

Project Report



Perceptions of Agrochemical Use and Associated Risks Among Farmers in Thoddoo Island, Maldives

The Small Island Conservancy

S206, One Avenue, Hulhumale
Male', Maldives



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Eliminating Persistent Organic
Pollutants through
Sound Management
of Chemicals



June, 2025

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Report Prepared by The Small Island Conservancy (The Silc)
Male City, Republic of Maldives

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PROJECT REPORT

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1. Introduction



1.1 Background

Agriculture in the Maldives, although historically overshadowed by the tourism sector, has long been a critical part of the nation's economy and food security infrastructure. As a small island developing state (SIDS), the Maldives is uniquely vulnerable to both environmental and socio-economic pressures. Despite its relatively minor direct contribution to the nation's GDP, agriculture plays an indispensable role in ensuring food security and providing livelihoods for many Maldivians. The country's agricultural systems, which primarily consist of horticultural crops, are fundamental in meeting the food demands of an ever-growing population. However, the agricultural sector faces significant challenges that threaten its sustainability and the long-term health of both the environment and the people who rely on it.

In the 21st century, agriculture's economic importance in the Maldives has been in decline due to the rapid growth of the tourism industry, which became the cornerstone of the economy. In 2015, tourism contributed 30% to the national GDP, while agriculture accounted for less than 5%, reflecting the growing dominance of the tourism sector in economic activities (Food and Agriculture Organization of the United Nations, 2018). Despite its small share in the overall economic output, agriculture remains vital to the livelihoods of a substantial portion of the population, particularly in rural areas where a majority of Maldivians are engaged in farming activities. The agricultural sector is also an important contributor to the nation's food security, as it provides a steady supply of essential crops for household consumption. The issue of food security is critical in the Maldives due to its reliance on food imports to meet the demands of a growing population and the pressures placed on local agricultural systems.

1.2 Agricultural Landscape in the Maldives

The agricultural landscape of the Maldives is distinctively shaped by its geography and the limited arable land available for cultivation. The archipelago consists of 1,192 coral islands, of which only around 200 are inhabited. Of these islands, a small fraction is dedicated to agricultural activities, with the total arable land area estimated to range from 2,800 to 3,000 hectares (FAO, 2018). These islands are divided into inhabited and uninhabited categories, with agriculture being carried out on a relatively small number of islands compared to the overall landmass of the country. As of 2015, there were 32 uninhabited islands designated for agricultural production, each ranging from 5 to 40 hectares in size. These agricultural islands are managed by both local and foreign entrepreneurs, with varying degrees of success in terms of yield and stability. Environmental factors, as well as

differences in agricultural practices, contribute to disparities in production, making some islands more productive than others.

The vast majority of agriculture in the Maldives takes place on inhabited islands, which collectively account for approximately two-thirds of the total arable land. This concentrated use of land for farming is a reflection of the need to balance agricultural productivity with the limited natural resources available on each island. Agricultural practices are predominantly focused on the cultivation of horticultural crops, including vegetables and tropical fruits such as watermelon, papaya, bananas, and local cash crops like betel leaves, chili, and local-kale. While there are no significant cereal grain crops grown in the Maldives, coconut and tropical almonds are also cultivated, adding to the diversity of agricultural output. However, these crops are largely limited to a narrow range of plant families, and many of them are hybrid varieties that are imported into the country to meet the demands of local farmers.



Fig 1.1 Papaya Farm in the Maldives

1.3 Challenges and Importance of Agrochemical Use in Maldivian Agriculture

Agriculture remains a crucial source of food and income for many Maldivians, but the sector faces several challenges. One of the most significant issues is the growing dependence on agrochemicals—specifically synthetic fertilizers and pesticides—to maintain and boost agricultural productivity. This increased reliance on agrochemicals is largely driven by the rising demand for food due to population growth. In particular, fertilizers have become a primary tool for enhancing soil fertility, offering a rapid solution to meet the nutritional needs of plants. This surge in fertilizer use, which began in the late 1980s, has been remarkable. While the use of fertilizers was almost nonexistent in the Maldives before that time, by 2014, the country imported 770 tonnes of synthetic fertilizers—up from fewer than 70 tonnes in 2005—despite the cropped area remaining relatively constant at around 2,900 to 3,000 hectares (FAO, 2018).

Chemical fertilizers are essential for improving soil fertility, especially in island settings where resources are limited. These fertilizers provide essential nutrients quickly, leading to enhanced crop growth in a short period. The cost-effectiveness and easy availability of chemical fertilizers, compared to organic alternatives, have made them the preferred choice for many farmers. The quick response they offer in providing nutrients to plants has led to their increasing demand in the Maldives, as they help meet the food production needs of a growing population. However, while they support higher productivity, the long-term environmental impacts of fertilizer use cannot be ignored. Similarly, pesticides play a crucial role in pest and disease management, safeguarding agricultural yields and ensuring food security. It is estimated that about 40% of global agricultural products are lost to pests and diseases (Mahmood et al., 2015), which is why pesticides are essential in preventing crop damage. They help maintain a steady food supply by mitigating pest-related crop losses and reducing the risk of foodborne diseases. Pesticides can be categorized based on their mechanisms of action: some destroy, repel, or mitigate pests. By controlling pests effectively, pesticides not only contribute to higher crop yields but also reduce the overall cost of food production, making food commodities more affordable for consumers. Moreover, pesticides help ensure that agricultural products remain safe for consumption, thereby improving food quality and protecting public health.

The use of agrochemicals, particularly fertilizers and pesticides, has become indispensable in the modern agricultural system of the Maldives. These chemicals play a vital role in enhancing soil fertility, increasing agricultural productivity, and safeguarding crops from pests and diseases. As a result, they directly contribute to the economic stability of the country and help ensure food security.

However, it is important to balance the benefits of agrochemical use with the potential environmental and health risks, ensuring that their application is done in a sustainable and regulated manner to protect both the ecosystem and public health.



Fig. 1.2 Pest Infestation in Crops: (a) Stem Borer on Brinjal; (b) Mealy Bug on Papaya.

1.4 Environmental and Health Risks of Agrochemical Overreliance

The overuse of fertilizers in the Maldives has led to significant environmental and health risks, especially given the fragile nature of the Maldivian ecosystem. The shallow, sandy soils typical of the islands are highly prone to nutrient leaching, particularly nitrogen, a major component of many synthetic fertilizers. Leaching occurs when excess fertilizers dissolve in water and seep into the soil, potentially contaminating groundwater and surface water sources. This issue is exacerbated by the well-drained nature of the soils and the country's small landmass, which makes the islands particularly vulnerable to nutrient runoff. Nitrogen leaching not only harms ecosystems but also leads to the degradation of soil quality over time. As soil fertility declines, its productivity diminishes, which, in turn, increases the reliance on chemical fertilizers. In addition to nitrogen, other nutrients and chemicals found in synthetic fertilizers, such as phosphorus and potassium, can also leach into the environment, contributing further to pollution and ecosystem degradation. In addition to fertilizers, pesticides are widely used to control pests and diseases, yet their overuse brings severe consequences for both human health and the environment. Pesticides, particularly when applied incorrectly or in excessive amounts, can pose neurotoxic, endocrine-disrupting, and

carcinogenic risks. These chemicals are often used without proper guidelines or training, leading to misuse and contamination of soil, water, and air. The lack of a comprehensive regulatory framework governing the import, sale, and use of agrochemicals in the Maldives further exacerbates these issues. While some regulations exist regarding agrochemical imports, the absence of strict enforcement means pesticide misuse remains a significant problem.

Another challenge facing the agricultural sector is the increasing pressure on available agricultural land. As arable land becomes scarcer, farmers are compelled to cultivate the same plots year after year without allowing the soil to rest and replenish. This practice accelerates soil degradation and depletes essential nutrients, intensifying the need for chemical inputs to maintain crop yields. Despite the growing availability of organic fertilizers, many farmers continue to prefer chemical fertilizers due to their cost-effectiveness, ease of use, and immediate results.

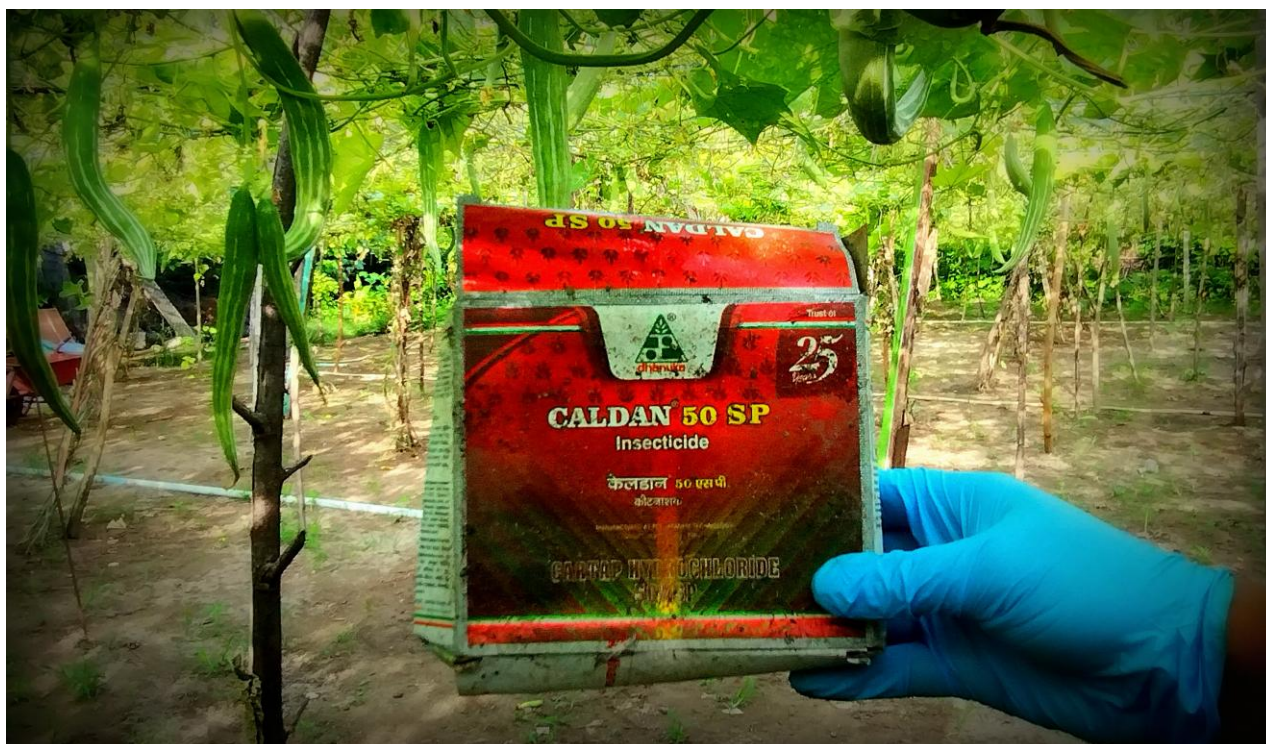


Fig. 1.3 Discarded Empty Container of a Widely Used Insecticide in the Background of a Snake Gourd Farm, Maldives.

1.5 Agriculture on Thoddoo Island, Maldives

Thoddoo Island, a part of the Maldivian coral atoll ecosystem, is a vital agricultural hub, supplying fresh produce to Malé and other centrally located islands. It is particularly renowned for being the largest producer of watermelons in the country, with production peaking during the holy month of Ramadan when demand and market prices are highest. In addition to watermelons, farmers on Thoddoo cultivate a diverse range of tropical fruits and vegetables, including papaya, honey melons, passion fruit, banana, water apple, mango, bitter gourd, chillies, brinjal, bottle gourd, radish, lettuce, drumstick, ladies' finger (okra), and pumpkin. The island is also recognized for its significant production of betel leaf.

As a coral island, Thoddoo's unique environment presents both opportunities and challenges for agriculture. The delicate coral-based ecosystem may be highly susceptible to human activities. Like elsewhere in the Maldives, Thoddoo may face issues related to the overuse of agrochemicals. The excessive application of fertilizers, pesticides, and herbicides may lead to the contamination of shallow groundwater systems, which in turn may seep into the surrounding coral reef lagoon. This may impact on agricultural sustainability and pose risks to coral reefs, which are vital for coastal protection and marine biodiversity. Improper handling of agricultural inputs, limited awareness of sustainable farming practices, and insufficient waste management systems may exacerbate these challenges. Runoff containing agrochemical residues may harm sensitive marine habitats and disrupt the intricate balance of the coral reef ecosystem. Additionally, the island's reliance on agriculture for livelihoods highlights the need for strategies that balance productivity with environmental preservation.

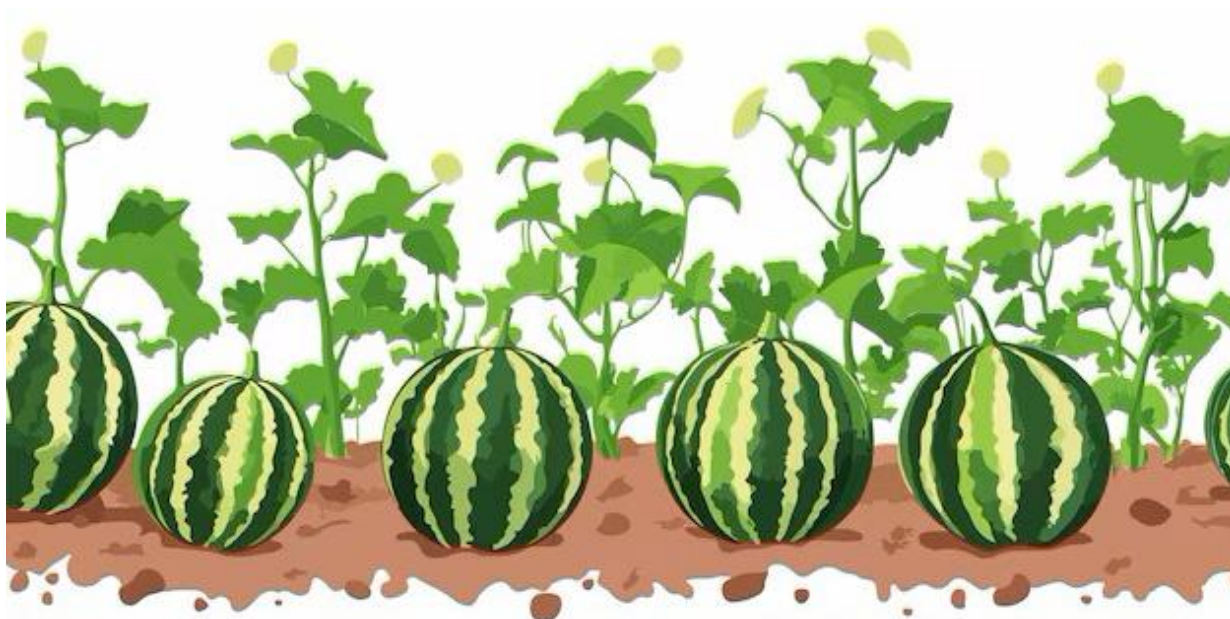


Fig. 1.4 A Watermelon Farm on Thoddoo Island, Maldives.

Understanding agrochemical usage and its potential impact on both terrestrial and marine ecosystems is critical for Thoddoo. This study aims to assess current practices, explore possible environmental and socio-economic implications, and propose sustainable agricultural and environmental management solutions for the long-term resilience of this coral island. This study aims to assess the current practices, identify key impacts, and propose strategies for sustainable agricultural management on Thoddoo Island.

1.6 Objectives of the Study

- To identify commonly used fertilizers and pesticides and analyze the frequency and methods of agrochemical application among farmers on Thoddoo Island.
- To assess farmers' knowledge of pesticide toxicity, safe handling practices, and the environmental impacts associated with the overuse of agrochemicals.
- To determine the concentration of pesticide residues in commonly cultivated and consumed crops on Thoddoo Island.
- To conduct a comprehensive examination of heavy metal bioaccumulation in commonly cultivated and consumed crops on Thoddoo Island, along with a carcinogenic and non-carcinogenic risk assessment for public health.
- To propose actionable strategies aimed at minimizing agrochemical usage and mitigating its adverse impacts on soil health, crop quality, and human health.
- To develop targeted awareness and capacity-building programs for farmers, the island council, and pesticide distributors, emphasizing the safe handling, responsible usage, and sustainable management of agrochemicals.



2. Materials & Methods



2.1 Study Location

The study was conducted on Thoddoo Island, one of the main agricultural hubs in the Maldives, renowned for its favorable environment for crop cultivation. The study was carried out over three days, from 2nd August 2024 to 4th August 2024. Various farms across the island were selected to capture a diverse range of agricultural practices and crop types. The farms included cultivating watermelon, luffa gourd, papaya, snake gourd, cucumber, brinjal, lettuce, passion fruit, and other vegetables and fruits. Thoddoo's prominence as an agricultural island stems from its significant contribution to the local and national food supply, with its produce often meeting high seasonal demands, particularly during Ramadan. The selection of diverse farms allowed for a comprehensive assessment of agrochemical usage across different crops and farming practices on the island.



Fig. 1.5 Thoddoo Island

2.2 Survey of agrochemical usage among farmers and farm workers

The survey was conducted among vegetable farmers and farm workers in Thoddoo Island, Maldives, using a structured questionnaire (Annexure 1) to assess the usage of agrochemicals in vegetable production. The questionnaire was divided into three sections: general demographics and farm characteristics, knowledge and attitudes towards pesticide and fertilizer use, and food consumption and body weight. Data was collected through face-to-face interviews, ensuring clarity and accuracy in the responses. The target population included farmers actively engaged in vegetable cultivation and workers involved in farm operations, who were selected using purposive sampling to capture diverse farming practices and experiences. Questions were designed to gather both quantitative and qualitative data, including household demographics, farm size, crop types, agrochemical usage patterns, and safety practices. Respondents were also asked about their food consumption habits and body weight to explore potential health implications. Ethical considerations were upheld by obtaining informed consent from participants and assuring them of the confidentiality of their responses. The data collected were analyzed to identify trends in agrochemical usage, safety awareness, and attitudes toward alternative practices.

2.3 Interaction with Thoddoo Council Members

As part of the survey, interactions were held with the council members of Thoddoo Island to gather government data and additional agricultural information. These discussions provided valuable insights into the regulatory framework governing agrochemical use, existing policies for sustainable farming, and support programs available for farmers. The council members also highlighted the practice of leasing farmland, particularly during the Ramadan season, to meet the increased demand for watermelon cultivation. They shared data on land use patterns, the extent of vegetable and fruit cultivation, and the measures taken to support farmers during peak agricultural seasons. This engagement ensured that the survey incorporated critical contextual information about local governance and agricultural dynamics in Thoddoo.

2.4 Sample Collection and Preparation

2.4.1 Pesticide residue analysis in crops

A total of 30 crop samples, representing 18 varieties, including watermelon, luffa gourd, papaya, snake gourd, cucumber, brinjal, lettuce, and passion fruit, were collected from various fields on the island. Immediately after collection, the samples were packed in ziplock bags and placed in an icebox. During the sampling days on the island, the samples were stored in a freezer. After

transportation to the laboratory, the samples were carefully cut into pieces, individually packaged in labeled plastic bags, and stored at -20°C in the dark until chemical analysis.

The extraction and clean-up method used was based on QuEChERS (quick easy cheap effective rugged and safe) sample preparation method for pesticide (Anastassiades et al., 2003; Sharma et al., 2021). A representative portion of the sample, weighing 250 g, was chopped into small pieces and blended using a food processor. From this, 15 g of the crushed sample was weighed into a 50 mL centrifuge tube. To this, 15 mL of 1% acetic acid in acetonitrile was added, followed by vortexing for 30 seconds. Subsequently, 6 g of anhydrous MgSO_4 , 1.5 g of anhydrous sodium acetate, and 75 μL of the Internal Standard (I.S.) solution were added. The mixture was shaken vigorously for 1 minute and then centrifuged at 4000 rpm for 1 minute. After centrifugation, 1 mL of the supernatant was transferred into a 15 mL centrifuge tube containing 50 mg of PSA (Primary Secondary Amine) and 150 mg of anhydrous MgSO_4 . The tube was shaken for 30 seconds and centrifuged again at 4000 rpm for 1 minute. For Gas Chromatography-Mass Spectrometry/Mass Spectrometry (GC-MS/MS) analysis, 0.6 mL of the extract was transferred into a GC vial and TPP (Triphenyl Phosphate) was added. For Liquid Chromatography-Mass Spectrometry/Mass Spectrometry (LC-MS/MS) analysis, 0.25 mL of the extract was combined with 0.75 mL of water and transferred into an LC vial. Finally, the pesticides were identified and quantified using GC-MS/MS and LC-MS/MS.

2.4.2 Heavy metal analysis in sediment matrix

For heavy metal analysis, sediment samples were collected from different types of farmlands during August 2024. Sediment samples were collected from selected study stations using plastic scoop in ziplock covers and oven-dried at 60°C. Powdered samples (0.5g) were subjected to nitric-perchloric acid ($\text{HNO}_3\text{:HClO}_4$) digestion in block digester (Pelican KES 20L R TS) at an initial temperature of 80 °C for 1 h, 100 °C for 2 h, and 150 °C for 2 h (AOAC, 1990). The resulting sample was filtered through a 0.45 μm filter paper and made up to a volume of 25 mL using Milli Q water and metals were analyzed in Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) (Agilent 5110).

2.4.3 Heavy metal analysis in crops

Eighteen different sample species of vegetables and fruits were collected from different farmland during August 2024. All samples were washed and stored in fresh polybag and brought to laboratory for analysis. In the sample preparation, all samples were cleaned with deionized water and chopped with stainless steel blade. Then, all samples were dried in oven at 60°C for 48 h, and

powdered using mortar and pestle. The samples were then transferred to boiling tubes and were digested by perchloric acid (HClO₄) and nitric acid (HNO₃) in 1:3 ratio at 180 °C in block digester (Pelican KES 20L R TS) until the formation of a clear solution, which then filtered in Whatman filter paper (1µm) and made up to 25 ml using milli Q water (AOAC,1990).. The extracts were analyzed for the metals using Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES; Make: Agilent; Model: 5110).

2.5 Human health risk assessment

Estimated daily intake (EDI)

The EDI values were calculated using equation from (Varol et al., 2022; Chowdhuri et al., 2024):

$$ETDI = \frac{Ed \times Ef \times Fir \times Mc}{BWa \times ATn} \times 10^{-3}$$

Ed- Exposure duration (75 years); Ef – Exposure frequency (365 days year⁻¹); Fir –ingestion rate; Mc- Metal concentration in the vegetable; BWa- average body weight (66 kg); AT-Mean Exposure Period (Ef×Ed).

