Previous research has demonstrated that attitudes mediate the relationship between knowledge and behavior, and farmers with more positive attitudes with respect to safety practices are less likely to adopt poor pesticide handling practices (Ali *et al.*, 2020; Hailu, 2017; Houbraken *et al.*, 2016; Memon *et al.*, 2019).

In spite of these positive correlations, gaps in knowledge and attitude transformation still exist, which may stem from various socio-economic and educational influences. For instance, research has indicated that farmers with limited access to extension services or training opportunities often demonstrate lower adherence to safety protocols (Schreinemachers *et al.*, 2017).

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.0 Introduction

This chapter contains the final synthesis of the study. The conclusion summarizes the core findings on KAP related to pesticide use. Actionable recommendations based on the results are provided for farm managers and policymakers in order to improve worker safety. Finally, the chapter outlines specific avenues for future research by pinpointing some key questions that remain open and that will help guide further efforts in improving occupational health within the floriculture industry.

6.1 Conclusion

The study brings to light the KAP status of pesticide users on uses of pesticides as well as the safe use of pesticides.

6.1.1 Knowledge of pesticide use and exposure

In general, pesticide applicators had a relatively high level of knowledge of pesticide safety, especially regarding pathways of pesticide exposure, symptoms of pesticide poisoning, knowledge about banned chemicals, and substitutes available. Higher levels of knowledge were significantly associated with education and the number of years of working experience. Although the general knowledge was relatively good, there were some specific gaps, such as knowledge on pesticide residues in the air, that should be addressed by training and awareness programs.

6.1.2 Attitudes towards pesticide use

Even though the pesticide applicators had a positive attitude towards pesticide use, this did not often include thinking about safe use as something for which the individual had

personal responsibility, and this may have implications for safety. This underscores the importance of reinforcing personal responsibility as well as regulatory monitoring.

6.1.3 Safety practices and behaviours

The study found a significant number of pesticide applicators followed recommended safety practices such as using PPE and avoiding oral contact with equipment. Nonetheless there were substantial reports of risky behaviour. These include inappropriate spraying in windy conditions, lack of personal hygiene post-application and unsafe washing, all of which raise exposure risk.

6.2 Recommendations

The following recommendations address key organizations involved in the floriculture industry. Each player has a different role and can contribute in specific ways to improve pesticide safety while protecting workers who are commonly exposed to hazardous chemicals.

i. Government agricultural and environmental agencies.

Make training mandatory and consistent.

Government agencies should establish a mandatory, certified training program for all handlers, mixers, or sprayers of pesticides. Training programs should be provided in local languages to ensure understanding and retention. Training should clearly outline the three primary routes of pesticide entry into the body: inhaling contaminated air, skin absorption, and accidental ingestion of residues. Workers should also be taught early symptoms of pesticide poisoning, such as headaches, dizziness, nausea, or skin irritation, and basic first aid management while seeking medical attention.

The government should also publish an updated public list of banned and restricted pesticides. Most farm workers do not know which chemicals are considered the most dangerous; an available list would help not only the farms but also employers to make safer choices. The training should cover information on IPM, which promotes safer alternatives and more viable methods of conducting pest control, thus reducing reliance on hazardous chemicals.

Strengthen enforcement and monitoring.

No regulations will work without regular, persistent monitoring. Agencies must provide clear inspection standards that verify farm-level compliance with safety protocols, particularly regarding PPE use and pesticide storage. Inspections must be predictable, transparent, and fully supported in terms of resources. Agencies also need to establish a proper system of rewards and penalties: for example, compliant farms could be given some form of certification or public recognition, while breaches must result in fines or other penalties. Through these practices, accountability is created, leading to ongoing enhancement.

Implement targeted awareness campaigns

Government communication should not be based solely on formal education. Visual tools such as posters, brochures, and brief videos can successfully communicate information to workers with low literacy skills or restricted time for training. Knowledge gaps noted in this study, such as pesticide drift and exposure from air-borne residues, will be featured in the development of these visual resources. Good communication enhances safe practices and helps avoid accidental exposures both in the workplace and in surrounding communities.

ii. Owners and managers of floriculture farms.***Train pesticide applicators at the farm.***

Farm owners and managers should play front role in promoting occupational safety at workplace. Pre-season mandatory hands-on training should be provided, with refresher sessions throughout the year. Training should be practical and cover the correct mixing, application, and disposal of pesticides. Since many workers have very different levels of education and ages, instructions should be given using simple language and by demonstration rather than relying on written materials.

Ensure access to PPE and enforce use.