Target Hazard Quotient (THQ)

THQ and HI values below one (<1) suggest minimal non-carcinogenic health risks for consumers, while values above one (>1) indicate the potential health risk (USEPA,1989). They were calculated using (Buchman, 1999):

$$THQ = \frac{Ed \times Ef \times Fir \times Mc}{BWa \times ATn \times RfD} \times 10^{-3}$$

Target Cancer Risk (TCR)

The carcinogenic risk, Target Cancer Risk, was calculated using the equation below [USEPA, 2021]:

$$TCR = \frac{Ed \times Ef \times Fir \times Mc \times CPS_o}{BWa \times ATc} \times 10^{-3}$$

CPS_o- Carcinogenic Potency Slope where, 0.5, 6.3 and 0.0085 mg kg⁻¹day⁻¹ for Cr, Cd and Pb respectively [USEPA, 2021].

The risk of cancer is negligible if the TCR values are less than 10⁻⁶, unacceptable if they are greater than 10⁻⁴, and acceptable if they are between 10⁻⁶ and 10⁻⁴ (USEPA,1991).

Plate 2.1: Sample collection from different farms



Plate 2.2: Interaction with farmers, the Thoddoo council, and pesticide sellers.



3. Agrochemical Use and Risk Perceptions among Farmers



3.1 General Demographics and Farm Characteristics

Thoddoo is a major agricultural hub supplying produce to Malé and other centrally located islands. While the island grows a variety of fruits and vegetables, including papaya, bitter melon, radish, and lettuce, it is best known for its watermelon production. Agriculture plays a central role in the livelihoods of 32% of households, which are involved in cultivating crops or raising livestock. For these households, farming serves as both a critical source of income and an essential food supply. Approximately 40% of the island's total population is linked to farming activities carried out by those whose primary occupation is agriculture. Farm management is shared between males (60%) and females (40%), with the average age of respondents being 45.2 years. Education levels among farmers vary, with 60% having primary education, 25% having secondary education, and 15% having no formal education. The average household size is six members, and farming is the main income source for 80% of respondents.

In Thoddoo, agriculture occupies 22-25% of the total land area, amounting to approximately 30-35 hectares. Farm sizes range from 0.02 to 1 hectare, with most farmers cultivating a variety of fruiting, leafy, and root vegetables. Thoddoo stands out with an average of 3.0 farming parcels per household, the highest in the Maldives. Agriculture is the primary economic activity on the island, and 67% of farmers focus on single-crop farming, while 11% practice inter-planted cropping and 27% cultivate mixed crops. Every citizen registered in Thoddoo is entitled to a parcel of agricultural land, provided free of charge and officially allocated by the local council. In many cases, family or household members combine their individual parcels into larger, adjacent plots, enabling them to farm more efficiently on a larger scale. Notably, Thoddoo is renowned for its watermelon cultivation, particularly during Ramadan. To meet the increased demand for watermelon during this period, the council allocates additional parcels of land to farmers specifically for this purpose, significantly boosting production to match the seasonal spike in consumption. During the period from 2010 to 2020, the council allocated additional parcels of land to farmers specifically for watermelon cultivation during Ramadan. This initiative significantly boosted production to meet the heightened seasonal demand, as shown in figure 3.1.

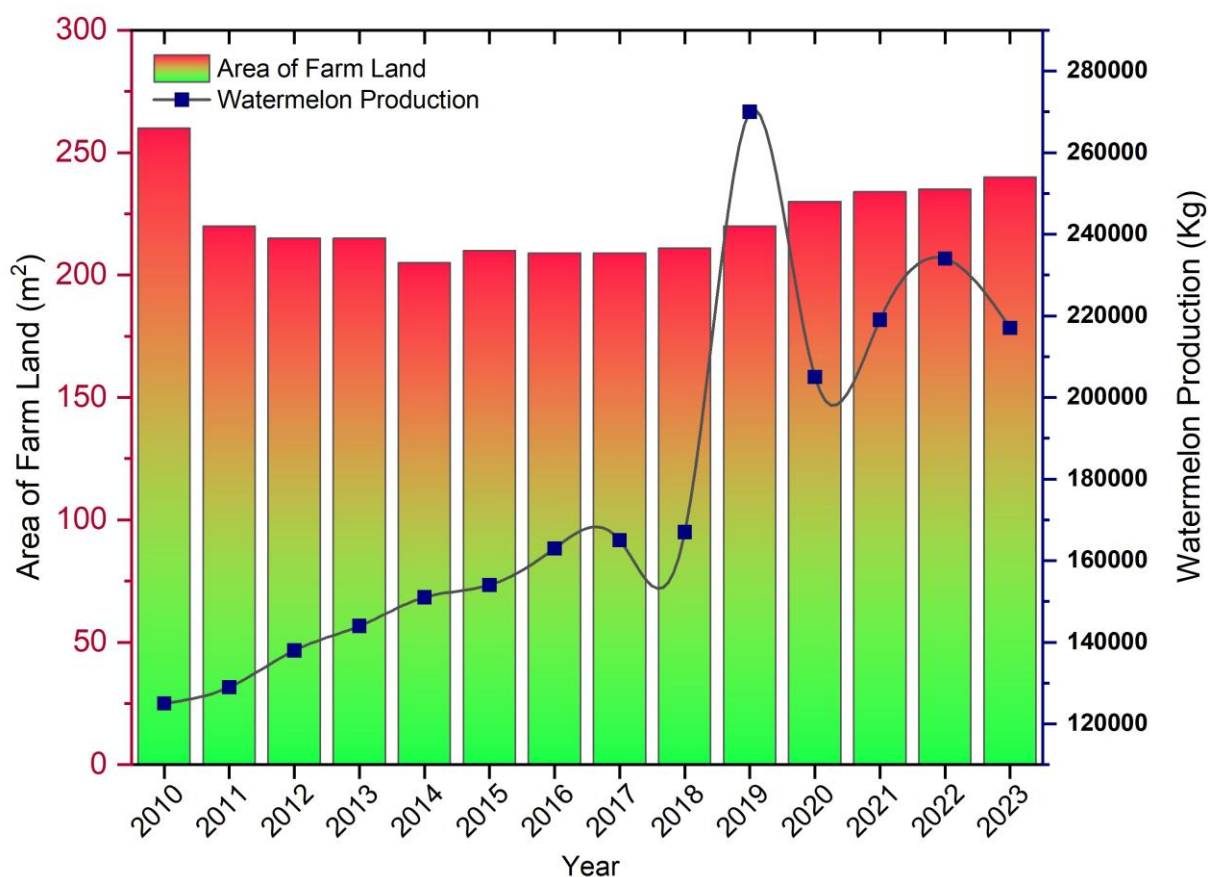


Fig. 3.1 Area of land provided to grow watermelon during Ramadan & Production of Watermelon, 2010-2020. (Source: Thoddoo Council)

However, during the study period, the most commonly grown crops included luffa gourd (10.4%), bitter gourd (8.1%), snake gourd (13.2%), long beans (1.7%), watermelon (4.5%), red spinach (0.9%), pumpkin (2%), Malabar spinach (2.9%), white radish or daikon (6.2%), green chilli (1.4%), curry leaves (2.2%), papaya (17.5%), lettuce (7%), brinjal (5.2%), cucumber (7.8%), winter melon (3.2%), passion fruit (3.9%), and betel (1.9%), shown in figure 3.2. Irrigation methods primarily relied on manual techniques, with 85% of farmers using methods such as drag hose spraying and watering cans, while 15% utilized sprinkler systems or other advanced methods. The primary source of irrigation water was well water. Most of the farm labor was carried out by workers from Bangladesh (90 %) and Northern India (10%), who predominantly lacked formal education, with 70% having no schooling and the rest possessing only primary-level education.

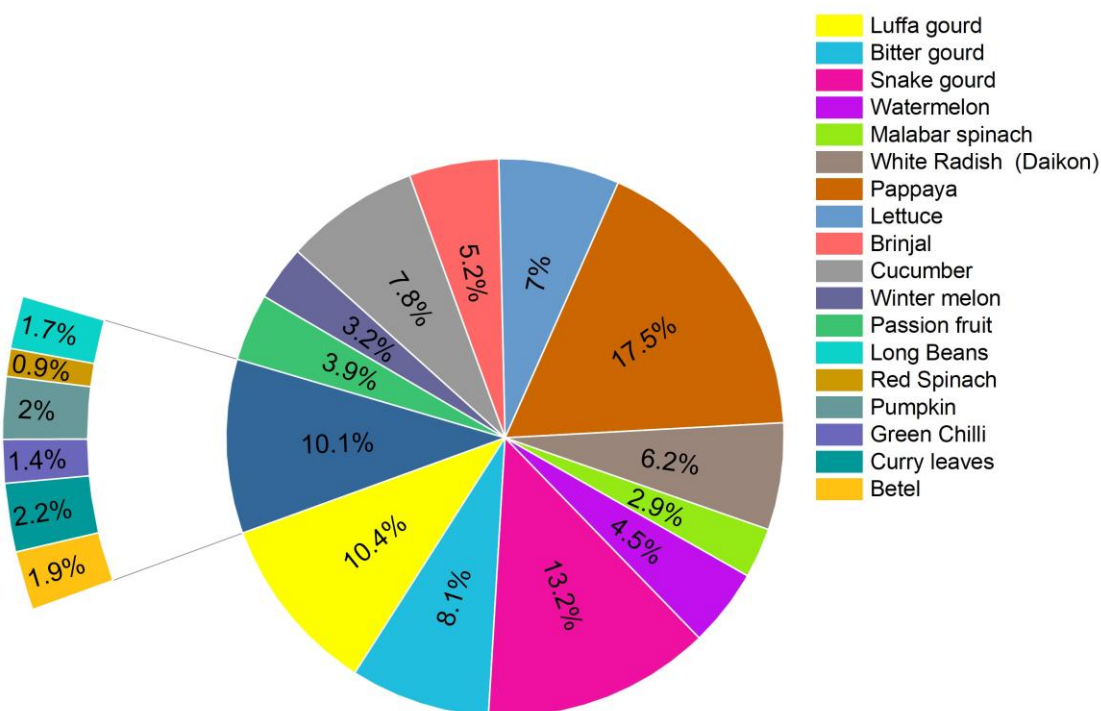


Fig. 3.2 Crop distribution in Thoddoo during the study period.

3.2 Pesticide and Fertilizer Usage

Fertilizers and pesticides are the most commonly used chemicals in the agricultural sector of the Maldives. Pesticides include fungicides, herbicides, anti-sprouting products, plant growth regulators, rodenticides, insecticides, and disinfectants, all of which are imported from countries such as Thailand, India, Sri Lanka, and Malaysia. Figure 3.3 illustrates the volume of pesticide imports to the Maldives, with insecticides comprising the largest share. Over a five-year period, the import of insecticides showed a significant increase, rising from 229.63 tonnes to 1,292.54 tonnes (MoECCT, 2022). Pesticides in the toxicity category WHO class I (Ia Extremely hazardous and Ib Highly hazardous) or any other pesticides in the banned pesticide list 35 issued by MoFMRA are not permitted for import to the Maldives. Pesticides imported into the Maldives are not solely intended for agricultural use. Chemicals such as rodenticides, insecticides, and disinfectants are also widely utilized in other sectors, including tourism, industrial applications, households, and commercial establishments.

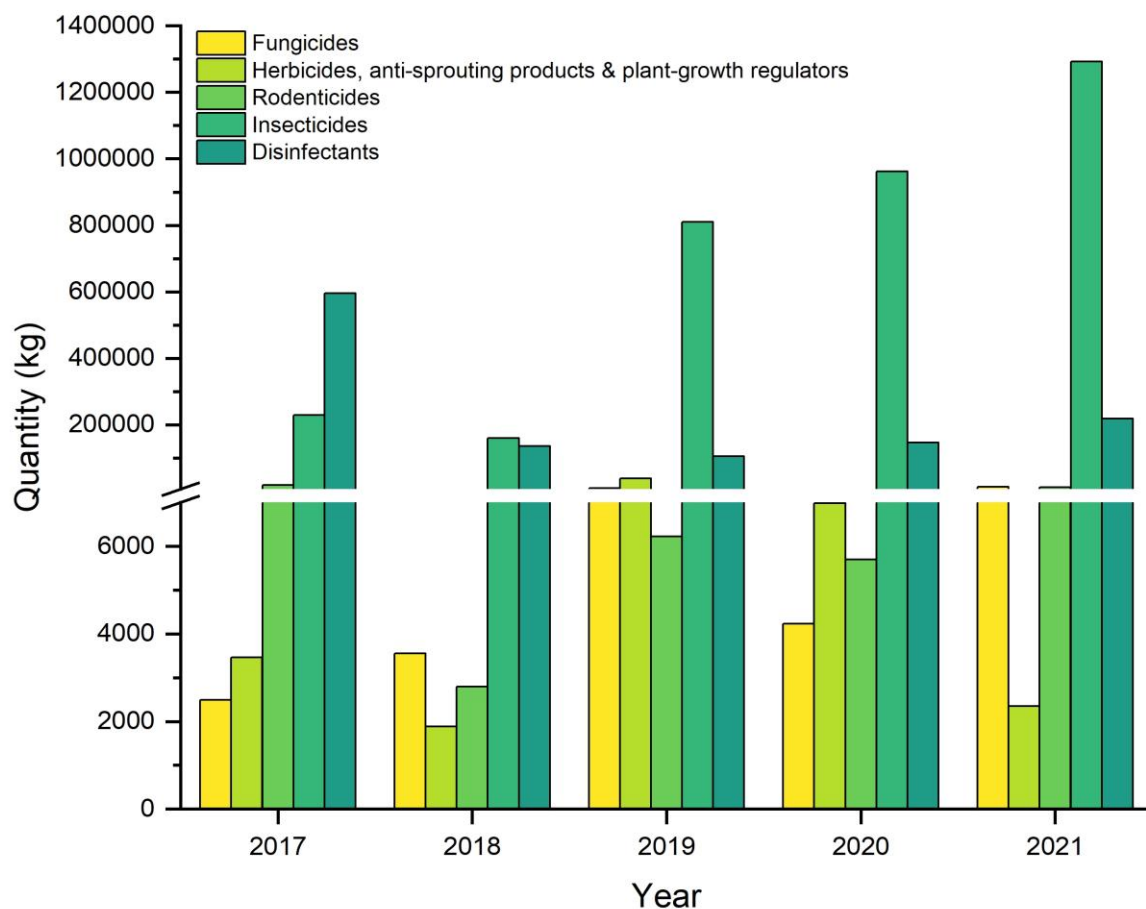


Fig. 3.3 Quantity of pesticides imported to the Maldives from 2017 to 2021. (Source: MoECCT, 2022).

Fertilizers, both organic and inorganic, are extensively used in the agriculture sector of the Maldives. Over a five-year period, the import of organic fertilizers surpassed that of inorganic fertilizers, although the quantity of inorganic fertilizers remained consistent throughout (Fig. 3.4). Among the chemical fertilizers imported, nitrogenous fertilizers and NPK (Nitrogen, Phosphorus, Potassium) fertilizers enriched with microelements were the most prominent. Key suppliers of these fertilizers to the Maldives include India, Sri Lanka, Italy, Turkey, the Netherlands, and Malaysia, highlighting a diverse sourcing network to meet agricultural demands.

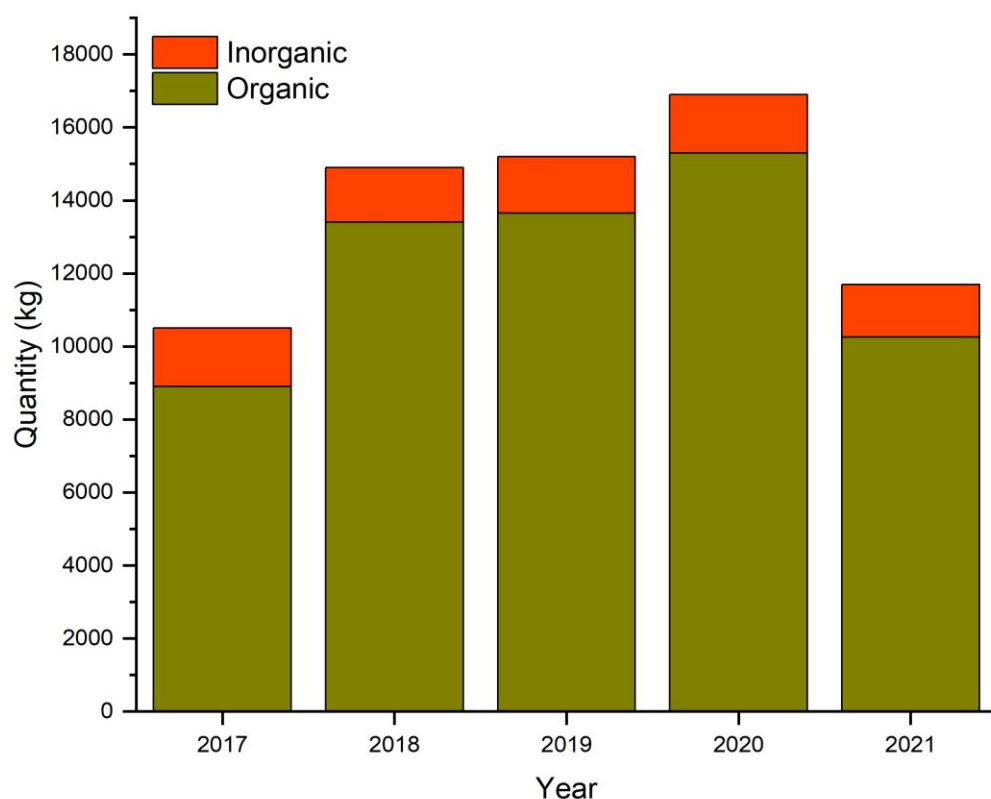


Fig. 3.4 Quantity of organic and inorganic fertilizers imported to the Maldives from 2017 to 2021. (Source: MoECCT, 2022).

In Thoddoo, all surveyed farmers reported using chemical pesticides and fertilizers. Among the farmers, the most commonly used type of pesticide was insecticides (67.5%), followed by fungicides (21.6%) and acaricides (5.4%). The survey highlighted the prominent and widely used pesticides, including Acetamiprid 20% SP, Cartap Hydrochloride 50% SP, Dimethoate, Mancozeb, Imidacloprid 70% WG, Permethrin 25% EC, Diafenthiuron 50% WP, Thiram, and Carbendazim. The study revealed that vegetable farmers on the island use a total of 34 commercially branded pesticides, which are categorized into 19 chemical families (Table. 3.1). Most of the identified pesticides belong to the following chemical classes: Neonicotinoid (16.2%), Pyrethroid (10.8%), Carbamate (10.8%), and Organophosphate (8.1%) (Fig. 3.5). Additionally, it was found that the pesticides used in Thoddoo are predominantly imported from Thailand (46.8%), India (43.87%), and Sri Lanka (6.25%). In addition to chemical pesticides, some farmers use neem oil and tobacco extract as organic alternatives, though their usage remains quite limited. When it comes to chemical fertilizer usage, nitrogen-based fertilizers are the most

prevalent. The most prominent types include NPK (Nitrogen, Phosphorus, Potassium) fertilizers enriched with microelements or sulfur (70%), urea (25%), and potash (5%).

Table. 3.1 Major pesticides used in Thoddoo identified during the study

Trade Name	Chemical Name	Chemical Class	Category	Origin
Admire	Imidacloprid 70% WG	Neonicotinoid	Insecticide	India
Amsac	Indoxacarb 14.5% SC	Oxadiazine	Insecticide	India
Baurs Sulphur	Sulphur 80% WDG	Inorganic Sulfur	Fungicide	Sri Lanka
Bifensin 10	Bifenthrin 10% EC	Pyrethroid	Insecticide	Thailand
Bochum	Ethaboxam	Thiazole Carboxamide	Fungicide	Thailand
Bryda	Imidacloprid 70% WG	Neonicotinoid	Insecticide	Thailand
Bucklin	Lambda Cyhalothrin 2.5 % EC	Pyrethroids	Insecticide	Thailand
Caldan 50 SP	Cartap Hydrochloride 50 % SP	Nereistoxin	Insecticide	India
C-Cron	Profenofos	Organophosphate	Insecticide	Sri Lanka
Clipper 20sl	Acetamiprid 20% SP	Neonicotinide	Insecticide	Malaysia
Commando	Trizinc Diphosphide 80 PW	Inorganic	Rodenticide	Thailand
Cover	Chlorantraniliprole 18.5% SC	Anthranilic Diamide	Insecticide	India
Cypermethrin	Cypermethrin	Pyrethroid	Insecticide	
Dhan Preet	Acetamiprid 20% SP	Neonicotinide	Insecticide	India
Dimethoade	Dimethoate	Organophosphate	Insecticide	Thailand
Dithane NTM 45	Mancozeb	Dithiocarbamate/Alkylenebis	Fungicide	Thailand
Erasulfan	Carbosulfan	Carbamate	Insecticide	Thailand
Eravil	Hexaconazole	Triazole	Fungicide	Thailand
Exalt	Spinetoram 12% SC	Spinosyn	Insecticide	Thailand
Fenobu	Fenobucarb 50% EC	Carbamate	Insecticide	Thailand
Folicur	Tebuconazole 250 EC	Triazole	Fungicide	India
Jimmy	Diafenthiuron 50% WC	Thiourea	Insecticide & Acaricide	India
Kobra Imidacloprid	Imidacloprid 20% SL	Neonicotinoid	Insecticide	Sri Lanka
Megavet	Sulphur 80% WDG	Inorganic Sulfur	Fungicide	India
Pager	Diafenthiuron 50%	Thiourea	Insecticide	India
Permeet	Permethrin 25% EC	Pyrethroid	Insecticide	India
Profex	Profenofos 50% EC	Organophosphate	Insecticide	India
Q-Mectin	Abamectin 1.8% EC	Avermectin	Insecticide, Acaricide & Nematicide	Thailand
Safal	Carbendazim 12%+Mancozeb 63%	Benzimidazoles & Dithiocarbamate	Fungicide	India
Senora	Novaluron 5.25% + Indoxacarb 4.5% SC	Benzoylurea & Oxadiazine	Insecticide	India
Sevin	Carbaryl 50 WP	Carbamate	Insecticide	Germany
Starkle G	Dinotefuran	Neonicotinoid	Insecticide	Thailand
Thianosan	Thiram	Dithiocarbamate/Alkylenebis	Fungicide	Thailand
Zordar	Emamectin Benzoate 1.5%+ Fipronil 3.5% SC	Avermectin & Phenylpyrazole	Insecticide	India

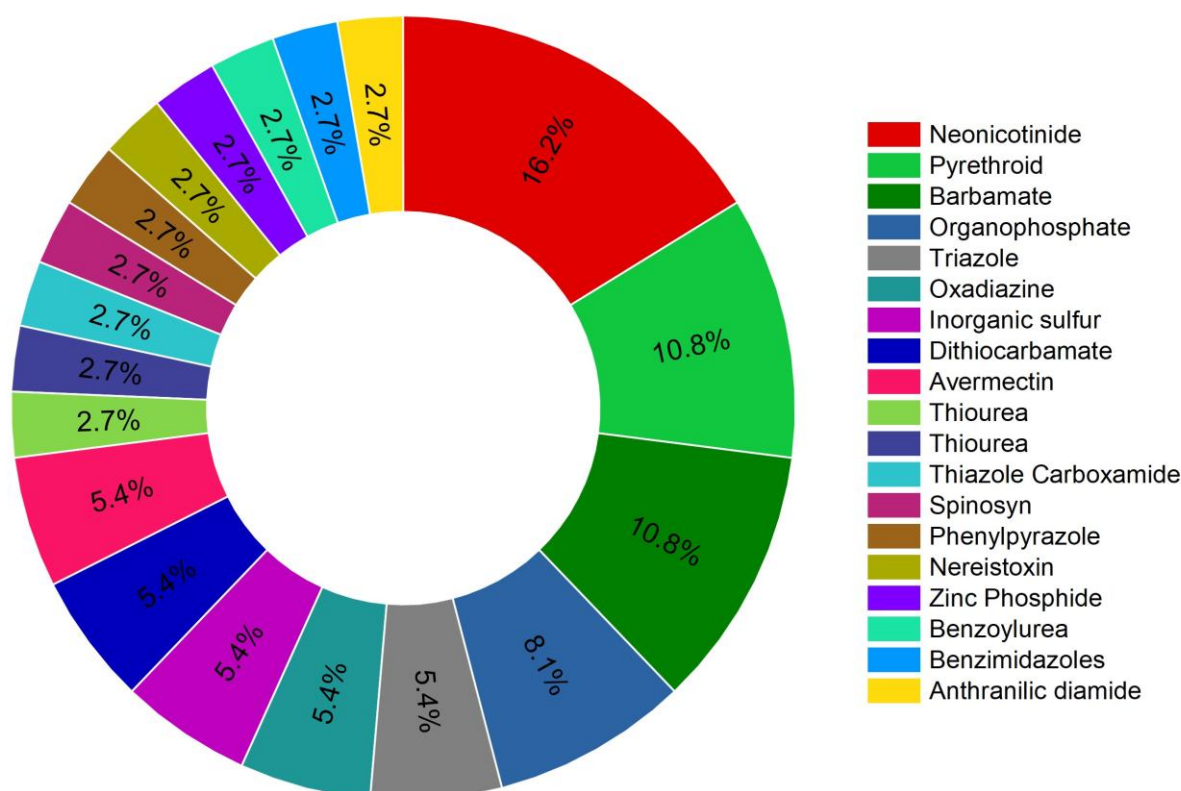


Fig. 3.5 Percentage distribution of identified pesticide chemical classes.

Based on the survey and discussions with the Thoddoo Council, significant changes have been observed in the island's farming practices over the years. Prior to the 1980s, farmers primarily relied on traditional methods for cultivation. Pest control was achieved using natural substances like tobacco extract and neem oil, while cow dung and cattle manure served as the main sources of fertilizer. Land preparation was done manually, involving the clearing of natural vegetation, which was then dried and burned to produce ash. This ash was spread over the fields using wooden rakes to enrich the soil. However, with the shift towards conventional farming practices after 2000, chemical pesticides and fertilizers became more widely used due to their perceived effectiveness and cost-efficiency. This transition coincided with a noticeable increase in pest pressures on the island. Pests such as mosaic viruses, stem borers, leaf rollers, aphids, and mealybugs have become more prevalent, posing serious challenges to crop production. Crops like papaya, pumpkin, melon, and cucumber are particularly vulnerable to mosaic virus infections. Despite the growing use of chemical inputs, many farmers continue to apply organic fertilizers

and cow dung to maintain soil fertility, reflecting a blend of traditional and modern farming approaches.

The annual import data (Fig. 3.4) reveals that the Maldives consistently imports a higher quantity of organic fertilizers compared to chemical fertilizers. This disparity is primarily due to the larger volumes of organic fertilizers required to achieve desired effects in crop production. Unlike inorganic fertilizers, which are potent and used in smaller quantities, organic fertilizers need to be applied in bulk, resulting in higher import tonnage. Despite this, Maldivian farmers continue to rely on chemical fertilizers alongside organic options. Inorganic fertilizers are widely preferred due to their cost-effectiveness, efficiency, and availability. Nearly all the farmers interviewed expressed a clear preference for chemical fertilizers such as NPK (Nitrogen, Phosphorus, Potassium) over organic alternatives. They reported that inorganic fertilizers offer better crop yields with smaller application volumes, making them more economical and practical for regular use. These chemical fertilizers commonly supply one or more of the essential macronutrients—nitrogen, phosphorus, and potassium—along with secondary nutrients like calcium, magnesium, and sulfur, and micronutrients including copper, iron, manganese, zinc, and boron, which are vital for plant health and productivity. It is important to note that Thoddoo Island has only two agrochemical shops, which serve as the primary sources for farmers to obtain pest control products and agricultural inputs. This limited access could influence the availability and timely use of fertilizers and pesticides on the island.

3.3 Knowledge, Practices, and Risk Perceptions

Farmers on Thoddoo Island exhibit a significant lack of knowledge regarding pesticide toxicity and do not adhere to specific guidelines for pesticide application. Instead, they employ a non-systematic approach, applying various pesticides to different crops based on personal experience and traditional methods. A large proportion of farm workers (90%) determine the quantity of agrochemicals to use based on personal judgment, often passed down from previous workers on the farm, rather than relying on manufacturer instructions or guidance from agricultural councils. The survey findings reveal that most farmers do not follow the recommended dosage of pesticides indicated on product labels, leading to instances of overdosing. A major challenge identified during the survey is that most agrochemicals are imported, with labels predominantly written in the regional languages of the exporting countries, such as Thai, Hindi, Sinhala, and occasionally English. This language barrier prevents local farmers from understanding the label instructions, contributing to improper pesticide use. None of the participants considered it necessary to strictly

follow the pesticide application directions. Additionally, no farmer had a designated storage area for pesticides. The majority of respondents stored pesticides haphazardly, alongside fertilizers and other farm equipment.

The majority of farmers reported routine pesticide applications as a preventive measure against pest invasions. Preventive spraying once a week was the most commonly practiced frequency, with 45% of respondents indicating this schedule. Some farmers applied pesticides more than twice a week on a regular basis, while the average frequency across all participants was twice a month. Manual spraying was the primary method employed by all farmers for pesticide application.

Island farmers continue to use chemical fertilizers in conjunction with organic options, as they are considered more cost-effective, efficient, and readily available. All the farmers interviewed identified NPK fertilizers as their primary chemical fertilizer, with many also using potassium-based fertilizers. Additionally, farmers apply cow dung as an organic fertilizer every 2-3 months. The majority of farmers (60%) applied fertilizers more than twice a week on a regular basis, with the average frequency across all participants being four times per month. In cases where crops appeared weak, some farmers increased their application to four times a week. The primary methods of fertilizer application were broadcasting (60%), spraying (20%), and banding (10%).

Risk perceptions varied, 35 % of respondents were aware of the health risks posed by agrochemical overuse, such as respiratory problems, skin irritation, and chronic conditions, 20 % expressed neutrality, and 45 % were largely unaware of these risks. Despite this, farmers had not received adequate training on the safe handling and application of pesticides and fertilizers. Only 60 % of farmers consistently used personal protective equipment (PPE), with cloth wraps around the nose and mouth, as well as full-sleeved clothing, and a glove being the most commonly used items. Notably, none of the farmers fully adhered to PPE guidelines, leaving areas such as the respiratory system, head, eyes, and hands unprotected. The main reasons cited for inadequate protection were a lack of awareness about pesticide hazards and the high cost of protective equipment.

All the farmers interviewed admitted to overusing agrochemicals, citing perceived pest resistance and the desire to maximize yields as the primary reasons. While 70% believed agrochemicals were essential for successful vegetable production, 20% expressed interest in exploring alternatives like organic fertilizers and biological control methods. However, barriers such as high

costs (64%) and a lack of awareness (36%) hindered the adoption of these practices. Interestingly, none of the farmers were aware of the harmful effects of agrochemical overuse on soil and ecology, including soil infertility, acidification, salinization, water contamination, microbial imbalance, biodiversity loss, and the emergence of resistant pests and weeds—factors that pose serious threats to sustainable agriculture and environmental health.

The survey revealed that farmers on Thoddoo Island predominantly use manual spraying for pesticide application and broadcasting for fertilizer application. These methods, while familiar and convenient, are often implemented without adherence to recommended guidelines, leading to significant health and environmental risks. Manual spraying, used by all surveyed farmers, frequently results in pesticide overdosing and direct exposure due to the absence of proper personal protective equipment (PPE). Similarly, broadcasting—practiced by 60% of farmers—leads to uneven fertilizer distribution, nutrient runoff, and long-term soil degradation. Spraying of fertilizers and the more targeted banding method were far less common, despite their potential for greater efficiency and reduced environmental impact. Fertilizers and pesticides are applied routinely, often more than twice a week, driven by a perceived need for constant protection against pests and to enhance crop productivity. However, this non-systematic, high-frequency application has led to growing pest resistance and a dependency on agrochemicals. Although 60% of farmers use some form of PPE, such as cloth wraps and gloves, none fully adhere to safety protocols, citing the high cost of equipment and a lack of awareness. The widespread reliance on traditional knowledge, coupled with imported agrochemicals labeled in unfamiliar languages, further exacerbates misuse. These findings highlight the urgent need for training programs, improved access to protective gear, and promotion of safer and more sustainable agrochemical application methods to safeguard both human health and ecological integrity.

Table 3.2. Summary of Agrochemical Application Methods, Effectiveness, and Risks

Method	Usage (Based on Survey)	Effectiveness	Associated Risks
Manual Spraying (Pesticides)	100% of farmers	Effective short-term pest control, if properly applied	High risk of over-application, exposure to toxic chemicals, pest resistance, uneven coverage
Broadcasting (Fertilizers)	60% of farmers	Easy and quick, but often inefficient	Nutrient wastage, soil nutrient imbalance, and water contamination contribute to soil degradation
Spraying (Fertilizers)	20% of farmers	Potentially efficient with correct dilution and targeting	Same exposure risks as pesticide spraying; ineffective if instructions are not followed
Banding (Fertilizers)	10% of farmers	More precise nutrient delivery to root zones	Low, if done correctly, is an underutilized method despite its advantages
Frequency of Pesticide Application	Preventive weekly (45%), some >2x/week	May reduce pests temporarily	Promotes resistance, causes environmental buildup of chemicals
Frequency of Fertilizer Application	Most >2x/week; average 4x/month	Supports growth, but frequent use leads to dependency	Potential for soil salinization, acidification, and microbial disruption
Use of PPE	60% partial use (cloth wraps/gloves)	Reduces personal risk when complete	Incomplete PPE use exposes the respiratory system, eyes, and skin; high cost and lack of awareness cited

3.4 Disposal Practices

Waste management is a critical concern in the life cycle of agrochemicals. While solid waste management facilities have been established in various regions of the Maldives, no designated areas meet the environmental criteria for the disposal of chemicals. On many islands, waste segregation is not practiced, and all types of waste are either discarded in dump sites, burned, or dumped into the ocean. Agrochemical waste is treated similarly, with chemical containers mixed with other waste and improperly discarded. This issue is no different in Thoddoo, where similar waste disposal practices are observed. Improper disposal of pesticide and fertilizer containers has become a significant issue. Forty percent of respondents reported burning or burying these containers, while 20% admitted storing them on farms for occasional reuse. The remaining respondents indicated that they either handed the containers over to waste management collection teams or disposed of them at designated disposal sites, underscoring the need for better waste management systems.

3.5 Challenges Identified

- **High Dependency on Agrochemicals:** Farmers rely heavily on agrochemicals due to pest pressures and soil nutrient deficiencies.
- **Limited Training and Awareness:** Inadequate access to training programs contributes to unsafe agricultural practices.
- **Inadequate Waste Management:** Poor waste disposal systems increase environmental risks.
- **Language Barrier:** Most agrochemical labels are written in the regional languages of exporting countries (Thai, Hindi, Sinhala, and occasionally English), making it difficult for farmers to understand proper usage instructions.
- **Financial Constraints:** The high cost of organic or alternative methods limits their adoption.
- **Improper Guidance:** A lack of proper guidance on agrochemical application results in overuse behaviors.

3.6 Recommendations

Promote Integrated Pest and Nutrient Management (IPNM):

- Encourage the use of organic fertilizers, composting, and manure to improve soil health and reduce reliance on chemical fertilizers.
- Introducing farmers to eco-friendly pest control methods, such as neem oil, tobacco extracts, and other plant-based bio-pesticides.

Enhance Training and Awareness Programs:

- Conduct workshops on the preparation and use of organic fertilizers, compost, and natural pest control methods.
- Educate farmers on the long-term benefits of sustainable farming practices, including soil fertility restoration and cost savings.

Improve Waste Management Systems:

- Set up designated collection points for safe disposal of pesticide and fertilizer containers.
- Provide training on proper disposal methods and the importance of recycling containers to prevent environmental hazards.

Address Language Barriers:

- Ensure agrochemical labels and usage instructions are translated into the dhivehi language and include user-friendly visuals for easy understanding.

- Develop dhivehi & multilingual guides and video tutorials for farmers to understand safe application practices.

Subsidize Sustainable Practices:

- Provide financial incentives or subsidies for organic fertilizers, bio-pesticides, and composting tools.
- Offer support programs for transitioning to sustainable farming, such as grants for purchasing organic inputs or setting up composting units.

Strengthen Regulatory Oversight:

- Regulate the import and sale of agrochemicals to ensure proper labeling, quality standards, and controlled usage.
- Encourage the local production of organic inputs to reduce dependency on imported chemicals.

Encourage Farmer Collectives and Knowledge Sharing:

- Promote farmer cooperatives to share resources, knowledge, and experiences related to organic farming and natural pest control.
- Facilitate group training programs and field demonstrations of organic farming techniques.

Develop Local Research and Support Systems:

- Establish agricultural extension centers to provide real-time guidance on organic farming, composting, and eco-friendly pest management.
- Encourage research on region-specific natural pest control methods and organic farming innovations.

Foster Awareness of Long-Term Benefits:

- Highlight the economic and environmental advantages of adopting organic fertilizers and bio-pesticides, including improved soil fertility and reduced health risks.
- Showcase success stories of farmers who have successfully transitioned to sustainable practices.

Plate 3.1: Different types of crop farms in Thoddoo



Plate 3.2: Different types of crop farms in Thoddoo

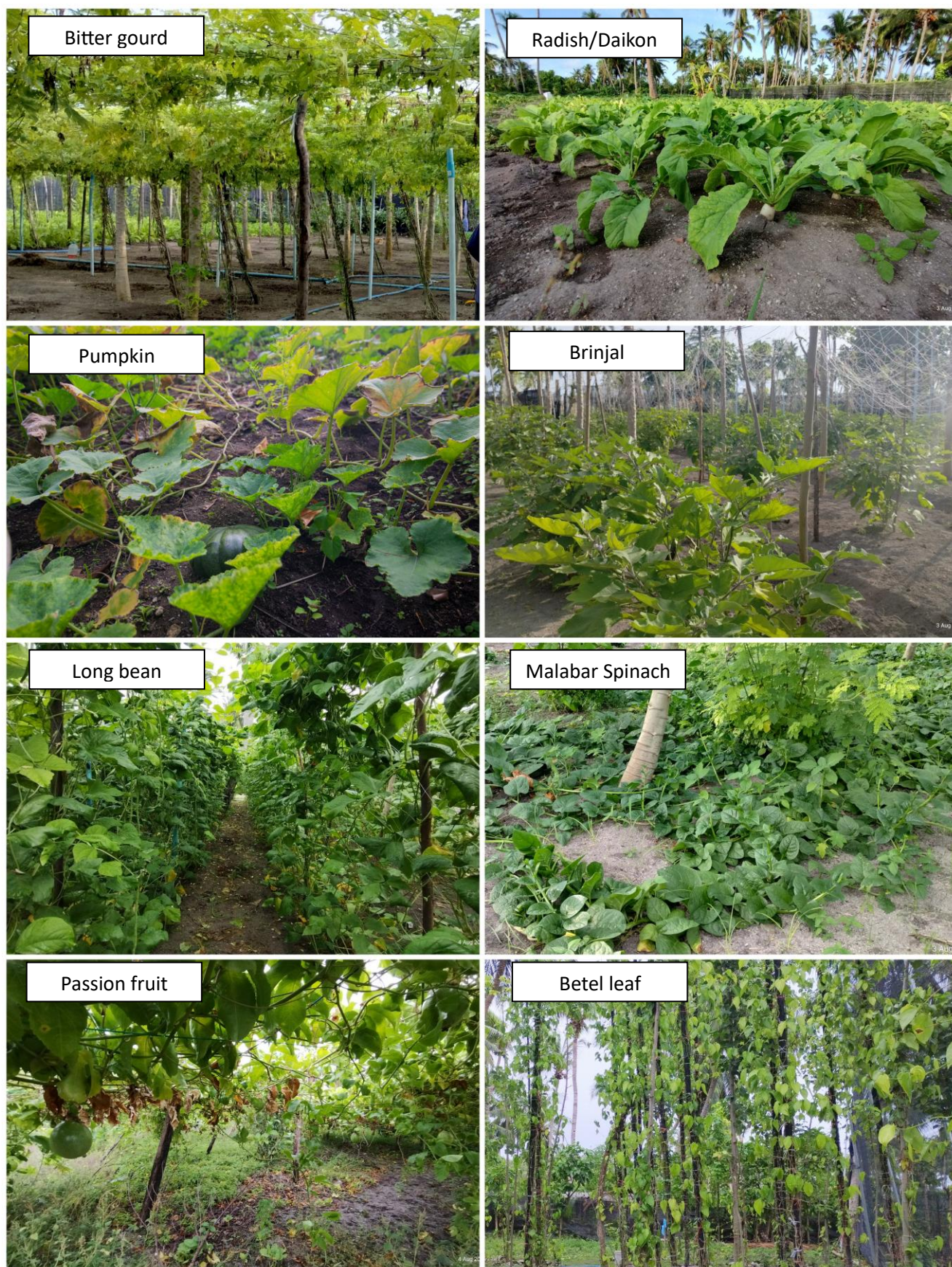
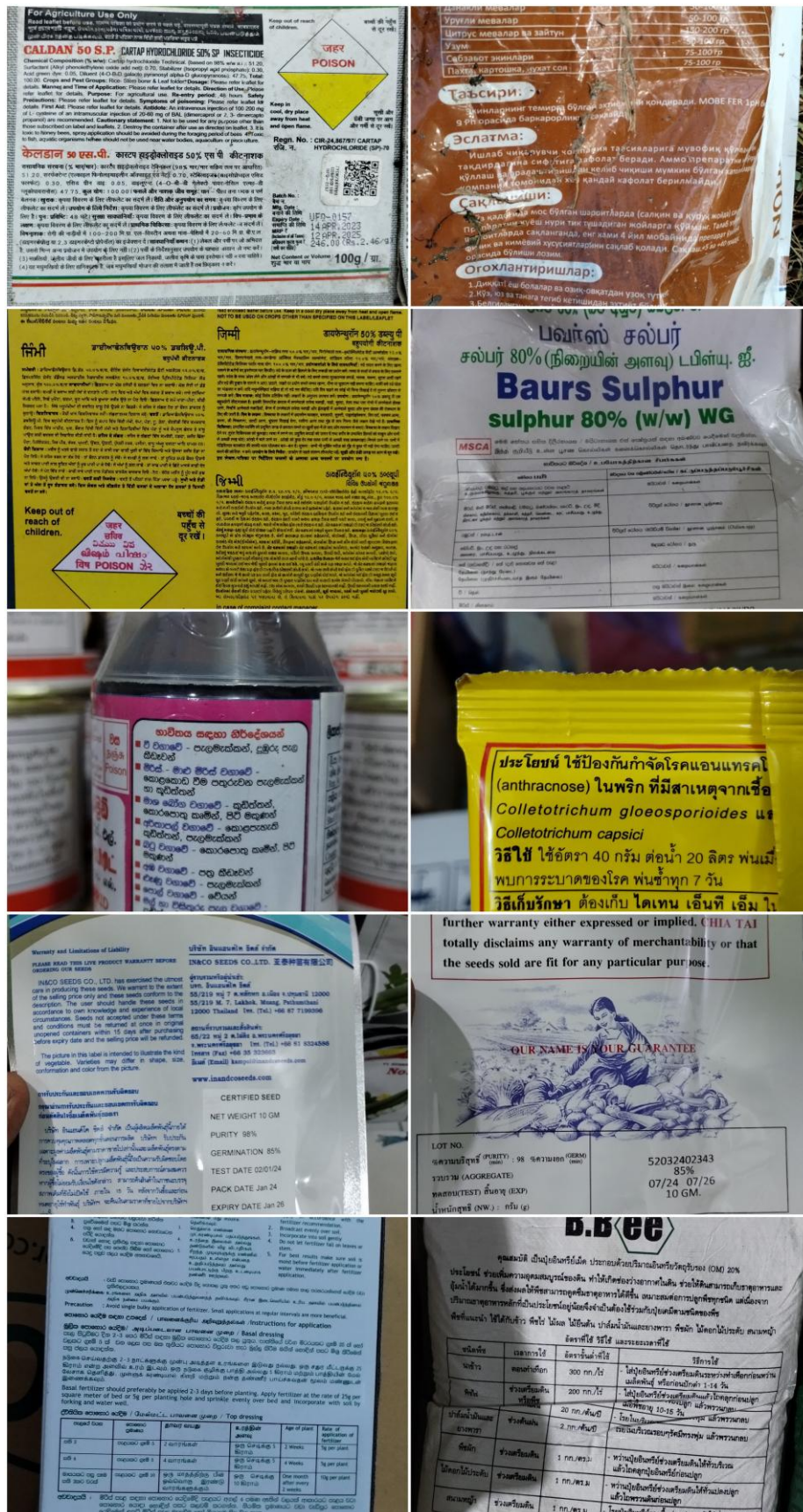


Plate 3.3: Empty pesticide and chemical fertilizer packets dumped in farmlands



Plate 3.4: Labeling and instructions on agrochemicals written in foreign languages



4. Pesticide Residue Analysis in Thoddoo Island Agriculture



The presence of pesticide residues in vegetables and fruits has emerged as a significant public health concern due to their potential adverse effects on human health and environmental sustainability. Prolonged exposure to these residues, even in trace amounts, has been associated with a range of health issues, including endocrine disruption, neurotoxicity, and carcinogenicity. Furthermore, the accumulation of pesticide residues in soil and water resources can lead to long-term ecological damage. To ensure food safety, mitigate health risks, and comply with national and international regulatory standards, routine monitoring of pesticide residues in agricultural produce is imperative. Here we provide a detailed analysis of pesticide concentration in various vegetables and fruits, measured in milligrams per kilogram (mg/kg). The data spans ten different crops, with residues from multiple pesticides identified. The crops analyzed include Luffa gourd, Snake gourd, Watermelon, Red spinach, Daikon/Radish, Papaya, Lettuce, Brinjal, Cucumber, and Passion fruit. The pesticides identified and quantified include commonly used insecticides, fungicides, and acaricides, such as Acetamiprid, Carbaryl, Dimethoate, Permethrin, and Mancozeb. This includes both the individual pesticide concentration in each crop and the total pesticide load.