Workers cannot defend themselves without appropriate equipment. Thus, farms should provide complete sets of PPEs, which include gloves, masks, goggles, boots, and aprons, free of charge. PPE should always be available, well-fitting, and replaced immediately it is worn out. Managers should ensure a strict policy of "no PPE, no handling." Furthermore, farms should have clean, designated rooms for storing, cleaning, and drying PPE to prevent contamination.

Follow stringent safety practices.

Safety at work can't be compromised. Spraying should not be done under windy or unstable weather conditions as this increases the likelihood of drift. Workers must be provided with facilities for changing, soap, and clean water so that immediately after pesticide application, they can clean off the residues. Small improvements in day-to-day hygiene go a long way in minimizing the long-term health risks.

iii. Agricultural colleges

Agricultural training institutions have an important part to play in educating their students on safe handling of pesticides. They should ensure that pesticide risks, proper handling, and IPM are part of the curriculum for all agriculture-related programs. Students graduating from an agriculture college should leave with a strong foundation in pesticide hazards and safer options.

Also, educational institutions can enhance access to information by developing training videos, mobile applications, and user-friendly resource manuals. The information should focus on clear, step-by-step instructions and address common misunderstandings, such as the belief that a pesticide is safe simply because it is applied frequently.

iv. Industry associations and cooperatives

Industry associations can bring together farms, government bodies, health experts, and training institutions to align the safety messages. Coordinated standards help avoid mixed messages coming through, and all the workers receive the same information.

Forums should be regularly organized where, in the presence of associations, workers, supervisors, regulators, and health officials, openly discuss safety matters. These platforms will help identify persistent problems, share best practices, and build trust across the sector. Improvement in safety in the floriculture industry and protection of workers from the health effects of pesticide use requires collaboration between the government, farms, educators, and associations.

6.3 Suggestions for further research

The research concentrated mainly on pesticide applicators who worked in floriculture. Nevertheless, further studies in pesticide use and safety should be undertaken, utilizing the lessons and knowledge generated in the present study. Future research should explore the impact of educational interventions on knowledge, attitudes, and practices over an extended follow-up period, to ascertain whether these interventions result in a sustained safer practice. Furthermore, comparisons of different agricultural sectors can provide information about sector related problems and the effects of safety activities.

It is important to investigate the health and environmental effects of pesticide use in floriculture and all other agricultural sectors. This involves investigating the frequency of health problems among pesticide applicators and evaluating environmental degradation arising from pesticide application. Further development and refinement of risk assessment models for predicting and reducing pesticide exposure are critical for advancing safety assessments.

Research on digital apps and their potential benefits to improve pesticide application practices (with potential effects on safety and compliance) may be analyzed. Furthermore, by identifying the psychological determinants, such as risk perception and the decision-making process of pesticide use, it can get a better insight into the reasons for adopting such behaviours.

In light of the beneficial behavioural changes identified in this study, additional work may focus on the extent to which public health interventions to reduce pesticide exposures and enhance the health of pesticide applicators may be effective. Such interventions could include health promotion efforts, early screening or treatment.

Finally, exploring multi-stakeholder partnerships among government bodies, industry players, farm workers and community-based organizations, is needed to improve safer use of pesticides.

Taken together, studies in these distinct fields can help in building a more holistic view on pesticide use and safety. This holistic knowledge can eventually bring better practice, less health risks and more sustainable pest control in crop production systems.

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APPENDICES

Appendix A: Questionnaire

PESTICIDE APPLICATORS' KNOWLEDGE, ATTITUDES AND PRACTICES OF PESTICIDE USE AND EXPOSURE IN FLORICULTURE FARMS IN NAIVASHA, KENYA

Hello, my name is Samuel Muniu a student from Moi University. I want to start by thanking you for your help in this study. As part of the study program, I am carrying out a study on knowledge, attitudes and practices associated with pesticide use and exposure among Kenyan pesticides applicators in floriculture farms in Naivasha. The information will be used solely for the purpose of the study and all of your answers to these questions are completely confidential. If you feel uncomfortable answering any these questions, please let me know. The questions will last about one hour. You can decline to answer any question or pull out at any stage of conversation. We would appreciate it if you are as honest as possible in your answers. Do you have any questions before we begin? May we have the interview?

Yes [] No []

Serial no:

Date:

Floriculture farm:

PART I: SOCIO-DEMOGRAPHIC CHARACTERISTICS

- 1) How old are you? _____years
- 2) Gender?
Male [] Female []
- 3) What is your marital status?
Never married [] married [] widowed []
Separated [] divorced []
- 4) Can you read and write in English?
Yes [] No []
- 5) What is the highest level of education that you have completed?