4.1 Overview of Total Pesticide Residue

The cumulative pesticide residue for each crop varied significantly. Watermelon recorded the highest cumulative pesticide residue at 1.8068 mg/kg, followed by Red spinach (1.41 mg/kg) and Papaya (1.244 mg/kg). Snake gourd also had a relatively high cumulative residue of 1.067 mg/kg. On the other end of the spectrum, Passion fruit exhibited the lowest cumulative residue, measuring 0.403 mg/kg, while Cucumber (0.463 mg/kg) and Brinjal (0.473 mg/kg) were slightly higher (Fig. 4.1a). This variation reflects differences in pesticide application practices and crop susceptibility to pests, as well as differences in their surface area and pesticide retention properties.

4.2 Pesticide-Specific Analysis

Out of the 17 pesticide residues, Mancozeb has the highest mean concentration at 0.23 mg/kg \pm 0.128, followed by Carbendazim (0.216 mg/kg \pm 0.217), Dimethoate (0.214 mg/kg \pm 0.269), Permethrin (0.204 mg/kg \pm 0.361), and Acetamiprid (0.12 mg/kg \pm 0.066). The lowest concentrations were found in Bifenthrin (0.002 mg/kg \pm 0) and Diafenthiuron (0.006 mg/kg \pm 0) (Fig. 4.1b).

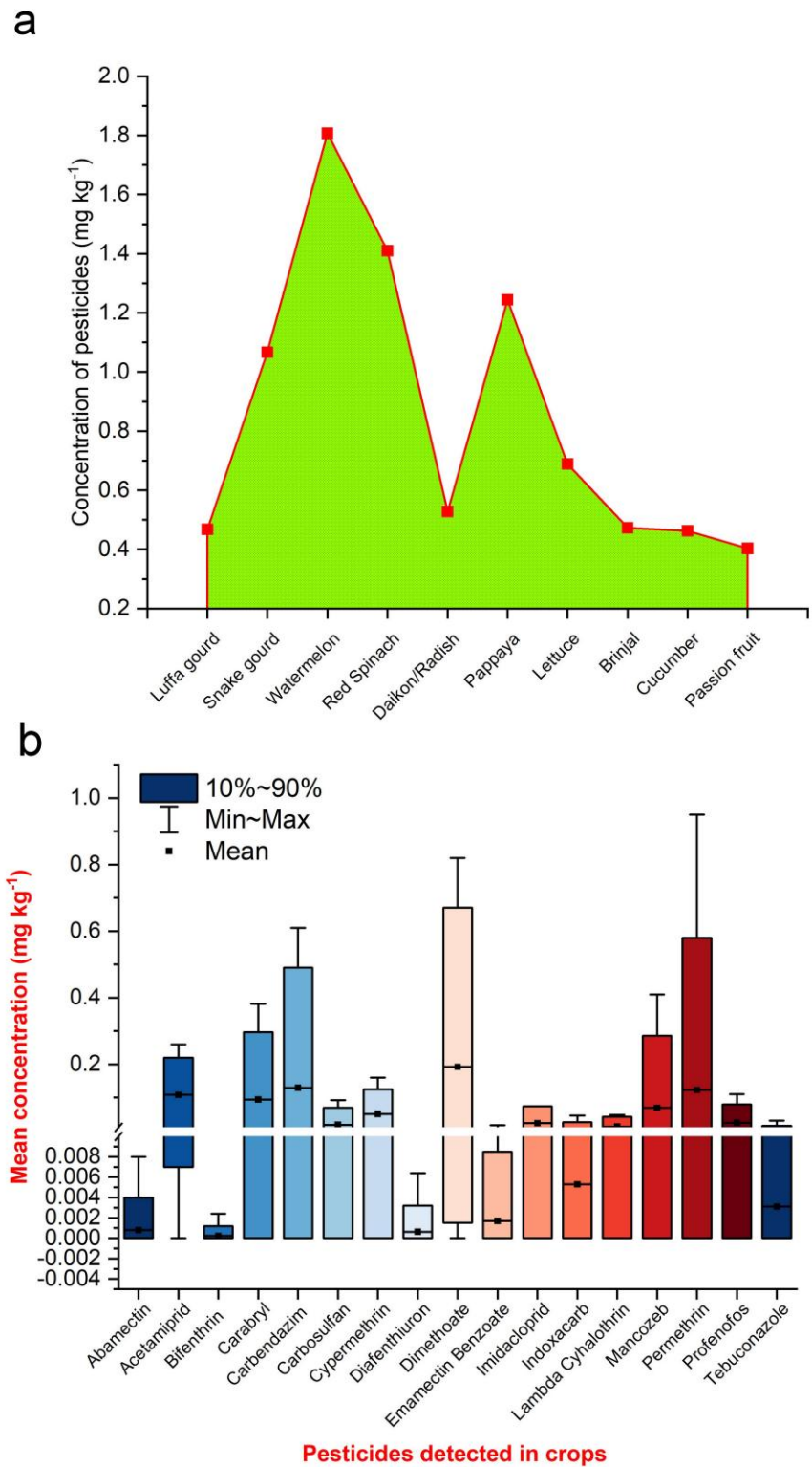


Fig. 4.1 (a) Total pesticide residue concentration detected in vegetables collected from the study area.; (b) Box plot illustrating the concentration of various pesticides detected in the vegetables.

The relative frequency distribution of detected pesticides reveals that Dimethoate contributes the highest frequency at 13.64%, closely followed by Acetamiprid at 13.6%. Cypermethrin, Carbendazim, and Permethrin each account for 9.02% of the frequency distribution. Carabryl contributes 7.5%, while Profenofos, Imidacloprid, and Lambda Cyhalothrin represent 6% and 6.6%, respectively. Indoxacarb and Carbosulfan show moderate frequencies at 3.03% and 4.55%, respectively. Mancozeb is detected in 4.5% of the cases, with lower contributions from Abamectin, Diafenthiuron, Emamectin Benzoate, and Tebuconazole, each at 1.5%. Bifenthrin exhibits a minimal presence, accounting for only 1.52%. This distribution highlights the varying prevalence of these pesticides in the samples analyzed (Fig. 4.2).

Abamectin, an avermectin-based insecticide, was detected solely in Brinjal at a concentration of 0.008 mg/kg, reflecting its application for controlling specific pests affecting solanaceous crops. Bifenthrin, a pyrethroid insecticide, was present exclusively in Watermelon at a concentration of 0.0024 mg/kg, likely used for its efficacy in managing insect pests in cucurbits. Diafenthiuron, a thiourea derivative insecticide, was also detected only in Watermelon at a concentration of 0.0064 mg/kg, highlighting its specific use for pest suppression in this fruit crop. Emamectin Benzoate, a semi-synthetic derivative of avermectin, was identified solely in Daikon/Radish at 0.017 mg/kg, signifying its application to control lepidopteran pests in root vegetables. Lastly, Tebuconazole, a triazole-based fungicide, was uniquely detected in Lettuce at a concentration of 0.031 mg/kg, indicating its role in managing fungal infections in leafy greens.

Acetamiprid, a systemic neonicotinoid insecticide effective against sucking insects, was found in all crops except Brinjal and Passion fruit, with the highest concentration recorded in Snake gourd at 0.18 mg/kg. Carbaryl, a broad-spectrum carbamate insecticide with moderate toxicity, was detected in Luffa gourd (0.1 mg/kg), Snake gourd (0.382 mg/kg), Watermelon (0.037 mg/kg), and Cucumber (0.211 mg/kg), with Snake gourd showing the highest levels (Table. 4.1).

Carbendazim, a fungicide used to control fungal pathogens in fruits and vegetables, was found in Snake gourd (0.37 mg/kg), Papaya (0.61 mg/kg), Lettuce (0.22 mg/kg), Brinjal (0.054 mg/kg), Cucumber (0.027 mg/kg), and Passion fruit (0.012 mg/kg). Papaya exhibited the highest concentration of this fungicide. Cypermethrin, a pyrethroid insecticide with high efficacy against pests, was present in Luffa gourd (0.16 mg/kg), Papaya (0.032 mg/kg), Brinjal (0.09 mg/kg), Cucumber (0.067 mg/kg), and Passion fruit (0.08 mg/kg), with Luffa gourd recording the highest level (Table. 4.1).

Dimethoate, an organophosphate insecticide, was found in all crops except Snake gourd, Papaya, and Lettuce, with the highest concentration in Red spinach (0.82 mg/kg). Mancozeb, a fungicide often applied to prevent fungal diseases, was detected in Red spinach (0.161 mg/kg) and Papaya (0.41 mg/kg), with Papaya showing a significantly higher concentration (Table. 4.1).

Permethrin, a synthetic pyrethroid used widely in agriculture, was present in Luffa gourd (0.017 mg/kg), Snake gourd (0.032 mg/kg), Watermelon (0.95 mg/kg), Red spinach (0.005 mg/kg), Papaya (0.012 mg/kg), and Lettuce (0.21 mg/kg). Watermelon exhibited an exceptionally high level of 0.95 mg/kg. Lambda Cyhalothrin, another synthetic pyrethroid, was detected in Luffa gourd (0.048 mg/kg), Brinjal (0.019 mg/kg), Cucumber (0.023 mg/kg), and Passion fruit (0.037 mg/kg), with the highest levels found in Luffa gourd (Table. 4.1).

Profenofos, an organophosphate insecticide with broad-spectrum activity, was detected in Watermelon (0.047 mg/kg), Papaya (0.11 mg/kg), Lettuce (0.04 mg/kg), and Brinjal (0.049 mg/kg). Papaya recorded the highest concentration of this pesticide (Table. 4.1).

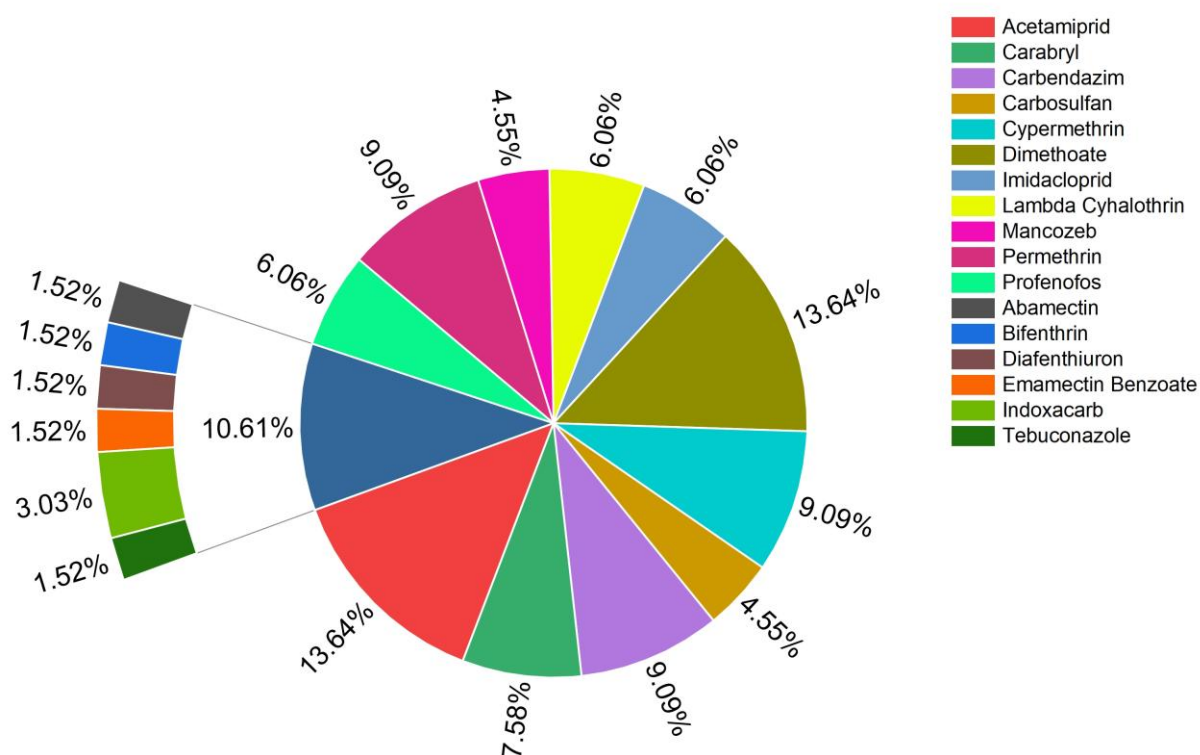


Fig. 4.2 Relative frequency distribution of detected pesticides in crops of Thoddoo during the study period.

Table.4.1.1. Pesticide Residue Levels in different crops of Thoddoo islands during the study period vs Maximum Residue Limits, MRL (European Union guidelines)

Name of the pesticide	Pesticide Residue in Crops (mg/kg) & MRL (mg/kg)									
	Luffa gourd	MRL	Snake gourd	MRL	Watermelon	MRL	Red Spinach	MRL	Daikon/Radish	MRL
Abamectin	0	0.02	0	0.02	0	0.01	0	0.01	0	0.01
Acetamiprid	0.09	0.3	0.18	0.3	0.12	0.2	0.14	0.6	0.26	0.01
Bifenthrin	0	0.01	0	0.01	0.0024	0.01	0	0.01	0	0.05
Carabryl	0.1	0.01	0.382	0.01	0.037	0.01	0.21	0.01	0	0.01
Carbendazim	0	0.1	0.37	0.1	0	0.1	0	0.1	0	0.1
Carbosulfan	0.047	0.002	0.092	0.002	0.044	0.01	0	0.005	0	0.002
Cypermethrin	0.16	0.2	0	0.2	0.08	0.2	0	0.7	0	0.05
Diafenthiuron	0	illegal	0	illegal	0.0064	illegal	0	illegal	0	illegal
Dimethoate	0.006	0.01	0.004	0.01	0.52	0.01	0.82	0.01	0.251	0.01
Emamectin Benzoate	0	0.007	0	0.007	0	0.008	0	0.2	0.017	0.002
Imidacloprid	0	0.4	0	0.4	0	0.15	0.074	0.01	0	0.01
Indoxacarb	0	0.01	0.007	0.01	0	0.01	0	0.01	0	0.01
Lambda Cyhalothrin	0.048	0.15	0	0.15	0	0.06	0	0.6	0	0.15
Mancozeb	0	2	0	2	0	1.5	0.161	0.05	0	2
Permethrin	0.017	0.05	0.032	0.05	0.95	0.05	0.005	0.05	0	0.05
Profenofos	0	0.01	0	0.01	0.047	0.01	0	0.01	0	0.01
Tebuconazole	0	0.6	0	0.6	0	0.15	0	0.02	0	0.02
Total Residue	0.468		1.067		1.8068		1.41		0.528	

Table.4.1. Pesticide Residue Levels in different crops of Thoddoo islands during the study period vs Maximum Residue Limits, MRL (European Union guidelines)

Name of the pesticide	Pesticide Residue in Crops (mg/kg) & MRL (mg/kg)									
	Papaya	MRL	Lettuce	MRL	Brinjal/Egg Plant	MRL	Cucumber	MRL	Passion fruit	MRL
Abamectin	0	0.01	0	0.15	0.009	0.05	0	0.02	0	0.01
Acetamiprid	0.07	0.01	0.11	1.5	0.014	0.2	0.1	0.3	0	0.01
Bifenthrin	0	0.4	0	0.01	0	0.3	0	0.01	0	0.01
Carabryl	0	0.01	0	0.01	0	0.01	0.211	0.01	0	0.01
Carbendazim	0.61	0.2	0.22	0.1	0.054	0.5	0.027	0.1	0.012	0.1
Carbosulfan	0	0.01	0	0.002	0	0.002	0	0.002	0	0.01
Cypermethrin	0.032	0.5	0	2	0.09	0.5	0.067	0.2	0.08	0.05
Diafenthiuron	0	illegal	0	illegal	0	illegal	0	illegal	0	illegal
Dimethoate	0	0.01	0.013	0.01	0.217	0.01	0.003	0.01	0.092	0.01
Emamectin Benzoate	0	0.002	0	0.2	0	0.02	0	0.007	0	0.002
Imidacloprid	0	0.01	0	0.01	0.041	0.3	0.032	0.5	0.062	0.01
Indoxacarb	0	0.01	0.046	0.01	0	0.01	0	0.01	0	0.01
Lambda Cyhalothrin	0	0.01	0.019	0.15	0	0.3	0.023	0.05	0.037	0.01
Mancozeb	0.41	7	0	5	0	3	0	2	0.12	0.05
Permethrin	0.012	0.05	0.21	0.05	0	0.05	0	0.05	0	0.05
Profenofos	0.11	0.01	0.04	0.01	0.049	0.01	0	0.01	0	0.01
Tebuconazole	0	2	0.031	0.5	0	0.4	0	0.6	0	1
Total Residue	1.244		0.689		0.474		0.463		0.403	

4.3 Crop-Specific Observations

Luffa gourd exhibited a total pesticide residue of 0.468 mg/kg, with dominant pesticides being Cypermethrin (0.16 mg/kg), Carbaryl (0.1 mg/kg), and Lambda Cyhalothrin (0.048 mg/kg). Snake gourd recorded a total pesticide residue of 1.067 mg/kg, with significant residues from Acetamiprid (0.18 mg/kg), Carbaryl (0.382 mg/kg), and Carbendazim (0.37 mg/kg) (Fig. 4.3). Watermelon, with the highest total pesticide residue of 1.8068 mg/kg, had prominent pesticides such as Permethrin (0.95 mg/kg), Carbendazim (0.37 mg/kg), and Carbaryl (0.037 mg/kg) (Fig. 4.3). Red spinach, with a total residue of 1.41 mg/kg, showed high levels of Dimethoate (0.82 mg/kg), Mancozeb (0.161 mg/kg), and Imidacloprid (0.074 mg/kg). Daikon/Radish recorded a total residue of 0.528 mg/kg, mainly from Dimethoate (0.251 mg/kg) and Acetamiprid (0.26 mg/kg). Papaya had a total pesticide residue of 1.244 mg/kg, with notable residues of Carbendazim (0.61 mg/kg) and Mancozeb (0.41 mg/kg). Lettuce recorded a total residue of 0.689 mg/kg, with prominent pesticides being Permethrin (0.21 mg/kg) and Carbendazim (0.22 mg/kg) (Fig. 4.3). Brinjal showed a total residue of 0.473 mg/kg, dominated by Dimethoate (0.217 mg/kg). Cucumber recorded a total pesticide residue of 0.463 mg/kg, with dominant residues of Carbaryl (0.211 mg/kg) and Dimethoate (0.003 mg/kg). Passion fruit had the lowest residue of 0.403 mg/kg, with major residues from Cypermethrin (0.08 mg/kg) (Fig. 4.3). The relative frequency distribution of detected pesticides in crops indicates that pesticides from the chemical class Pyrethroids dominated, accounting for 25.8%, followed by Organophosphates and Neonicotinoids, each contributing 19.7% (Fig. 4.4). Additionally, insecticides dominated (75%) in the pesticide category (Table. 4.2).

Table. 4.2 Pesticides detected in the crops with their corresponding chemical classes and categories

Pesticides	No. of Vegetables	Chemical Class	Category
Abamectin	1	Avermectin	Insecticide, Acaricide and Nematicide
Acetamiprid	9	Neonicotinide	Insecticide
Bifenthrin	1	Pyrethroid	Insecticide
Carabryl	5	Carbamate	Insecticide
Carbendazim	6	Benzimidazole	Fungicide
Carbosulfan	3	Carbamate	Insecticide
Cypermethrin	6	Pyrethroid	Insecticide
Diafenthiuron	1	Thiourea	Insecticide
Dimethoate	9	Organophosphate	Insecticide
Emamectin Benzoate	1	Avermectin	Insecticide
Imidacloprid	4	Neonicotinoid	Insecticide
Indoxacarb	2	Oxadiazine	Insecticide
Lambda Cyhalothrin	4	Pyrethroids	Insecticide
Mancozeb	3	Dithiocarbamate	Fungicide
Permethrin	6	Pyrethroid	Insecticide
Profenofos	4	Organophosphate	Insecticide
Tebuconazole	1	Triazole	Fungicide

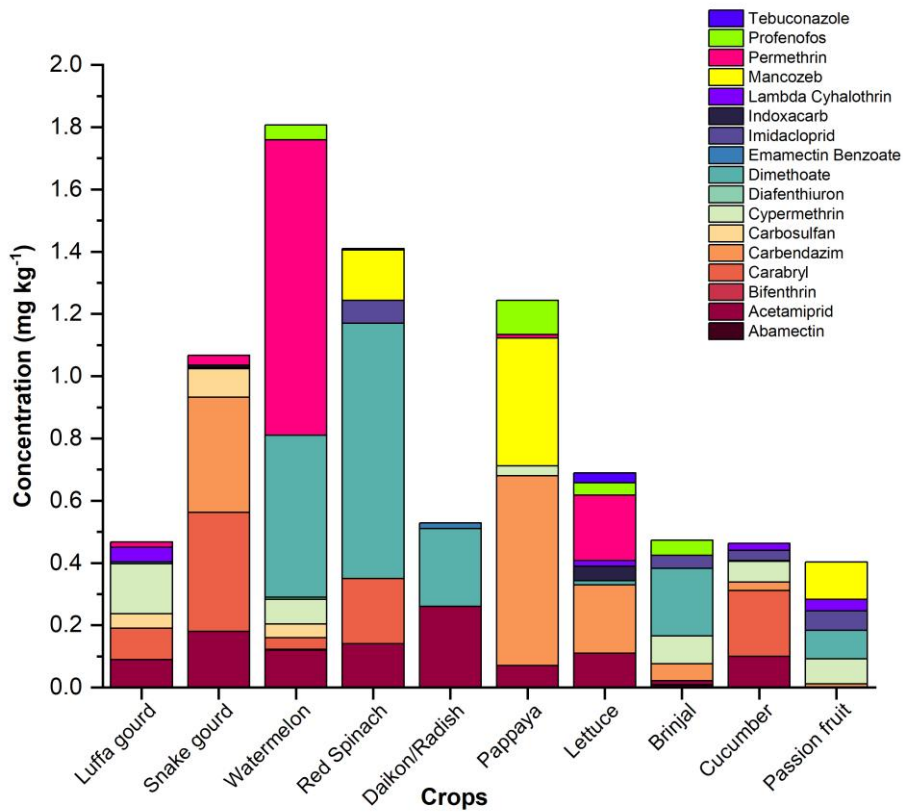


Fig. 4.3 Concentration of pesticide residue in vegetables collected from the study area.

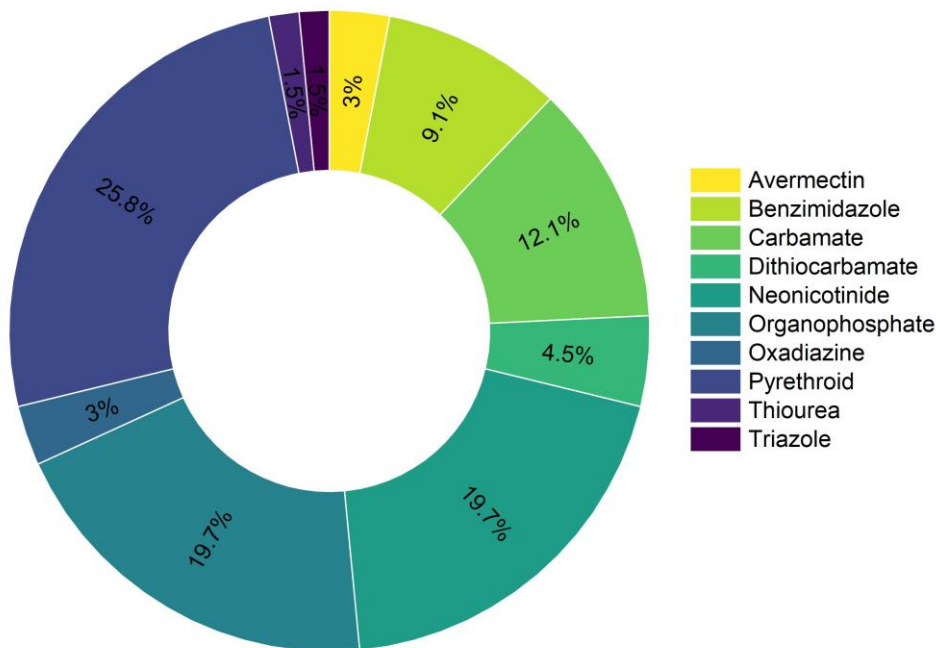


Fig. 4.4 Relative frequency distribution of detected pesticide based on chemical classes

4.4 MRL Breaches and Food Safety Concerns

The analysis of pesticide residues in vegetables and fruits cultivated in Thoddoo Island, Maldives, has raised significant concerns regarding food safety. The study detected residues of various pesticides, and alarmingly, several of these were present at concentrations exceeding the Maximum Residue Limits (MRLs) established by the European Commission. MRLs are scientifically determined thresholds that represent the maximum concentration of pesticide residues legally allowed in food products, assuming the pesticide was applied correctly following Good Agricultural Practices (GAP). These limits are set to protect consumers from potential toxic effects, ensure that food is safe for consumption, and facilitate international trade by maintaining uniform safety standards. They are not safety limits per se but are established far below levels considered harmful to human health, often incorporating large safety margins.

The pesticide residue analysis of vegetables and fruits from Thoddoo Island, Maldives, reveals several instances where detected levels exceed the European Union's Maximum Residue Limits (MRLs), raising serious concerns about potential misuse or over-application (Table 4.1). Notably, Carbaryl and Diafenthiuron, both of which are not authorized for use on food crops under European Union (EU) regulations, were detected in various samples. Since these substances are banned for food crop use in the EU, their presence at any detectable level is considered illegal and highly alarming. Carbaryl was found in luffa gourd, snake gourd, watermelon, red spinach, cucumber, and other crops, indicating widespread and possibly unregulated usage. Diafenthiuron was similarly detected in papaya, snake gourd, cucumber, and red spinach. In addition to these banned pesticides, other regulated chemicals such as Dimethoate exceeded MRLs in watermelon (0.52 mg/kg vs. 0.01 mg/kg), red spinach (0.82 mg/kg), daikon/radish (0.251 mg/kg), and brinjal (0.217 mg/kg). Carbendazim surpassed limits in snake gourd (0.37 mg/kg vs. 0.1 mg/kg), papaya (0.61 mg/kg vs. 0.2 mg/kg), and lettuce (0.22 mg/kg vs. 0.1 mg/kg). Profenofos was above MRL in papaya (0.11 mg/kg vs. 0.01 mg/kg), while Permethrin exceeded in watermelon (0.95 mg/kg vs. 0.05 mg/kg). Mancozeb residues were higher than permitted in red spinach (0.161 mg/kg vs. 0.05 mg/kg). These findings emphasize the pressing need for stringent monitoring and regulation of pesticide use in the region.

It is essential that farmers are educated on the importance of responsible pesticide use, pre-harvest intervals, and adherence to internationally accepted practices. Strengthening regulatory enforcement and promoting sustainable, safer alternatives can help mitigate these risks and ensure that the food supply remains both safe and marketable.

4.5 Health Implications

The presence of unauthorized and excessive pesticide residues in Thoddoo's produce poses serious public health risks. Banned substances like Carbaryl and Diafenthiuron were detected in multiple crops, while other pesticides such as Dimethoate, Carbendazim, and Permethrin exceeded MRLs. These violations suggest overuse and weak regulatory enforcement. Even residues within MRLs are concerning due to potential chronic effects. Prolonged exposure to compounds like organophosphates and synthetic pyrethroids can cause neurotoxicity, endocrine disruption, and reproductive harm. The cumulative intake of multiple pesticide residues across crops further amplifies health risks. Such findings not only endanger consumer health but also threaten the credibility and marketability of local produce. Strengthening monitoring, farmer awareness, and promoting safer alternatives is vital for ensuring food safety.

4.6 Recommendations

To reduce pesticide residues in food and ensure public health safety, the adoption of Integrated Pest Management (IPM) practices must be prioritized to minimize chemical inputs. Farmers should be educated on responsible pesticide use, including the importance of pre-harvest intervals and adherence to Good Agricultural Practices (GAP) aligned with international standards. Regulatory authorities must strengthen enforcement, conduct regular residue monitoring, and ensure compliance with Maximum Residue Limits (MRLs). Public awareness campaigns can inform consumers about simple steps like washing and peeling to reduce intake. In the long term, promoting organic farming and sustainable alternatives will help transition toward a safer and more marketable food system.

5. Bioaccumulation of Heavy Metals in Agricultural Resources & Health Risk Assessment



The sustained use of agrochemicals in modern agriculture has raised growing concerns over the long-term accumulation of heavy metals in the environment, particularly in island ecosystems with fragile soil and water systems. Thoddoo Island, known for its intensive horticultural production, presents a relevant case study for understanding these dynamics in small island agricultural systems. While the primary focus of this study is on farmers' perceptions and practices related to agrochemicals, it is equally critical to assess the environmental and health consequences arising from those practices. The inclusion of heavy metal analysis is thus integral to understanding the broader implications of agrochemical use on the island.

All farmers interviewed during the study identified NPK fertilizers as their primary chemical input, often complemented by potassium-based fertilizers. This is particularly concerning because the phosphate component of NPK fertilizers is known to contain trace levels of toxic heavy metals such as cadmium (Cd), lead (Pb), and arsenic (As), originating from phosphate rock. Prolonged and repeated use can result in the gradual buildup of these metals in agricultural soils. Additionally, commonly used pesticide formulations also contribute to the island's heavy metal burden. For instance, mancozeb introduces manganese and zinc; thiram, a dithiocarbamate fungicide, adds sulfur and potential trace metals; and trizinc diphosphide (zinc phosphide), a rodenticide, directly contributes zinc. Even sulfur-based fungicides may harbor trace metal contaminants depending on their source.

Unlike organic pesticide residues that degrade over time, heavy metals are persistent, non-biodegradable, and capable of bioaccumulating in soils and plants. These risks are amplified in sandy or porous island soils, like those found in Thoddoo, where metals are more prone to leaching into groundwater. Since groundwater is a primary source for both drinking water and agricultural irrigation on the island, this leads to a cyclical contamination loop, where metals move from soil to water and back into the soil through irrigation, thereby compounding long-term exposure risks and environmental degradation.

To address these concerns, this study assessed heavy metal concentrations in agricultural soils and crop samples while also evaluating the potential health risks associated with dietary exposure. Key risk assessment indicators included the Estimated Daily Intake (EDI), Target Hazard Quotient (THQ), and Target Carcinogenic Risk (TCR). These metrics provide insight into both non-carcinogenic and carcinogenic risks faced by consumers of locally grown produce.

5.1 Metal concentration in soil

The metal concentrations in the soil from Thoddoo Island revealed zinc (Zn) as the highest at 107.5 ± 12.8 mg/kg, followed by manganese (Mn) at 92.51 ± 17.4 mg/kg. In contrast, the lowest concentrations were observed for mercury (Hg) at 0.41 ± 0.09 mg/kg and cadmium (Cd) at 0.58 ± 0.12 mg/kg. The metal concentrations ranked in the following order: Zn > Mn > Cr > Cu > Ni > Pb > Cd > Hg (Fig.5.1).

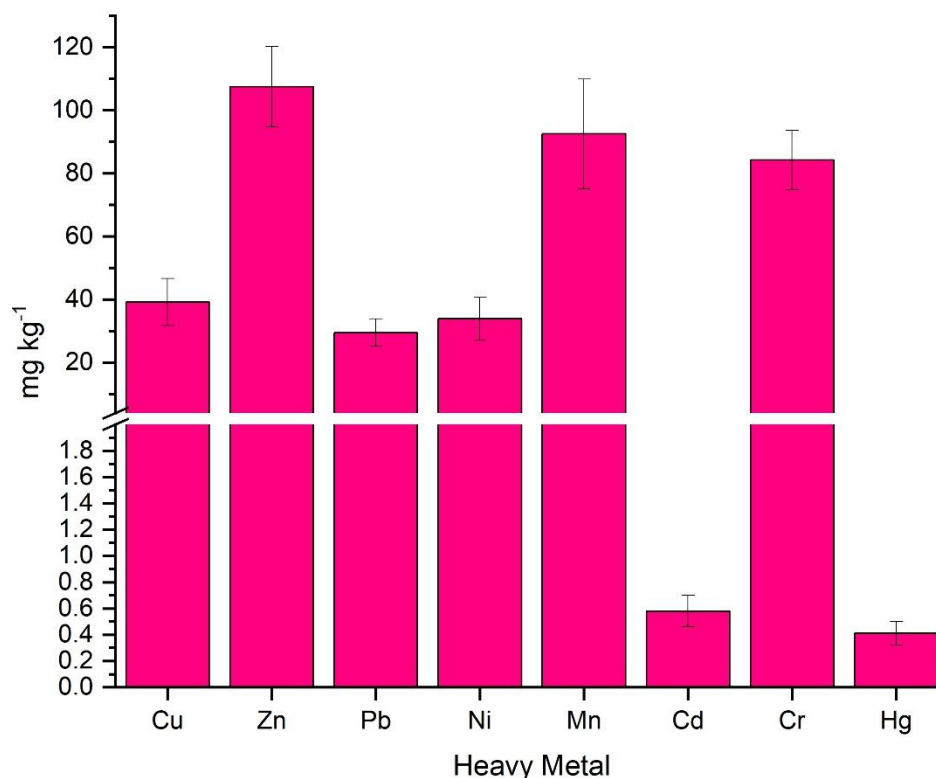


Fig. 5.1 Heavy metal concentration in soil from farmlands of Thoddoo.

5.2 Metal Accumulation in Crops

The accumulation of heavy metals in crops from Thoddoo Island was analyzed to evaluate potential risks to human health through the consumption of these crops. The levels of various heavy metals, including copper (Cu), zinc (Zn), lead (Pb), cadmium (Cd), manganese (Mn), nickel (Ni), chromium (Cr), and mercury (Hg), were determined in a selection of vegetables. The results showed significant variation in metal concentrations across different crops, highlighting both potential health concerns and minimal risks for consumers (Table. 5.1).

Copper (Cu) concentrations were highest in lettuce (19.60 mg/kg), followed by red spinach (15.68 mg/kg) and luffa gourd (11.76 mg/kg) (Fig.5.2) & (Table. 5.1). While copper is an essential nutrient, excessive intake can lead to toxicity, and these high concentrations in

lettuce and red spinach might raise concerns if consumed frequently. On the other hand, watermelon and papaya had relatively low copper levels, suggesting that their consumption poses minimal risk in terms of copper exposure.

For zinc (Zn), the highest levels were recorded in lettuce (139.09 mg/kg), followed by red spinach (129 mg/kg) (Fig. 5.2). These elevated zinc concentrations are significant, as excessive zinc intake can lead to gastrointestinal distress and interfere with copper absorption. However, since zinc is an essential nutrient, the levels found in these crops may not pose an immediate risk unless consumed in large quantities over time. Luffa gourd and snake gourd also showed considerable zinc accumulation, but to a lesser extent compared to lettuce and red spinach.

Lead (Pb) levels were notably higher in lettuce (3.53 mg/kg), followed by red spinach (2.94 mg/kg) and white radish (2.06 mg/kg) (Fig. 5.2). Lead is a toxic metal, and chronic exposure can lead to serious health issues, including neurodevelopmental impairments and kidney damage. The presence of lead in lettuce and red spinach is concerning, particularly if these vegetables are consumed regularly, suggesting a potential risk for consumers.

Cadmium (Cd) concentrations were also elevated in lettuce (0.87 mg/kg) and red spinach (0.70 mg/kg) (Fig. 5.2). While cadmium is typically present in trace amounts in food, its accumulation in these crops could pose a long-term health risk, as cadmium is a known carcinogen and toxic to the kidneys. Luffa gourd and white radish also showed noticeable levels of cadmium, although these were somewhat lower than those found in lettuce and red spinach.

The highest manganese (Mn) levels were found in lettuce (166.52 mg/kg), followed by red spinach (138.77 mg/kg) and luffa gourd (92.51 mg/kg) (Fig. 5.2). Manganese is an essential nutrient, but excessive intake can lead to neurotoxic effects, particularly in vulnerable populations such as children. The high manganese levels in lettuce and red spinach are concerning, as they could lead to toxicity if consumed in large quantities over time.

Nickel (Ni) was most concentrated in lettuce (16.90 mg/kg), followed by red spinach (13.52 mg/kg) (Fig. 5.2). Nickel, though an essential trace element, can cause allergic reactions and other health issues when consumed in excessive amounts. Given the elevated nickel concentrations in lettuce and red spinach, these crops may pose a higher risk of nickel exposure, particularly for consumers who eat these vegetables frequently.

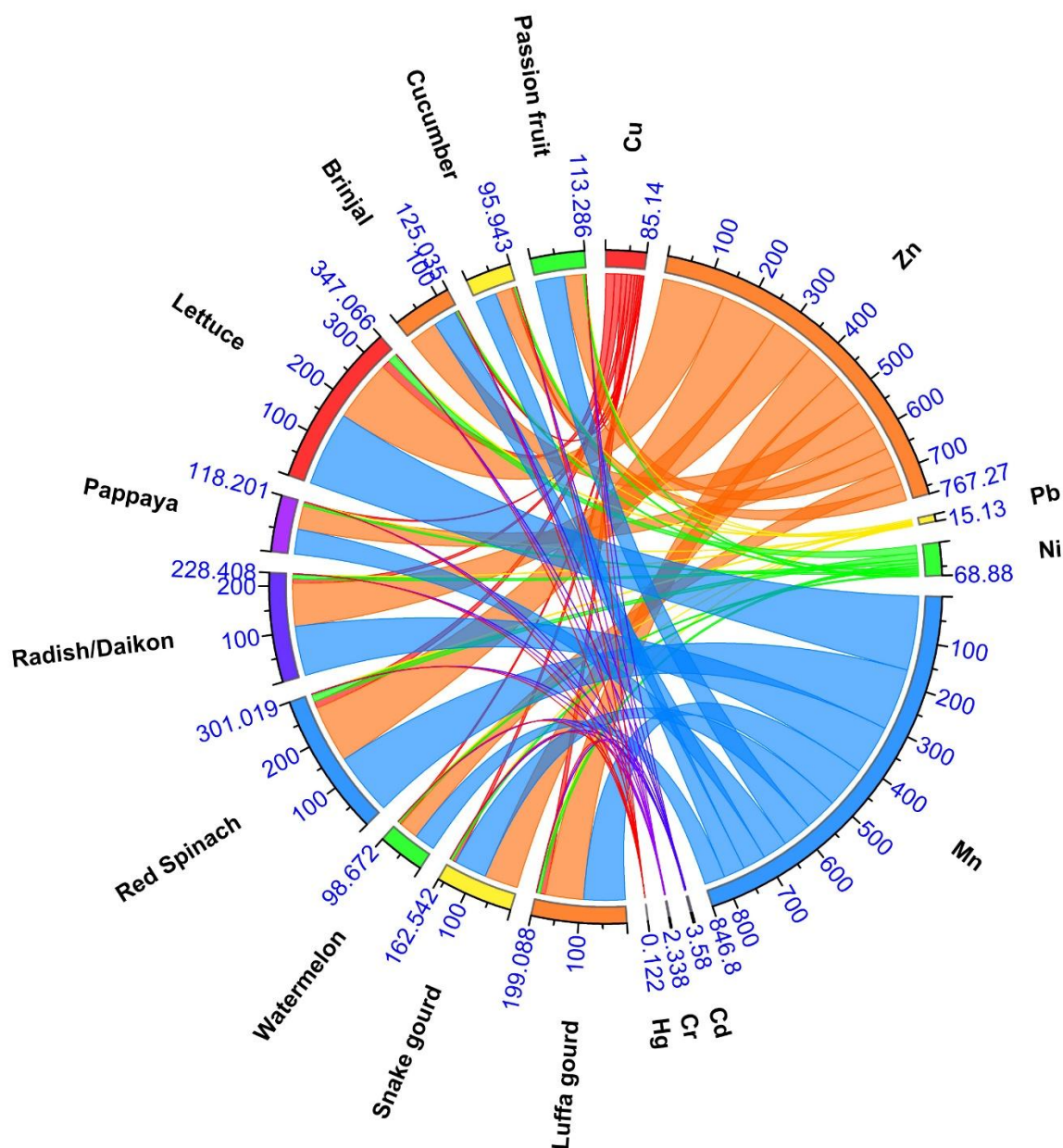


Fig. 5.2 Chord diagram showing metal concentration in different crops of Thoddoo island.

Chromium (Cr) levels were highest in lettuce (0.54 mg/kg), followed by red spinach (0.39 mg/kg) and white radish (0.31 mg/kg) (Fig. 5.2). While chromium is an essential element, excessive intake can lead to adverse health effects. The chromium concentrations in these crops were not excessively high but given that lettuce and red spinach accumulated other metals at elevated levels, caution is warranted.

Lastly, mercury (Hg) was found in trace amounts across all crops, with watermelon (0.034 mg/kg) showing the highest concentration. While mercury accumulation was low overall, it

remains a toxic metal, and its presence in watermelon warrants monitoring. However, given the low levels observed, the risk from mercury exposure through these crops is minimal.

Overall, lettuce consistently showed the highest levels of heavy metal accumulation across multiple metals, including copper, zinc, lead, cadmium, manganese, nickel, and chromium (Table. 5.1). This suggests that frequent consumption of lettuce could pose a potential health risk, particularly due to its accumulation of toxic metals like lead, cadmium, and manganese. Similarly, red spinach also exhibited elevated levels of lead, cadmium, and manganese, making it another crop of concern. Watermelon and papaya, on the other hand, had relatively lower levels of heavy metals and are unlikely to pose significant health risks. These findings emphasize the importance of monitoring heavy metal concentrations in locally grown crops and taking appropriate measures to mitigate exposure, particularly for high-risk groups such as children and pregnant women. Regular assessments of metal contamination are crucial to ensuring food safety on Thoddoo Island.

Table. 5.1 Heavy Metal Concentration in different crops of Thoddoo Island.

Crops	Heavy Metal Concentration (mg kg ⁻¹)								Total
	Cu	Zn	Pb	Ni	Mn	Cd	Cr	Hg	
Luffa gourd	11.76	86	1.47	6.76	92.51	0.35	0.23	0.008	199.088
Snake gourd	7.84	75.25	0.92	5.07	73.01	0.29	0.16	0.002	162.542
Watermelon	4.52	43	1.13	3.38	46.26	0.27	0.078	0.034	98.672
Red Spinach	15.68	129	2.94	13.52	138.77	0.7	0.39	0.019	301.019
Radish/Daikon	9.8	96.31	2.06	8.45	111.01	0.46	0.31	0.008	228.408
Pappaya	3.92	53.75	0.59	4.18	55.51	0.09	0.15	0.011	118.201
Lettuce	19.6	139.09	3.53	16.9	166.52	0.87	0.54	0.016	347.066
Brinjal	4.01	64.5	0.88	3.81	51.32	0.23	0.27	0.015	125.035
Cucumber	5.88	37.22	1.24	4.19	47.13	0.19	0.09	0.003	95.943
Passion fruit	2.13	43.15	0.37	2.62	64.76	0.13	0.12	0.006	113.286

5.3 Human Health Risk Assessment

5.3.1 Estimated Daily Intake (EDI)

The Estimated Daily Intake (EDI) of heavy metals was determined for ten commonly consumed crops in Thoddoo Island, Maldives. The results were compared to the oral Reference Dose (RfD) for each metal to assess potential health risks (Table.5.2). The detailed findings are presented below:

The EDI for copper across all crops ranged between 2.23 µg/kg bw/day in white radish and 20.8 µg/kg bw/day in lettuce. All values were significantly below the RfD of 40 µg/kg bw/day, indicating that copper intake from these crops does not pose a health risk. Lettuce had the highest copper content, while white radish had the lowest.