- 6) How many members are in your family? (*including interviewee*)
_____person(s)
- 7) How long have you been working in floriculture farms? _____ months
_____years
- 8) How long have you applied pesticides in floriculture farms? _____ months
_____years

PART II: KNOWLEDGE REGARDING PESTICIDE EXPOSURE

| Question | Yes | No |
|---|-----|----|
| 9) Do you know that, the exposure to pesticides has an adverse health effect or impact on the human health? | | |
| 10) If Q9 is yes, do all the pesticides have the same adverse health effect on human health? | | |
| 11) Which of the following is/are intake pathways for pesticides? | | |
| A. Inhalation | | |
| B. Skin absorption | | |
| C. Swallowing | | |
| 12) According to your knowledge, the toxicity symptoms of pesticides can be which of the following? | | |
| A. Headache | | |
| B. Watery eye / sore eyes | | |
| C. Heart attack / stroke | | |
| D. Nausea / vomiting | | |
| E. Excessive salivation | | |
| F. Cough / cold / chest pain / breathlessness | | |

| | | |
|---|--|--|
| G. Skin rash / skin irritation / itching | | |
| H. Abdominal pain / diarrhoea | | |
| I. Muscle weakness / fatigue / body pain | | |
| 13) Do you know that the pesticides residue may exist in the following? | | |
| A. The soil | | |
| B. The air | | |
| C. Ground water | | |
| D. Fruits, seeds or plant leaves | | |
| 14) Do you know that, there are internationally prohibited or forbidden pesticides? | | |
| 15) Do you know any other ways of pest control rather than pesticide use? | | |
| 16) If yes to Q23, do the pest control methods you know include the following? | | |
| A. Biological control | | |
| B. Natural control | | |
| 17) Do you know the names of pesticides you apply? | | |

18) If reply to Q17 is yes, please specify the names of the commonly used pesticides.

| | | |
|-------|-------|-------|
| _____ | _____ | _____ |
| _____ | | |
| _____ | _____ | _____ |
| _____ | | |
| _____ | _____ | _____ |
| _____ | | |

PART III: ATTITUDES TOWARDS PESTICIDES EXPOSURE

| Questions | Strongly agree | Agree | Disagree | Strongly disagree | Code |
|--|----------------|-------|----------|-------------------|------|
| 19) When spraying pesticides, you should not wear protective clothing thoroughly | | | | | |
| 20) It is necessary to use pesticides every time there is flower cultivation | | | | | |
| 21) A pesticide consisting of many compounds is of good quality | | | | | |
| 22) Spraying tank can be washed in a river/canal without any harm to the animals | | | | | |
| 23) Pesticides are harmful to the human health and environment | | | | | |
| 24) You should stand windward while spraying | | | | | |
| 25) All workers should have medical check-up for pesticide exposure at least once a year | | | | | |
| 26) You can smoke, drink and eat during pesticide spraying | | | | | |
| 27) During the spread of pests, increase the amount and concentration of the pesticide used | | | | | |
| 28) Anyone receiving pesticides will have a headache, become tired/exhausted and feel nauseated | | | | | |
| 29) You must stop spraying immediately it is windy | | | | | |
| 30) After using pesticides for a number of years, a person can develop an immunity to pesticides | | | | | |
| 31) Do you agree that every person who uses pesticides is responsible for its safe use? | | | | | |

PART IV: PRACTICE IN PESTICIDE USE

| Question | Yes | No |
|---|-----|----|
| 32) Do you have to spray pesticides the whole day? | | |
| 33) When a nozzle is clogged up, do you blow it with your mouth? | | |
| 34) What do you wear during preparing and spraying pesticides? | | |
| A. Gloves | | |
| B. Goggles | | |
| C. Wide brimmed hat | | |
| D. Mask | | |
| E. Special boots | | |
| F. Overall | | |
| 35) Do you spray both upwind and downwind? | | |
| 36) Have you ever done the following during spraying? | | |
| A. Smoking | | |
| B. Drinking | | |
| C. Eating | | |
| D. Chewing gum | | |
| 37) When you stop spraying for a meal, you only wash your hands? | | |
| 38) Do you stop spraying when it is windy? | | |
| 39) Do you continue spraying although your clothes are soaked in pesticides? | | |
| 40) Do you spray spreading over a large area? | | |
| 41) Do you clean the sprayer after finishing? | | |
| 42) Do you take shower after spraying? | | |
| 43) If yes to Q50, do you take the shower immediately after spraying? | | |
| 44) Do you wash the clothes you wear during spraying together with other clothes? | | |
| 45) Do you spray two or more mixed pesticides? | | |
| 46) Do you apply pesticides by spraying? | | |
| 47) Do you have a first aid place in the farm? | | |
| 48) Have you ever received basic training for applying pesticides? | | |
| 49) If Yes to Q48, did that training also include training on how to use protective equipment and clothing? | | |