Zinc levels ranged from 9.81 µg/kg bw/day in passion fruit to 163.0 µg/kg bw/day in watermelon. Despite the high zinc content in watermelon and lettuce (148.0 µg/kg bw/day), all values were well within the RfD of 300 µg/kg bw/day, suggesting no significant health concerns related to zinc intake.

The EDI for lead showed some concerning results. While most crops had lead levels below the RfD of 3.5 µg/kg bw/day, watermelon (4.28 µg/kg bw/day) and lettuce (3.74 µg/kg bw/day) exceeded the RfD. These findings highlight a potential health risk for regular consumers of these crops due to lead contamination. The other crops, including passion fruit (0.0841 µg/kg bw/day) and white radish (0.468 µg/kg bw/day), had lead levels well within safe limits.

Cadmium levels ranged from 0.0295 µg/kg bw/day in passion fruit to 1.02 µg/kg bw/day in watermelon. Most crops were below the RfD of 1 µg/kg bw/day, except for watermelon, which slightly exceeded the limit. This marginal exceedance indicates a mild health concern that warrants further investigation. Manganese exposure was relatively high in lettuce (177.0 µg/kg bw/day) and watermelon (175.0 µg/kg bw/day), with values close to or slightly exceeding the RfD of 140 µg/kg bw/day. Other crops, such as passion fruit (14.7 µg/kg bw/day) and white radish (25.2 µg/kg bw/day), had manganese levels well within safe limits. Regular consumption of high-manganese crops like lettuce and watermelon could pose a risk over time. Nickel EDI values ranged from 0.595 µg/kg bw/day in passion fruit to 17.9 µg/kg bw/day in lettuce. These values were below the RfD of 20 µg/kg bw/day for all crops. Thus, nickel exposure from the analyzed crops is unlikely to cause any adverse health effects.

Chromium levels across the crops were minimal, ranging between 0.0273 µg/kg bw/day in passion fruit and 0.573 µg/kg bw/day in lettuce. All values were significantly below the RfD of 0.9 µg/kg bw/day, indicating negligible risk of chromium exposure from these crops.

Mercury exposure was extremely low, with values ranging from 0.00136 $\mu\text{g/kg bw/day}$ in passion fruit to 0.129 $\mu\text{g/kg bw/day}$ in watermelon. All crops were well below the RfD of 0.3 $\mu\text{g/kg bw/day}$, indicating no significant health risk from mercury contamination.

The analysis revealed that the majority of heavy metals in the crops from Thoddoo Island were within safe limits when compared to their respective oral Reference Dose (RfD) values. Copper, zinc, nickel, chromium, and mercury levels in all the crops were well below their RfD values, indicating minimal risk of adverse health effects from their consumption. However, some concerning trends were observed for lead, cadmium, and manganese. Lead levels in watermelon (4.28 $\mu\text{g/kg bw/day}$) and lettuce (3.74 $\mu\text{g/kg bw/day}$) exceeded the RfD of 3.5 $\mu\text{g/kg bw/day}$, posing a potential health risk. Cadmium in watermelon (1.02 $\mu\text{g/kg bw/day}$) slightly exceeded the RfD of 1 $\mu\text{g/kg bw/day}$, raising a mild concern. Similarly, manganese levels in lettuce (177.0 $\mu\text{g/kg bw/day}$) and watermelon (175.0 $\mu\text{g/kg bw/day}$) were close to or slightly above the RfD of 140 $\mu\text{g/kg bw/day}$, indicating the need for further monitoring. These findings underscore the importance of regular assessment and mitigation measures to ensure food safety and public health in the region.

Table. 5.2 Estimated daily intake of heavy metals ($\mu\text{g}^{-1} \text{ kg bw}^{-1} \text{ day}^{-1}$) from the crops from Thoddoo and its comparison with RfD (USEPA)

Crops	Estimated daily intake of heavy metals ($\mu\text{g kg}^{-1} \text{ bw}^{-1} \text{ day}^{-1}$)							
	Cu	Zn	Pb	CD	MN	Ni	Cr	Hg
Luffa gourd	5.35	39.09	0.16	0.16	42.05	3.07	0.10	0.00
Snake gourd	5.94	57.01	0.22	0.22	55.31	3.84	0.12	0.00
Watermelon	17.12	162.88	4.28	1.02	175.23	12.80	0.30	0.13
Red Spinach	7.13	58.64	1.34	0.32	63.08	6.15	0.18	0.01
Radish/Daikon	2.23	21.89	0.47	0.10	25.23	1.92	0.07	0.00
Pappaya	8.91	122.16	1.34	0.20	126.16	9.50	0.34	0.03
Lettuce	20.79	147.52	3.74	0.92	176.61	17.92	0.57	0.02
Brinjal	3.65	58.64	0.80	0.21	46.65	3.46	0.25	0.01
Cucumber	8.91	56.39	1.88	0.29	71.41	6.35	0.14	0.00
Passion fruit	0.48	9.81	0.08	0.03	14.72	0.60	0.03	0.00
RfD ($\mu\text{g kg}^{-1} \text{ day}^{-1}$)	40	300	3.5	1	140	20	0.9	0.3

5.3.2 Target Hazard Quotient (THQ)

The Target Hazard Quotient (THQ) values provide an indication of the non-carcinogenic health risks posed by heavy metal exposure from consuming different crops. A THQ value less than 1 suggests minimal health risks, while values greater than 1 indicate potential health concerns. In this study, the THQ values for the heavy metals in crops from Thoddoo Island were assessed, and the findings provide key insights into the safety of consuming these crops. The THQ values for the metals followed the sequence: Mn > Pb > Cd > Ni > Zn > Cr > Cu > Hg (Fig. 5.3a).

The Target Hazard Quotient (THQ) values for copper (Cu) in all crops were below 1, indicating no significant health risk. The highest THQ for Cu was in lettuce (0.520), still below the threshold of concern. Similarly, zinc (Zn) THQ values remained under 1, with watermelon showing the highest value (0.543), suggesting minimal health risks. However, lead (Pb) raised concerns, as THQ values for watermelon (1.22) and lettuce (1.07) exceeded 1, indicating potential non-carcinogenic risks from frequent consumption. Lead, a toxic metal, can accumulate in the body and cause severe health issues over time (Fig. 5.3b).

For cadmium (Cd), the THQ values in watermelon (1.02) and lettuce (0.923) were close to or slightly above 1, suggesting a mild health risk. Manganese (Mn) posed higher risks, with THQ values for watermelon (1.25) and lettuce (1.26) exceeding the safety limit, indicating potential health concerns with regular intake. In contrast, nickel (Ni) and chromium (Cr) showed THQ values below 1 for all crops, indicating no significant health risks from these metals (Fig. 5.3b).

Mercury (Hg) had its highest THQ value in watermelon (0.429), well below 1, suggesting a limited risk of mercury exposure through these crops (Fig. 5.3b). However, caution is warranted as mercury can accumulate over time with prolonged exposure.

Overall, most crops in Thoddoo Island had THQ values below 1, indicating minimal non-carcinogenic health risks from heavy metals. However, watermelon and lettuce emerged as crops of concern due to elevated THQ values for lead, cadmium, and manganese. Lead THQ values exceeded 1 in both crops, and manganese values were also above the safety limit, highlighting potential health risks. These findings underscore the importance of monitoring and limiting the consumption of watermelon and lettuce, especially for vulnerable populations. Regular assessments and mitigation measures are essential to ensure food safety and reduce heavy metal exposure risks on the island.

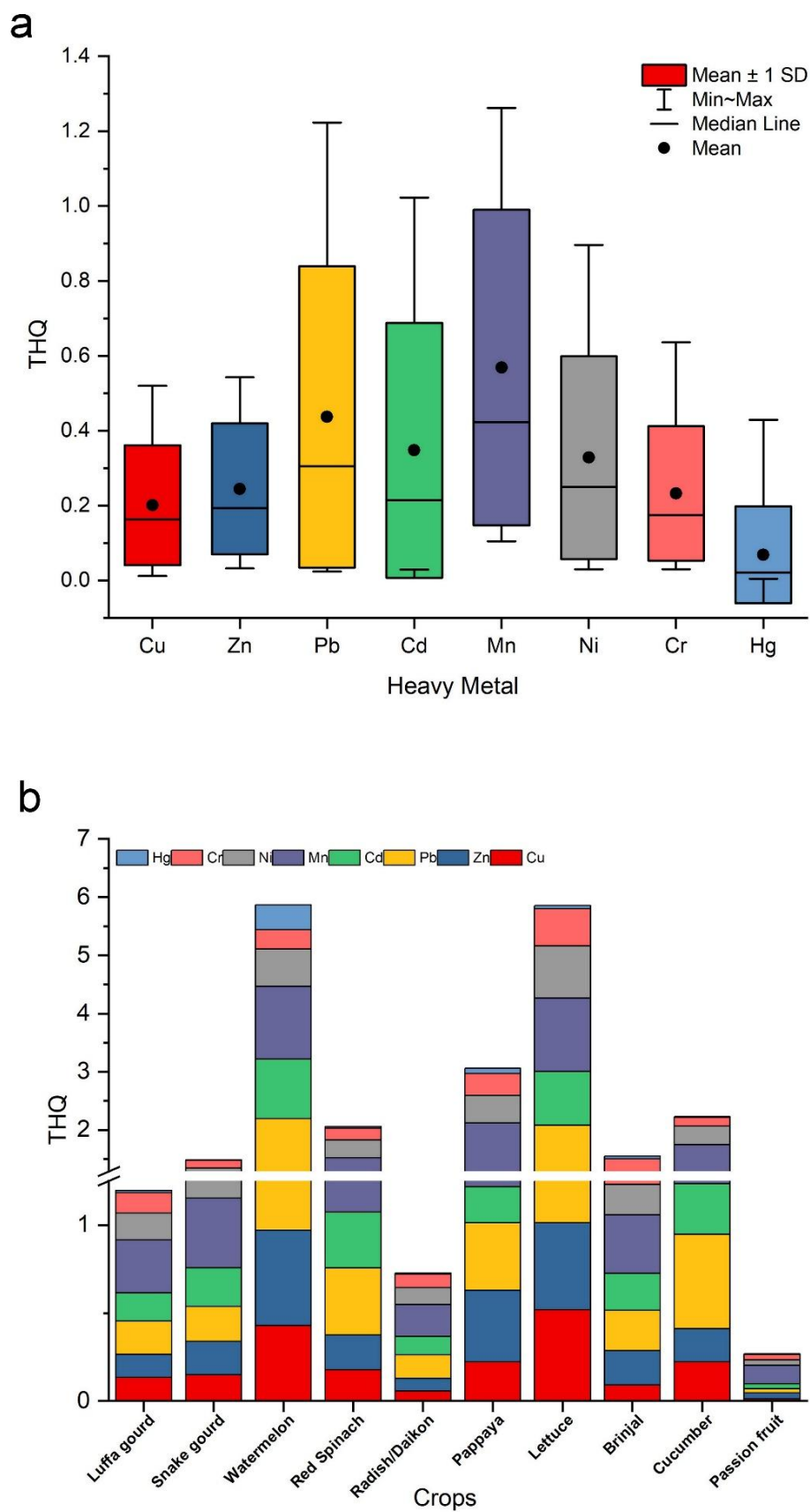


Fig. 5.3 Non-carcinogenic risk of heavy metals for consumers. (a) Mean target hazard quotient;(b) THQ in different crops of Thoddoo during the study.

5.3.3 Target Carcinogenic Risk (TCR)

The target carcinogenic risk for the heavy metals lead (Pb), cadmium (Cd), nickel (Ni), and chromium (Cr) was evaluated for various crops grown on Thoddoo Island. These metals are considered carcinogenic, and assessing their potential cancer risk is critical for ensuring food safety. The calculated carcinogenic risks for each crop are expressed as the probability of cancer per unit of exposure to these metals, and the results suggest varying levels of concern based on the metal concentrations in the crops (Table. 5.3).

Lead (Pb): The cancer risk associated with lead exposure was relatively low across most crops. The highest risk was observed in watermelon ($3.64\text{E-}05$), followed by lettuce ($3.18\text{E-}05$) and red spinach ($1.14\text{E-}05$). These crops showed a moderate risk for lead exposure, although none of the crops exceeded the threshold for significant concern (a risk greater than 1 in 10,000). Passion fruit exhibited the lowest risk for lead exposure ($7.15\text{E-}07$), suggesting that it poses a minimal carcinogenic risk from lead (Table. 5.3).

Cadmium (Cd): Cadmium concentrations contributed significantly to the carcinogenic risk in many of the crops. Lettuce ($5.81\text{E-}03$) and watermelon ($6.44\text{E-}03$) showed the highest cadmium-related cancer risks, indicating a higher concern for these crops. Red spinach ($2.00\text{E-}03$) and papaya ($1.29\text{E-}03$) also showed notable risks, while white radish ($6.59\text{E-}04$) and luffa gourd ($1.00\text{E-}03$) presented lower but still significant risks. Passion fruit ($1.86\text{E-}04$) posed the least cancer risk from cadmium, reinforcing its relatively safer profile for cadmium exposure (Table. 5.3).

Nickel (Ni): Nickel posed the highest cancer risk across several crops. Lettuce ($3.05\text{E-}02$) and papaya ($1.62\text{E-}02$) had the most elevated risks, suggesting a significant carcinogenic concern for these crops due to nickel. Watermelon ($2.18\text{E-}02$) and red spinach ($1.04\text{E-}02$) also had substantial risks, while crops such as cucumber ($1.08\text{E-}02$) and snake gourd ($6.53\text{E-}03$) had somewhat lower, but still concerning, nickel-related cancer risks. Passion fruit ($1.01\text{E-}03$) showed the lowest nickel-related risk, indicating it is less of a concern in terms of cancer risk from nickel (Table. 5.3).

Chromium (Cr): The carcinogenic risk from chromium was also prominent, with lettuce ($2.86\text{E-}04$) and papaya ($1.70\text{E-}04$) exhibiting the highest risks, followed by watermelon ($1.48\text{E-}04$) and red spinach ($8.86\text{E-}05$). While these levels suggest a moderate carcinogenic risk, the concentrations of chromium were generally lower compared to cadmium and nickel. Passion fruit ($1.36\text{E-}05$) posed the least risk from chromium, similar to its lower risks from other metals (Table. 5.3).

Table.5.3 TCR of Pb, Cd, Ni, and Cr for different crops

Crop	Pb	Cd	Ni	Cr
Luffa gourd	5.68E-06	1.00E-03	5.22E-03	5.23E-05
Snake gourd	5.92E-06	2.55E-05	6.53E-03	6.06E-05
Watermelon	3.63826E-05	6.44E-03	2.18E-02	1.48E-04
Red Spinach	1.13591E-05	2.00E-03	1.04E-02	8.86E-05
Radish/Daikon	3.97955E-06	6.59E-04	3.26E-03	3.52E-05
Pappaya	1.13977E-05	1.29E-03	1.62E-02	1.70E-04
Lettuce	3.18235E-05	5.81E-03	3.05E-02	2.86E-04
Brinjal	0.0000068	1.32E-03	5.89E-03	1.23E-04
Cucumber	1.59697E-05	1.81E-03	1.08E-02	6.82E-05
Passion fruit	7.15E-07	1.86E-04	1.01E-03	1.36E-05

The assessment of target carcinogenic risks associated with lead, cadmium, nickel, and chromium in crops grown on Thoddoo Island indicates that lettuce, watermelon, and papaya present the highest cancer risks due to elevated concentrations of cadmium, nickel, and chromium. These crops could potentially pose a significant health risk when consumed frequently, especially in populations with high dietary intake of these vegetables. Passion fruit consistently showed the lowest risks for all metals, making it a safer option in terms of carcinogenic exposure. Overall, this highlights the importance of regularly monitoring heavy metal concentrations in crops, particularly in high-risk vegetables such as lettuce and watermelon, to mitigate potential health risks for consumers.

5.4 Health Implications and Recommendations for Mitigating Heavy Metal Exposure

The presence of heavy metals in Thoddoo Island's agricultural system presents serious and multifaceted risks to human health and environmental sustainability. Chronic exposure to lead (Pb), cadmium (Cd), manganese (Mn), and nickel (Ni) through contaminated crops can lead to devastating health consequences, particularly for vulnerable populations. These toxic elements accumulate in the body over time, causing neurological damage in children, increasing cancer risks, impairing organ function, and disrupting critical immune and endocrine systems. The situation demands immediate, coordinated action across agricultural, policy, and community sectors to break the cycle of contamination and protect public health.

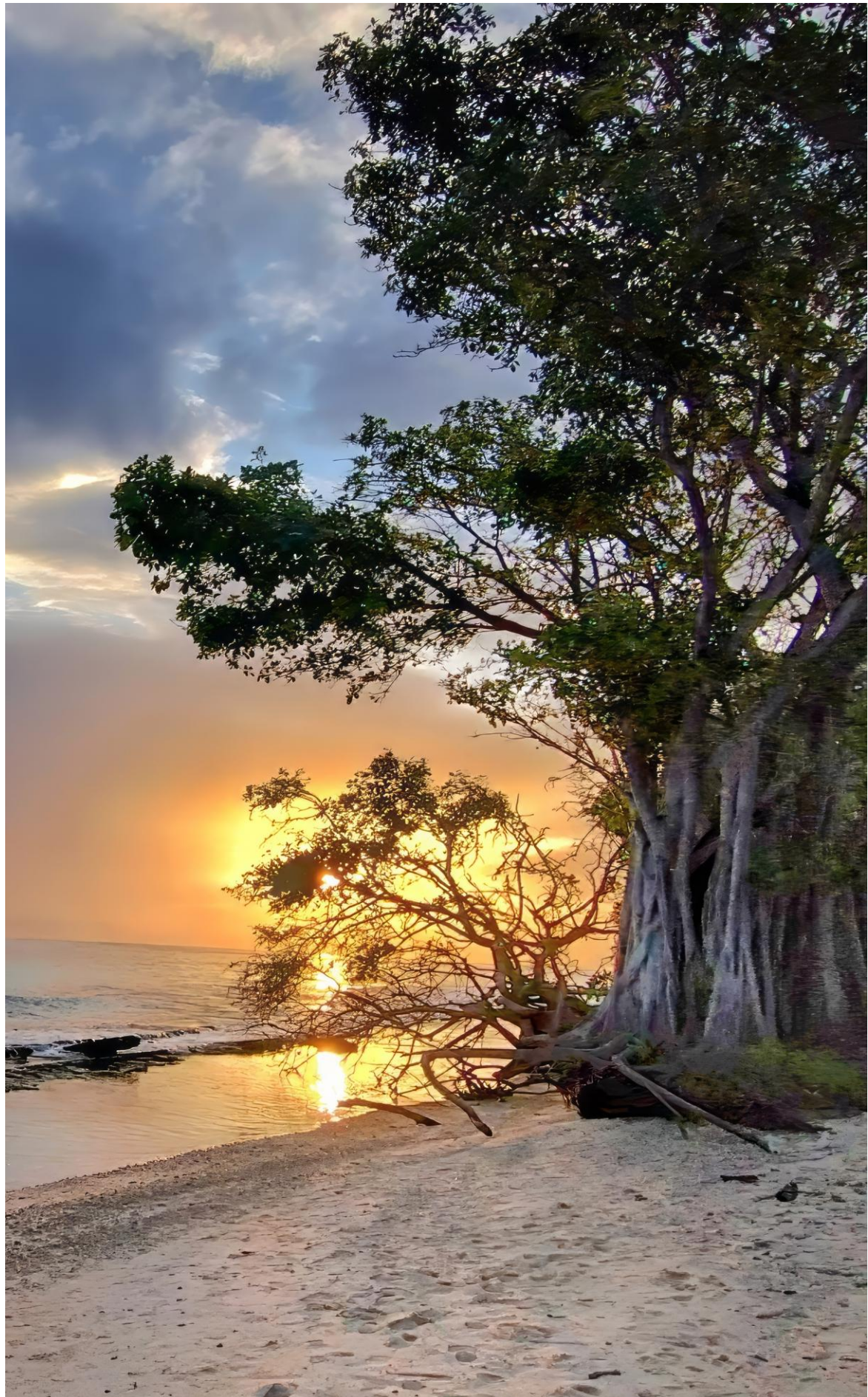
5.5 Critical Need for Mitigation

Heavy metal contamination represents both an urgent health crisis and a long-term environmental threat. These persistent pollutants accumulate in soils, enter groundwater systems, and bioaccumulate in crops - particularly high-risk varieties like lettuce and watermelon. Once established in the ecosystem, heavy metals become extremely difficult and costly to remove. Their impacts extend beyond immediate health effects, potentially causing generational harm through developmental disorders and creating lasting damage to agricultural productivity and island biodiversity. Proactive mitigation is essential to prevent irreversible damage to both human health and the island's fragile ecosystem.

5.6 Recommendations

To effectively address heavy metal contamination on Thoddoo Island, immediate agricultural reforms must prioritize shifting to low-metal agrochemicals, implementing soil remediation techniques like biochar and phytoremediation, and replacing high-risk crops with safer alternatives. Concurrently, food safety initiatives should promote dietary diversification from contaminated produce while educating on proper food preparation to minimize exposure. Policy enforcement needs to strengthen regulations on agrochemical imports, establish rigorous contamination monitoring systems, and implement strict food safety standards. Critical to success is comprehensive community engagement through targeted education programs about risks and mitigation strategies for both farmers and vulnerable populations. The path forward requires urgent action to prevent further contamination paired with long-term monitoring and soil recovery efforts - a coordinated approach across agricultural, policy, and health sectors is essential to protect community health, ensure agricultural sustainability, and preserve the island's fragile ecosystem before irreversible damage occurs.

6. Agrochemical Governance in the Maldives: Policies and Gaps



6.1 Current policies and regulations

Due to its unique geography and reliance on marine ecosystems and tourism, the Maldives maintains a strict yet evolving regulatory framework for the use of pesticides and chemical fertilizers. The country places high priority on environmental protection, food safety, and public health. However, challenges remain in effective regulation, monitoring, and enforcement. The following are key policies and regulations that govern the use of agrochemicals in the Maldives:

- ❖ The **National Environmental Action Plan (NEAP)** of the Maldives aims to deliver measurable environmental outcomes that directly benefit its people. It emphasizes the sustainable use of chemicals and the protection of natural ecosystems, with a particular focus on vulnerable coral reefs and freshwater lenses threatened by pollution.
- ❖ The **Maldives Climate Change Policy Framework (MCCPF)**, developed by the Ministry of Environment and Energy, outlines a national strategic vision for addressing climate change impacts across various sectors. It indirectly influences agrochemical use by encouraging climate-resilient and environmentally sustainable agricultural practices.
- ❖ The **Environment Protection and Preservation Act (Law No. 4/93)** provides a regulatory framework for managing hazardous waste in the Maldives, including the safe handling and disposal of substances such as agrochemicals. It prohibits the release of harmful materials—including toxic, hazardous, or chemical waste—into the environment and mandates oversight by designated authorities. The Act supports environmental assessments and promotes sustainable practices, ensuring that agricultural activities do not compromise environmental health.
- ❖ The **Import Prohibition Act (Law No. 4/75)** regulates the import of restricted and hazardous substances into the Maldives, including certain chemicals used in pesticides and agrochemicals. These substances are classified as controlled and may only be imported, manufactured, or used with special permission from the Ministry of Defence and National Security. The Act aims to prevent the misuse of hazardous chemicals, particularly those with potential dual use in chemical weapons, by enforcing strict import controls.
- ❖ The **Agricultural Pesticide Control Act (Law No. 21/2019)** regulates the entire lifecycle of agricultural pesticides in the Maldives, including their import, export, production, sale, usage, storage, and disposal. The Ministry of Fisheries, Marine Resources and Agriculture (MoFMRA) is authorized to maintain and publish a register of approved pesticides, detailing their names, formulations, concentrations, permitted uses, and required safety information. The Act mandates licensing and compliance with usage guidelines outlined in safety data

sheets, prohibiting any unauthorized application or instruction. It also places responsibility on users to follow safety measures to prevent environmental and health risks. A list of banned pesticides in the Maldives is provided in **Annexure 2**.

- ❖ The **Agricultural Pest Control Regulation (Regulation No. 2021/R-12)** establishes rules for the sustainable use, sale, transport, storage, and disposal of agricultural pesticides in the Maldives, with a focus on protecting human health and the environment. It emphasizes preventive measures to reduce risks and prevent hazardous pesticide use. The regulation outlines standards for pesticide waste management, including disposal methods, prohibited disposal practices, and designated waste types. It also sets safety requirements for pesticide storage facilities and transport vessels.
- ❖ The **Plant Protection Act (Act No. 12/2011)** aims to safeguard plants and plant products by regulating pest control measures and the application of pesticides. It establishes sanitary standards to prevent infestations and the spread of harmful organisms, while also addressing risks to human and animal health from pesticide use. The Act supports the development of phytosanitary procedures and restricts the manufacture and distribution of harmful plant protection products, aligning with relevant international guidelines.
- ❖ The **Hazardous Chemical Regulation (Regulation No. 2019/R-1057)** governs the import, storage, use, and disposal of non-explosive hazardous chemicals in the Maldives, including those used in pesticide formulations. It classifies hazardous substances and establishes strict safety and procedural requirements, such as obtaining separate import permits for each shipment. The regulation, enforced by the Ministry of Defence, aims to ensure safe handling and use of toxic chemicals to minimize risks to human health and the environment.
- ❖ The **Maldives Standard for Good Agricultural Practices (MGAP)** for fruits and vegetables is a certification scheme developed by the Ministry of Fisheries, Marine Resources, and Agriculture (MoFMRMA) with support from the Food and Agriculture Organization (FAO). It promotes sustainable agriculture by emphasizing food safety, environmental protection, produce quality, and worker health and safety. To enhance national food safety governance, including the regulation of pesticide use and residues, the Maldives Food and Drug Authority under the Ministry of Health introduced the National Food Safety Policy 2017–2026.

The Maldives has developed an integrated regulatory framework for managing pesticides and chemical fertilizers, with a strong focus on environmental protection, public health, and sustainable agriculture. Key legislation such as the Plant Protection Act, Agricultural Pesticide Control Act,

and Hazardous Chemical Regulation governs the import, use, and disposal of agrochemicals. Initiatives like the Maldives Good Agricultural Practices (MGAP) and related food safety measures promote responsible usage and align with global standards. A national registry of approved pesticides enhances transparency and informed decision-making. However, the absence of a dedicated, standalone food safety policy poses limitations in ensuring uniform enforcement and coordination across relevant sectors.

6.2 Regulatory Discrepancies in Pesticide Management

A comparative assessment of pesticide regulatory frameworks between the Maldives and the European Union (EU), using the World Health Organization (WHO) hazard classification and global policy benchmarks, reveals significant discrepancies in pesticide governance. While the EU adopts a precautionary, science-based approach to pesticide regulation, the Maldives continues to permit several agrochemicals that are either banned or heavily restricted elsewhere due to their documented health and environmental risks (Table 6.1 for a detailed list).

Abamectin, classified by the WHO as a highly hazardous pesticide (Class Ib), is approved for use in the Maldives. Notably, several other pesticides currently approved in the country — including Carbaryl, Dimethoate, Emamectin Benzoate, Fipronil, Fenobucarb, Imidacloprid, Indoxacarb, Permethrin, and Thiram (Table 6.1) — are also classified by the WHO as moderately hazardous (Class II). Despite their known environmental persistence, bioaccumulation potential, and toxicity to non-target organisms (including pollinators and aquatic species), these substances are still in circulation. In contrast, the EU has banned these compounds, citing their unacceptable ecological and toxicological profiles. An even more alarming issue is the continued availability and use of banned or unapproved pesticides in the Maldives. Field observations from Thoddoo indicate that five pesticides not approved for use in the country (Table 6.1) are still widely sold in local agrochemical outlets. Among these, Zinc phosphide (Trizinc diphosphide), a highly hazardous pesticide classified by the WHO as Class Ib due to its acute toxicity, is widely used. In contrast, the European Union has already banned or strictly regulated these substances, highlighting a significant divergence in risk perception and regulatory standards. Further compounding the issue are pesticides such as Carbosulfan, Ethaboxam, Hexaconazole, and Lambda Cyhalothrin, which are also not approved in the Maldives (Annexure 2). The continued presence and sale of these chemicals reflect serious enforcement failures and compliance gaps at the grassroots level, raising concerns about the effectiveness of existing bans and raises serious concerns about pesticide monitoring and public safety. Conversely, there are emerging signs of progress. Pesticides such as Carbendazim, Chlorantraniliprole, Mancozeb, Spinetoram, and Novaluron—classified as unlikely to present acute

hazard in normal use (WHO Class U)—are permitted in both the Maldives and the EU. These reduced-risk compounds reflect a gradual shift toward safer and more sustainable pest control options. However, their adoption remains limited, and broader policy support is needed to mainstream such alternatives.

Table. 6.1. Comparative status of pesticides identified in Thoddoo Island during the study

Pesticides	WHO Class	WHO Hazard grade	MoFMRA Status	European Union Status
Abamectin	Class Ib	Highly hazardous	Approved	Restricted
Acetamiprid	Class II	Moderately hazardous	Approved	Not banned
Bifenthrin	Class II	Moderately hazardous	Approved	Restricted
Carbaryl	Class II	Moderately hazardous	Approved	Banned
Carbendazim	Class U	Reduced-risk	Approved	Banned
Carbosulfan	Class II	Moderately hazardous	Not Approved	Banned
Cartap Hydrochloride	Class II	Moderately hazardous	Approved	Not banned
Chlorantraniliprole	Class U	Reduced-risk	Approved	Not banned
Cypermethrin	Class II	Moderately hazardous	Approved	Not banned
Diafenthuron	Class III	Slightly hazardous	Approved	Banned
Dimethoate	Class II	Moderately hazardous	Approved	Banned
Dinotefuran	Class III	Slightly hazardous	Approved	Not banned
Emamectin Benzoate	Class II	Moderately hazardous	Approved	Not banned
Fipronil	Class II	Moderately hazardous	Approved	Banned
Ethaboxam	NA	Not Available	Not Approved	Not banned
Fenobucarb	Class II	Moderately hazardous	Approved	Banned
Hexaconazole	Class III	Slightly hazardous	Not Approved	Banned
Imidacloprid	Class II	Moderately hazardous	Approved	Banned
Indoxacarb	Class II	Moderately hazardous	Approved	Banned
Lambda Cyhalothrin	Class II	Moderately hazardous	Not Approved	Not banned
Mancozeb	Class U	Reduced-risk	Approved	Banned
Novaluron	Class U	Reduced-risk	Approved	Banned
Permethrin	Class II	Moderately hazardous	Approved	Banned
Profenofos	Class II	Moderately hazardous	Approved	Banned
Spinetoram	Class U	Reduced-risk	Approved	Not banned
Sulfur/Sulphur	Class III	Slightly hazardous	Approved	Not banned
Tebuconazole	Class II	Moderately hazardous	Approved	Not banned
Thiram	Class II	Moderately hazardous	Approved	Banned
Trizinc diphosphide / Zinc phosphide	Class Ib	Highly hazardous	Not Approved	Banned

In addition to ecological concerns, many widely used pesticides pose significant long-term health hazards, particularly carcinogenicity. Regulatory agencies like the U.S. Environmental Protection Agency (EPA) and the International Agency for Research on Cancer (IARC) have identified several pesticides with potential cancer risks. These include Carbaryl, Diazinon, Mancozeb, Bifenthrin, Carbendazim, Cypermethrin, Dimethoate, Fipronil, Hexaconazole, Propiconazole, Tebuconazole, Ethaboxam, Malathion, Permethrin, and Nitrobenzene. Multiple epidemiological studies have linked chronic pesticide exposure to increased incidences of leukemia, lymphoma, brain tumors, breast cancer, and prostate cancer. Despite these findings, the Maldives currently lacks any regulatory provisions explicitly targeting the carcinogenic potential of agrochemicals. Field surveys conducted during this study, import data by the Ministry of Environment, Climate Change and Technology (MoECCT, 2022) and the Maldives National Chemical Profile (2015) confirm the continued use of over 27 potentially carcinogenic pesticides (Table 6.2 for detailed list), underscoring the urgency for science-driven policy reform.

The Maldives faces clear and pressing challenges in aligning its pesticide regulatory framework with international best practices. While some progress is evident through limited adoption of reduced-risk pesticides, major gaps remain in terms of hazard classification integration, enforcement of existing bans, monitoring of retail practices, and assessment of chronic health risks, particularly carcinogenicity. Bridging these regulatory and enforcement gaps is critical for safeguarding environmental and human health and for advancing toward more sustainable agricultural practices in the country.

Table. 6.2. Pesticides with Potential Carcinogenic Risk as Classified by the US EPA, Imported into the Maldives (Source: Collected data during this study, MOECCT 2022, MNCP 2015)

Pesticides	Cancer Classification
Acephate	Group C: possible human carcinogen
Amitraz*	Group C--Possible Human Carcinogen
Benomyl*	Group C--Possible Human Carcinogen
Bifenthrin	Group C--Possible Human Carcinogen
Buprofezin	Suggestive Evidence of Carcinogenicity, but Not Sufficient to Assess Human Carcinogenic Potential
Captan	Group B2--Probable Human Carcinogen
Carbaryl	Likely to be Carcinogenic to Humans
Carbendazim	Group C--Possible Human Carcinogen
Chlorothalonil	Likely to be Carcinogenic to Humans
Cypermethrin	Group C--Possible Human Carcinogen
Diazinon	Group 2A: Probably carcinogenic to humans
Dimethoate	Group C--Possible Human Carcinogen
Ethaboxam*	Suggestive Evidence of Carcinogenicity
Fipronil	Group C--Possible Human Carcinogen
Hexaconazole*	Group C--Possible Human Carcinogen
Hexythiazox	Likely to be Carcinogenic to Humans
Iprodione	Likely to be Carcinogenic to Humans
Malathion	Suggestive Evidence of Carcinogenicity, but Not Sufficient to Assess Human Carcinogenic Potential
Mancozeb	Group B2--Probable Human Carcinogen
Metaldehyde	Suggestive Evidence of Carcinogenic Potential
Nitrobenzene	Reasonably anticipated to be carcinogenic to humans
Permethrin	Suggestive Evidence of Carcinogenicity, but Not Sufficient to Assess Human Carcinogenic Potential
Propiconazole*	Group C-- Possible Human Carcinogen
Propineb	Likely to be Carcinogenic to Humans
Tebuconazole	Group C--Possible Human Carcinogen
Tetramethrin	Group C: possible human carcinogen
Trichlorfon*	Likely to be Carcinogenic to Humans (High Doses), Not Likely to be Carcinogenic to Humans (Low Doses)

* Not approved as per the latest Approved Agricultural Pesticide Registry issued by the Ministry of Fisheries, Marine Resources, and Agriculture (Annexure 2)

6.3 Key Challenges in the Management of Agrochemicals in the Maldives

Disparities in Pesticide Regulation and Health Risk Oversight

- Regulatory focus is largely limited to import permits and basic labeling requirements, with insufficient emphasis on toxicological profiling, residue monitoring, or cumulative exposure assessments.
- There is no comprehensive risk assessment framework in place to evaluate the health or ecological impacts of pesticides prior to approval.
- Pesticides are often approved based on external registrations (e.g., in India or the EU) and label compliance, without adequate context-specific evaluations.
- There are no clear legal provisions for banning hazardous pesticides, restricting their use by crop type, or revoking registrations in response to emerging risks.
- The absence of a formal system for assessing toxicological, ecological, or cumulative health risks hinders science-based regulatory decisions.
- A lack of dedicated penalty frameworks for violations in pesticide imports, distribution, or misuse weakens deterrence against unsafe practices.
- Enforcement of occupational and public health safeguards for pesticide handlers and farm workers remains poor.
- Sectoral governance suffers from unclear accountability structures, resulting in weak oversight of health and environmental risk assessments.
- The lack of a national health surveillance system prevents effective detection and response to pesticide poisoning incidents or chronic exposure effects among farmers and rural communities.

Weak Monitoring of Use, Residues, and Environmental Impact

- There is no national program for monitoring pesticide residues in food, soil, water, or air, resulting in a critical data gap.
- Groundwater contamination from agricultural runoff—particularly in densely farmed island and atoll ecosystems—is suspected but remains unquantified.
- Pesticide residue levels in food and water, as well as their environmental persistence and bioaccumulation in marine species, are poorly studied or undocumented.
- Local data on soil degradation, pesticide accumulation in ecosystems, and associated ecological risks are lacking.

- The absence of agro-ecological and toxicological research undermines evidence-based policymaking and weakens the response to emerging environmental and health threats.

Limited Institutional Capacity for Enforcement and Inspection

- The government system lacks trained pesticide inspectors, toxicologists, and agricultural safety officers, severely limiting enforcement capacity.
- Ports are not equipped with dedicated personnel or infrastructure for the inspection, classification, or quarantine of pesticide consignments.
- Field-level regulatory activities are minimal, with infrequent farm visits and no system for routine audits, leading to widespread misuse, overapplication, and mixing of unapproved chemicals.
- Absence of domestic testing facilities for analyzing pesticide residues, persistent organic pollutants (POPs), or heavy metals in food and environmental samples.

Lack of Centralized Data and Coordination Mechanisms

- Agrochemical data is scattered across institutions with no centralized national database on pesticide use, trade, or health/environmental impacts.
- The Makudi Portal has improved permit tracking but fails to capture usage patterns, storage locations, and disposal practices.
- Low inter-agency coordination hinders integrated responses to pesticide-related incidents and undermines surveillance capacity.

Improper Handling, Storage, and Disposal Practices

- Agrochemicals are often stored in unmarked or poorly ventilated spaces on islands, with no temperature or safety controls.
- Empty pesticide containers are not collected or recycled, often ending up in the environment or repurposed unsafely.
- There are no protocols or infrastructure for safe pesticide waste disposal, even for expired or banned stocks

Low Awareness and Risk Perception among Farmers

- Farmers, agricultural workers, and the general public have limited awareness of the health and environmental risks associated with pesticide misuse.
- Safe handling practices and the use of personal protective equipment (PPE) are rarely adopted due to low awareness, lack of training, and cost constraints.

- Farmers often depend on informal sources, such as traders or peers, for pesticide advice, resulting in incorrect dosages, unsafe mixing, and excessive application.
- Knowledge of sustainable alternatives like Integrated Pest Management (IPM), organic farming, and Good Agricultural Practices (GAP) certification is limited, and adoption remains low.
- While organic farming is promoted, there is inadequate institutional support to help farmers transition away from synthetic agrochemicals.

6.4 Recommendations for Strengthening Agrochemical Governance

Enact a National Pesticide Management Law

- Develop and implement a Pesticide Act that defines registration protocols, licensing, import/export controls, usage norms, labeling standards, and penalties.
- Establish a Pesticide Regulatory Authority (PRA) with representation from agriculture, health, environment, and customs.
- Define provisions for periodic review and deregistration of hazardous pesticides based on new scientific evidence.

Institutionalize Risk Assessment and Health Safeguards

- Mandate pre-registration risk assessments using internationally recognized toxicology and environmental data (e.g., WHO/FAO Joint Meeting on Pesticide Residues).
- Include vulnerable population exposure, especially women, children, and island communities, in health risk assessments.
- Integrate pesticide exposure reporting into health information systems to track acute and chronic poisoning cases.

Establish Residue Monitoring and Environmental Surveillance

- Set up a national residue testing program for agricultural products, groundwater, and marine products in high-use areas.
- Create a Maldives Maximum Residue Limit (MRL) framework, harmonized with Codex standards but tailored to local consumption patterns.
- Initiate pilot studies on pesticide contamination in reef systems, lagoons, and aquifers in intensively farmed islands.

Develop Technical and Inspection Capacity

- Train and appoint pesticide inspectors and agrochemical safety officers across key islands and at port entry points.

- Equip the customs and agriculture departments with field detection kits and guidelines for safe handling and sampling.
- Introduce electronic tracking of pesticide consignments from import to end-use via the expanded Makudi Portal.

Promote Safe Use and Stewardship at the Farm Level

- Launch structured training programs on Integrated Pest Management (IPM), judicious pesticide use, and PPE adoption.
- Work with local councils and farmer groups to set up island-level pesticide storage hubs with proper ventilation and security.
- Create a pesticide container return scheme with incentives or subsidies to prevent environmental disposal.

Enable Research and Data-Driven Decision Making

- Commission research on agrochemical use patterns, pesticide resistance, and environmental fate in the Maldivian context.
- Partner with regional or international labs for toxicological profiling and eco-risk modeling of commonly used pesticides.
- Build a centralized pesticide use database integrated with import permits, field usage reports, and adverse event tracking



Plate 6.1: Pesticides Not Approved in Maldives sold in Thoddoo



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**Survey Questionnaire on the Usage of Agrochemicals in Vegetable Production on Thoddoo
Island, Maldives**

Part 1: General Demographics and Farm Characteristics

1. Household Information:

- Name of respondent:
- Age:
- Gender:
- Education level:
 - No formal education
 - Primary education
 - Secondary education
 - Tertiary education
- Household size:
- Main source of income:
 - Farming
 - Business
 - Employment
 - Other (specify):

2. Farm Information:

- Location of the farm:
- Size of the farm (in acres/hectares):
 - Type of vegetables grown:
 - Leafy vegetables (e.g., spinach, lettuce)
 - Fruiting vegetables (e.g., tomatoes, peppers)
 - Root vegetables (e.g., carrots, potatoes)
 - Others (specify):
- Years of farming experience:
- Do you practice monoculture or crop rotation?
 - Monoculture
 - Crop rotation
- Type of irrigation used:
 - Rain-fed
 - Manual irrigation

- Drip irrigation
- Sprinkler irrigation
- Other (specify):

Part 2: Farmers' Knowledge and Attitudes Related to the Use of Pesticides and Chemical Fertilizers

3. Pesticide Application:

- Do you use of Pesticides and Chemical Fertilizers on your farm?
 - Yes
 - No
- If yes, what types of pesticides do you use? (Tick all that apply)
 - Insecticides
 - Herbicides
 - Fungicides
 - Others (specify):
- What types of chemical fertilizers do you use? (Tick all that apply)
 - Nitrogen-based
 - Phosphorus-based
 - Potassium-based
 - Others (specify):
- How often do you apply pesticides and chemical Fertilizers?
 - Daily
 - Weekly
 - Monthly
 - Seasonally
 - As needed
- What method do you use to apply pesticides?
 - Manual spraying
 - Motorized spraying
 - Other (specify):
- What method do you use to apply chemical fertilizers?
 - Broadcasting
 - Banding
 - Foliar spraying

- Fertigation
- Other (specify):

4. Knowledge and Attitudes:

- How do you determine the amount of pesticide and chemical fertilizer to use?
 - Personal experience
 - Recommendation by extension officer
 - Manufacturer's instructions
 - Advice from other farmers
 - Other (specify):
- Are you aware of the health risks associated with pesticide and chemical fertilizer use?
 - Yes
 - No
- Have you received any training on the safe use of pesticide and chemical fertilizer?
 - Yes
 - No
- Do you use any personal protective equipment (PPE) when applying pesticide and chemical fertilizer?
 - Yes
 - No
- If yes, what types of PPE do you use? (Tick all that apply)
 - Gloves
 - Masks
 - Goggles
 - Protective clothing
 - Others (specify):
- How do you dispose of pesticide and fertilizer containers/packages?
 - Reuse for other purposes
 - Dispose in a designated area
 - Burn or bury
 - Other (specify):

5. Attitudes Towards Pesticide Use:

- Do you believe pesticide and chemical Fertilizer are necessary for vegetable production?
 - Strongly agree
 - Agree
 - Neutral

- Disagree
- Strongly disagree
- Would you consider using alternative pest control and fertilization methods (e.g., organic pesticides, biological control, organic fertilizers)?
 - Yes
 - No
 - If no, why not?