Appendix B: List of Members of Lake Naivasha Growers Group

| | |
|----|---|
| 1 | Blooming Oasis Ltd |
| 2 | Bilashaka Flowers |
| 3 | Florema (K) Ltd |
| 4 | Kentalya (K) Ltd |
| 5 | Florensis (K) Ltd |
| 6 | Homegrown Ltd (all farms within Naivasha) |
| 7 | Kenya Nut Company Ltd |
| 8 | Lamorna Ltd |
| 9 | Longonot Farm Ltd |
| 10 | Longonot Horticulture Ltd |
| 11 | Nini Ltd |
| 12 | Norflora (K) Ltd |
| 13 | Ol' Njorowa Ltd |
| 14 | Oserian Development Company (including Stokman Rozen) |
| 15 | De Ruiters (K) Ltd |
| 16 | Plantation Plants (K) Ltd |
| 17 | Savanna International Ltd |
| 18 | Shalimar Ltd |
| 19 | Wildfire Flowers Ltd |

Appendix C: Test of Normality**Table 7. 1: Test of normality of knowledge, attitude and practice scores**

| | Kolmogorov-Smirnova ^a | | | Shapiro-Wilk | | |
|-----------------|----------------------------------|-----|-------|--------------|-----|-------|
| | Statistic | df | Sig. | Statistic | df | Sig. |
| Knowledge Score | 0.156 | 168 | 0.000 | 0.892 | 168 | 0.000 |
| Attitude Score | 0.090 | 168 | 0.002 | 0.974 | 168 | 0.003 |
| Practice Score | 0.184 | 168 | 0.000 | 0.953 | 168 | 0.000 |

a. Lilliefors Significance Correction

Appendix D: IREC Approval



MOI TEACHING AND REFERRAL HOSPITAL
P.O. BOX 3
ELDORET
Tel: 33471/2/3
Reference: IREC/2013/231
Approval Number: 0001140



MOI UNIVERSITY
SCHOOL OF MEDICINE
P.O. BOX 4606
ELDORET
12th February, 2014

INSTITUTIONAL RESEARCH AND ETHICS COMMITTEE (IREC)

Mr. Muniu Samuel Kimani,
Moi University,
School of Public Health,
P.O. Box 4606 - 30100,
ELDORET- KENYA.



Dear Mr. Kimani,

RE: FORMAL APPROVAL

The Institutional Research and Ethics Committee has reviewed your research proposal titled:-

"Pesticide Applicators' Knowledge, Attitude and Practices of Pesticide use and Exposure in Floriculture Farms in Naivasha Kenya."

Your proposal has been granted a Formal Approval Number: **FAN: IREC 1140** on 12th February, 2014. You are therefore permitted to begin your investigations.

Note that this approval is for 1 year; it will thus expire on 11th February, 2015. If it is necessary to continue with this research beyond the expiry date, a request for continuation should be made in writing to IREC Secretariat two months prior to the expiry date.

You are required to submit progress report(s) regularly as dictated by your proposal. Furthermore, you must notify the Committee of any proposal change (s) or amendment (s), serious or unexpected outcomes related to the conduct of the study, or study termination for any reason. The Committee expects to receive a final report at the end of the study.

Sincerely,

DR. W. ARUASA
DEPUTY-CHAIRMAN
INSTITUTIONAL RESEARCH AND ETHICS COMMITTEE

cc Director - MTRH
Principal - CHS
Dean - SOM
Dean - SOP
Dean - SON
Dean - SOD

Appendix E: Plagiarism Report

SR852

ISO 9001:2019 Certified Institution

THESIS WRITING COURSE***PLAGIARISM AWARENESS CERTIFICATE***

This certificate is awarded to

MUNTU SAMUEL KIMANI

SPH/PGH/1037/11

In recognition for passing the University's plagiarism

Awareness test for Thesis **entitled: PESTICIDE APPLICATORS' KNOWLEDGE, ATTITUDES AND PRACTICES OF PESTICIDE USE AND EXPOSURE IN FLORICULTURE FARMS IN NAIVASHA, KENYA** with similarity index of 5% and striving to maintain academic integrity.

Word count:22078

Awarded by

Prof. Anne Syomwene Kisilu

CERM-ESA Project Leader Date: 23/05/2025