Part 3: Food Consumption and Body Weight

6. Food Consumption:

- How often do you consume vegetables?
 - Daily
 - Several times a week
 - Weekly
 - Occasionally
 - Rarely
- What is the average amount of vegetables you consume per meal? (grams or servings)
- Do you consume vegetables from your own farm?
 - Yes
 - No
- Do you wash your vegetables thoroughly before consumption? (Yes/No)
- Do you cook or consume vegetables raw more often? (Cooked/Raw/Both)

7. Body Weight:

- What is your current body weight? (in kilograms or pounds)

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Ministry of Agriculture and Animal Welfare

Male', Maldives

Approved Agricultural Pesticide Registry							
Common Name / Active Ingredient	Formulations	Concentration (%)	Pesticide Type	US EPA Toxicity Class	WHO Hazard Class	Host Plant/Area	Target Pest
1- Naphthaleneacetic acid							
Acephate	WP, SP	2.5, 75	Insecticide	III	Class II	fruit (including citrus), vine , peanuts, beet, brassicas, celery, beans, ornamentals, forestry and other crops	aphids, thrips, lepidopterous larvae, sawflies, leafminers, leafhoppers, cutworms
Acephate + Imidacloprid	SP	Acephate 50% + Imidacloprid 1.8%					
Acetamiprid	SP, SL, SG	20, 30, 45	Insecticide		Class II	fruit, vegetables, and ornamentals	Colorado beetle, flea hopper, fruit moth, leafhoppers, leafminers, plant bugs, thrips, whiteflies
Acetamiprid + monosultap	SP	Acetamiprid 15% + monosultap 30%					

Alanycarb				Insecticide	II	Class II	Vines, pome fruit, citrus fruit, and vegetable	coleoptera, hemiptera, lepidoptera and thysanoptera
Alcohol ethoxylate				Adjuvant				
Alpha-cypermethrin	SC, EC	1.47, 10, 9.88	Insecticide	II	Class II	fruit (including citrus), vegetables, Vines, maize, beet, forestry and other crops	Lepidoptera, coleoptera and hemiptera	
Aluminium phosphide			Fumigant, Fungicide, Rodenticide	I	FM		Rodents	
Aluminium sulfate			Plant Growth Regulator, Molluscicide					
Ametoctradin			Fungicide					
Aminocyclopyrachlor			Herbicide			Use on Turf		
Aminopyralid			Herbicide			industrial vegetation, rangeland, pastures		
Amisulbrom			Fungicide			fruits and vegetables	blight	
Ammonium Nonanoate			Herbicide			nurseries, greenhouses, landscapes, and interior scapes		
Azamethiphos	WP, SL	0.08, 1, 10	Insecticide	III	Class II		Beetle, bugs, flies, spiders and other arthropods	

Azoxystrobin + Difenoconazole + Alcohol, C16-18, Ethoxylated	SC	Azoxystrobin 18.2% + Difenoconazole 11.4% + Alcohol, C16-18, Ethoxylated 15-25%					
Benzalkonium chloride			Microbiocide, Algaecide, Herbicide				
Beta-cyfluthrin		25	Insecticide	II	Class Ib	deciduous fruit, vegetables, turf and ornamentals	Lepidoptera, coleoptera, hemiptera and homoptera
Beta-cypermethrin			Insecticide	II		fruits, grapes, sugar beat, and vegetables	coleoptera, diptera, hemiptera, lepidoptera and orthoptera
Bicyclopyrone			Herbicide				
Bifenthrin	EC, SC	10	Insecticide	II	Class II	citrus, fruit, grapes, ornamentals and vegetables	coleoptera, diptera, heteroptera, homoptera, lepidoptera and orthoptera
Bixafen			Fungicide			fruits, vegetables, ornamentals and forestry	
Borax			Insecticide, Herbicide, Fungicide	II	Class III	Non crop land	
Bordeaux mixture			Fungicide			Vegetables, fruits and nuts	insects, plants, fungus and algae
Boric acid	TB	2.5, 40, 60	Insecticide				Ant Poisons

Boric acid + Tricalcium phosphate		Boric acid 99% + Tricalcium phosphate <1%						
Brodifacoum	RB	0.0005, 0.005, 0.25, 0.3, 5	Rodenticide	I	Class Ia		Rodents, including strains resistant to conventional anticoagulant	
Bromadiolone	RB	0.005	Rodenticide	III	Class Ia		Control of rats and mice, including those resistant to warfarin	
Buprofezin	WP	25	Insect Growth Regulator, Insecticide	III	Class III	banana, Citrus, grapes, cucumbers, lettuce, melons, pumpkins, snap beans, squash, tomatoes, ornamentals	Mealybugs, planthoppers, scales, whiteflies	
Captan	WG, WP	50, 80	Fungicide	IV	U	Pome fruit, stone fruit, peach, cherries, apricot, plum, citrus fruit, vine, tomato, carrot, cucurbits, ornaments and other crops	scab, gloeosporium, rots, shot hole, leaf curl, brown rots, early and late blight, alternaria blight, leaf spot, anthracnose, downy mildew	
Carbaryl	WP	50, 80, 85	Insecticide, Plant Growth Regulator, Nematicide	II, III	Class II	Citrus fruit, vegetable, forage, forests, field crops, nuts, ornamentals, rangeland, turf, shade trees	lepidoptera, coleoptera, chewing and sucking insects	

Carbendazim	WP, DF, SC	50	Fungicide, Breakdown product	III	U	Banana, fruits, grape, mushroom, ornamentals, peanuts, plantation crops, turf, vegetable and other crops	Ascomycetes, fungi imperfecti, basidiomycetes
Cartap hydrochloride	GR, SP	4, 50	Insecticide	II	Class II	cabbage, peanut, sunflower, maize, pome fruit, stone fruit, citrus fruit, vines, ginger, tea, and sugar cane	potato beetle, diamondback moth, grass leafroller, rice stem borer, thrips
Chloralose/alphachloralose	WP	90	Rodenticide, Bird Repellent	II	Class II		birds, rodents, foxes, and other pest animals
Chlorantraniliprole			Insecticide			fruits, vegetables, ornamentals, forestry greenhouse and nursery plants	
Chlorantraniliprole + Thiamethoxam	WG	Chlorantraniliprole 20% + Thiamethoxam 20%					
Chlorfluazuron		0.1	Insect Growth Regulator, Insecticide		U	ornamental, tea, fruits and vegetables	Heliothis, Spodoptera, Bemisia tabaci and other chewing insects

Chlorothalonil	EC, SC, WP	40.3, 50, 53.94, 75, 78.12	Fungicide	I,II	U	pome fruit, stone fruit, citrus fruit, bush and cane fruit, cranberries, strawberries, pawpaws, banana, mango, coconut palm , vegetable, cucurbits, maize, ornamentals, mushroom, turf	many fungal diseases
Chlorothalonil + Iprodione + thiophanate methyl		Chlorothalonil 28.7% + Iprodione 9.4% + thiophanate methyl 9.4%					
Citronella Oil			Insect Repellent, Dog and Cat Repellent				
Clothianidin + Metofluthrin + Piperonyl Butoxide		Clothianidin 0.4% + Metofluthrin 0.01% + Piperonyl Butoxide 1%					
Copper hydroxide	WP	50, 60, 77	Fungicide, Microbiocide , Nematicide, Antibiotic	I	Class II	Vines, brassicas, celery, millet	peronosporaceae, Alternaria, phytophthora, Septoria, Leptosphaeria, Mycosphaerella
Copper oxide	WP	50, 77	Fungicide, Insecticide	III		Seed, horticulture crops, fruits and vegetables	blight, downy mildew, rust

Copper oxychloride	WP	50	Fungicide	III	Class II	beet, citrus, fruit, grapes, plantation crop, tomato, vegetables, ornamentals	late blight, leaf spot, downy mildew, canker, scab, melanose, rust, leaf curl, shot hole, cane, leaf scorch, anthracnose, blister blight, bacterial diseases
Copper sulfate			Fungicide, Algaecide, Molluscicide	I	Class II	Pond, lake, potable water, fish hatcheries, streams, ditches, swimming pools, sewer, crops and trees	Algae, Dutch elm, copper lime dust, tadpole shrimp
Coumatetralyl	RB, DP, WP	0.0375, 0.75	Rodenticide	I	Class Ib	Storage Area	Rats
Cyantraniliprole			Insecticide			cucurbits, fruiting vegetables, grapes, pome fruit, stone fruit	
Cyenoxyfen			Insecticide, Acaricide/Miticide			fruit, vegetables	
Cyfluthrin	EW	5	Insecticide	I,III	Class Ib	cereals, fruit and vegetables	cereal, corn, deciduous fruit, sugarcane, sunflower, vegetables
Cymoxanil			Fungicide	II	Class II	vines and tomatoes	downy mildew and late blight
Cymoxanil + Mancozeb	WP	Cymoxanil 8% + Mancozeb 64%					

Cypermethrin	EC	10.5, 10, 25, 35, 20, 10, 2.5, 25.3, 6.5	Insecticide	III	Class II		
Cypermethrin + 1-butanol + 1,2,4-trimethylbenzene + Naphthalene		Cypermethrin 26% + 1-butanol <2% + 1,2,4-trimethylbenzene <2% + Naphthalene <10%					
Cyphenothrin	EC	5, 7.2	Insecticide, Fumigant		Class II	Household use, public health, industrial use	Houseflies, midges, cockroaches
Cyphenothrin + D-tetramethrin	EC	Cyphenothrin 4% + D-tetramethrin 12%					
Cyprodinil			Fungicide	III		lemon, lime, cereal, field crops, grapes, stone fruit, pome fruit, strawberry, fruit, vegetable and as seed dressings	
Cyprodinil + Fludioxonil			Fungicide				
Cyprosulfamide			Herbicide Safener			corn	
Dazomet			Fumigant, Fungicide, Nematicide	II	Class II	Soil sterilant	Soil fungi, nematodes, germinating weed seeds and soil insects

Deltamethrin	EC, WP, SC, EW, ULV	4, 0.03, 1.25, 2, 2.5, 2.8, 3, 62.5, 98	Insecticide	II	Class II	citrus, grapes, maize, top fruits and vegetables, soil surface, stored grain	Coleoptera, heteroptera, homoptera, lepidoptera, thysanoptera, locusts, noctuidae, crawling and flying insects
Deltamethrin + Piperonyl Butoxide	SC	Deltamethrin 1% + Piperonyl Butoxide 8%					
Deltamethrin + S-bioallethrin	EC	Deltamethrin 2.8% + S-bioallethrin 0.89%					
Deltamethrin + S-bioallethrin + Piperonyl butoxide		Deltamethrin 0.6% + S-bioallethrin 0.85% + Piperonyl butoxide 11.90%					

Diazinon	GR, EC, EW	5, 50, 55, 80	Insecticide	II/III	Class II	deciduous fruit trees, citrus fruit, vines, bananas, pineapples, vegetables, beet, sugar cane, maize, sorghum, ornamentals, glasshouse crops, forestry, mushroom cultivation, animal houses, household use, seed treatment for maize, veterinary ectoparasiticide	sucking and chewing insects, mites, phorids, sciarid flies, flies, lice, mites, fleas, cockroaches, bedbugs, ants, fruit flies, birds
Diclosulam	WDG, DF	84	Herbicide	III		many crops	Broadleaf weeds
Difenacoum	RB	0.0005	Rodenticide	I	Class Ia		rats and mice
Difenoconazole	EC	25	Fungicide	III	Class II	Foliar and seed treatment fruits, cereals and vegetables,	Ascomycetes, Basidiomycetes and deuteromycetes and seed bone pathogens
Difethialone			Rodenticide		Class Ia		Commensal rats and mice (including warfarin resistant strains)
Difenthiuron	WP, SC	50	Insecticide	III		Cabbage, chilli, brinjal, tomato, citrus	controls Whiteflies, Aphids, Jassids, Thrips, Diamond Black Moth (DBM), & mites

Diflubenzuron				Insect Growth Regulator		Class III	forestry, woody ornamentals and fruits, citrus, vegetable, mushroom,	leaf eating insects, larvae of flies, mosquitoes, grasshoppers and migratory locusts. lice, fleas, blowfly larvae, codling moth, leafminers, mites, cotton boll weevil, army worm, leafworm
Dimethoate	EC, SL	30, 30.5, 40	Insecticide	II	Class II	citrus, fruit, grapes, pastures, tea, vegetables and ornaments	Acari, Aphididae, Aleyrodidae, Coccidae, Coleoptera, Collembola, Diptera, Lepidoptera, Pseudococcidae, Thysanoptera and flies	
Dimetilan			Insecticide		O			
Dinotefuran	GR, SL, WSG	1, 10, 40	Insecticide		Class III	brassica, cucurbits, fruiting and leafy vegetables, grapes, ornamentals		
D-phenothrin	EC	10	Insecticide	III	U	industrial location and outdoor use	Insects of public health	

d-phenothrin + n-Octyl bicycloheptene dicarboximide + Imidacloprid + Isobutane			d-phenothrin 0.4% + n-Octyl bicycloheptene dicarboximide 1% + Imidacloprid 0.05% + Isobutane 5< - >15						
Enrofloxacin (for veterinary use)									
Esfenvalerate	FL		5	Insecticide	II	Class II	fruit and vegetables	coleoptera, diptera, hemiptera, lepidoptera and orthoptera	
Ethephon	EC, SL		40, 48	Plant Growth Regulator	I, II, III	Class III	bromeliads, cantaloupe, cherries, cucumber, grapes, gauva, ornamentals, peppers, pineapple, squash, sugarcane, tomato,		
Ethion				Insecticide, Acaricide/Mi ticide	II	Class II	pome fruit, stone fruit, citrus fruit, vines, vegetables, ornamentals, maiz, sorghum, cucurbits, strawberries, turf and other crops	spider mites, aphids, scale insects, thrips, lepidopterous larvae, leafhoppers, suckers, soil-dwelling, and other insects	

Etofenprox	EC	10	Insecticide	III	U	pome fruit, stone fruit, citrus fruit, brassicas, cucumber, aubergines and other crops	rice water weevils, skippers, leaf beetles, leafhoppers, planthoppers, bugs, aphids, moths, butterfly, whitefly, leaf miners, leaf rollers, thrips, borers
Fenitrothion			Insecticide, Acaricide/Miticide	III	Class II	soft fruit, tropical fruit, vines, sugar cane, vegetables, turf and forestry	chewing, sucking and boring insects
Fenobucarb	EC	50	Insecticide	II	Class II	sugar cane, cucurbits, aubergines, capsicum	leafhoppers, planthoppers, thrips, weevils, bollworm and aphids
Fenoxasulfone			Herbicide				
Fenpropathrin			Insecticide, Acaricide/Miticide	II	Class II	pome fruit, citrus fruit, vines, vegetables, ornamentals, field crops, cucurbits, tomatoes	mites, whitefly, lepidopterous larvae, leaf miners, leafworms, bollworms
Fenvalerate	SC	10	Insecticide	II	Class II	fruits, vines, nuts, vegetable, cucurbits, sunflower, maize, sorghum, beet, peanut, sugar cane, ornamentals, forestry and non crop land	chewing, sucking and boring insects (lepidoptera, diptera, orthoptera, Hemiptera, and Coleoptera

Ferrous sulphate				Herbicide, Molluscicide				lawn	Moss
Fipronil	SC, EC, WP, GR	5, 4.95, 2.5, 0.3, 0.05, 0.1, 0.001	Insecticide	II	Class II	crops and non crops	soil and foliar insects (corn rootworm beetle larvae, colorado potato beetle and rice water beetle)		
Flazasulfuron			Herbicide	III		turf, citrus, vine, sugarcane	broadleaf weeds, annual grass weeds, sedges		
Flocoumafen	RB	0.005	Rodenticide	III	Class Ia	field, plantation crop, sugar cane and buildings	Rodents which have become resistant to other anticoagulant rodenticides		
Flubendiamide	SC	30, 39, 48	Insecticide		Class III	Corn, fruit, nuts, vegetables, vines			
Flubendiamide + Glycerine	SC	Flubendiamide 39% + Glycerine 10%							
Fludioxonil			Fungicide	III	U	Seed treatment, non cereal crops, vines, stone fruit. vegetables, field crops and turf	Gibberella, Fusarium, Tilletia, Helminthosporium, Septoria, Botrytis, Monilia, Sclerotinia, Rhizoctonia, Alternaria		
Fluopyram			Fungicide			grapes, strawberries and tomatoes			
Flutianil			Fungicide			field crops, fruits, horticultural crops, ornamentals, trees, turf and vegetables			

Folpet				Fungicide	III	U	pome fruit, stone fruit, soft fruit, citrus fruit, vines, lettuce, cucurbits, onion, leeks. celery, tomato and ornamentals	downy mildew, powdery mildew, leaf spot disease, scab, gloeosporium rots, botrytis, alternaria, pythium, rhizoctonia
Fosetyl-aluminium				Fungicide, Antibiotic/Bactericide	III	U	lettuce, strawberries, pome fruit, citrus fruit, pineapple, avocado, vines, cucurbits, onions, cocoa, ornamental plants and shrubs	Phycomycetes (Phytophthora, Plasmopara, Bremia)
Glufosinate-ammonium		SL	28	Herbicide	III	Class II	fruit orchards, vineyards, plantation crops, oil palm plantation, ornamental trees, bushes, non crop land, pre emergence in vegetables	annual and perennial broad-leaved weeds and grasses
Glufosinate-P				Herbicide			field crops, fruits, horticultural crops, ornamentals, trees, turf and vegetables	
Hexythiazox				Insect Growth Regulator, Acaricide/Miticide	III	U	fruit, vines, vegetables and ornamentals (horticulture crops)	eggs and larvae of many phytophagous mites
Horticultural oil (white summer oil)								

Hydramethylnon	PC	1, 1.8, 2	Insecticide	III	Class II	agriculture and household use	agriculture and household formicidae
Imicyafos			Nematicide			field crops, fruits, horticultural crops, ornamentals, trees, turf and vegetables	
Imidacloprid	WG, SC, SL, GR, EC, TC	20, 10, 17.8, 0.5, 18.3, 21.4, 30.5, 70	Insecticide	III	Class II	Seed dressing and soil treatment and as foliar treatment of maize, vegetables, citrus fruit, pome fruit and stone fruit	sucking insects, termites, biting insects (rice weevil, Colorado beetle)
Imidacloprid + Beta-cyfluthrin		Imidacloprid 19.8% + Beta-cyfluthrin 8.5%					
Imidacloprid + Beta-Cyfluthrin	SC	Imidacloprid 2.1% + Beta-Cyfluthrin 1.05%					
Imidacloprid + Cyfluthrin	SC	Imidacloprid 21% + Cyfluthrin 10.5%					
Indaziflam			Herbicide			field crops, fruits, horticultural crops, ornamentals, trees, turf and vegetables	
Indoxacarb	SC, EC	0.05, 14.5, 15	Insecticide		Class II	field crops, vegetables and fruits	Lepidoptera and other pests
Ipfencarbazon			Herbicide				

Iprodione				Fungicide	III	Class III	vegetables, ornamentals, pome fruit, stone fruit, currants, strawberries, cucurbits, beet, sunflower, turf, and other crops. post harvest dip or seed treatment	Botrytis, Monilia, Sclerotinia, Alternaria, Corticium, Fusarium, Helminthosporium, Phoma, Rhizoctonia and Typhula
Isoprothiolane				Fungicide, Insecticide	III	Class II	fruits, vegetables and ornamentals	rice blast, rice stem rot and fusarium leaf spot
Isotanal				Fungicide			field crops, fruits, horticultural crops, ornamentals, trees, turf and vegetables	
Lufenuron				Insecticide, Acaricide/Miticide, Insect Growth Regulator		Class III	vegetables, citrus fruit, pets and houses	Lepidoptera larvae, Coleoptera larvae, citrus whitefly, rust mite, flea, cockroaches
Malathion	EC, UL	50, 57, 84, 96		Insecticide	III	Class III	pome, soft fruit, stone fruit, vegetables and stored grains	Coleoptera, Diptera, Hemiptera, Hymenoptera, Lepidoptera
Mancozeb				Fungicide	III	U	field crop, fruit, nuts and vegetables	blight, leaf spot, rust, downy mildew and scab
Maneb				Fungicide	III	U	field crop, fruit, nuts , vegetables, ornamentals and turf	blight, leaf spot, rust, downy mildew and scab

Meptyldinocap				Fungicide				field crops, fruits, horticultural crops, ornamentals, trees, turf and vegetables	powdery mildew
Metalaxyl				Fungicide		III	Class II	avocado, citrus fruit and seed treatment	downy mildew, late blight, soilborne disease caused by phytophthora and phythium
Metalaxyl-M + Mancozeb	WG		Metalaxyl-M 4% + Mancozeb 64%						
Metaldehyde	GR, WP		1, 6.7, 98	Molluscicide		III	Class II	field, greenhouse, citrus orchard, berries, and ornamentals, vegetables, fruits	slugs and snails
Metazosulfuron				Herbicide					
Methiozolin				Herbicide				turf and non food crops	
Nitrobenzene	EC		20, 22	Chemical intermediate					
Novaluron				Insecticide		III	U	fruit, nuts , vegetables, ornamentals and turf	Agromyzid leafminers, lepidoptera, and white flies
Novaluron + Indoxacarb	SC		Novaluron 5.25% + Indoxacarb 4.5%						
Penflufen				Fungicide					

Permethrin	EC	10, 25, 30, 50	Insecticide	II, III	Class II	fruits, vegetables and other crops, animal housing	Lepidoptera, coleoptera, animal eco parasites, biting flies, blattodea, diptera, hymenoptera, crawling insects, and flying insects
Permethrin + tetramethrin	EC	Permethrin 20% + tetramethrin 10%					
Phenthoate	EC	50	Insecticide	II	Class II	citrus fruit, pome fruit, berries, maize, sunflower, sugarcane, vegetables, cucurbits, and ornamentals	aphids, scale insects, jassids, lepidopterouslarvae, bollworms, borers, leafhoppers, planthoppers, mealybugs, lace bugs, suckers, thrips, whitefly and spidermites
Phoxim			Insecticide	III	Class II	granaries, mills, silos, ships, household, maize, vegetable, poatoes	stored-product insects, ants, caterpillars, soil insects, migratory locusts and other insects
Picloram			Herbicide	II	U	grasslands and non-crop areas	woody weed, bracken, fern, docks
Piperonyl butoxide	EW	10	Synergist, Insecticide		U		

Piperonyl Butoxide + Metofluthrin + d,d -T-Cyphenothrin 6.0%	EW	Piperonyl Butoxide 10% + Metofluthrin 0.1% + d,d -T- Cyphenothrin 6.0%							
Pirimiphos-methyl	EC	50	Insecticide	II	Class II	warehouse, stored grain, aminal house, domestic and industrial premises, vegetables, ornamentals, bulb flowers, sugar cane, maize, sorghum, citrus fruit, other fruit, tomato, cucumber, capsicum, aubergines, and other glasshouse crops	insects, mites, chewing insects, sucking insects, boring insects, mites, whitefly, thrips, mealybugs, and aphids		
Polybutene			Rodenticide						
Potassium salt of fatty acid		49.52, 47							
Potassium salts of Fatty acid + Neem oil + Pyrethrins		Potassium salts of Fatty acid 1% + Neem oil 0.9% + Pyrethrins 0.012%							
Primisulfuron-methyl			Herbicide	III		fruits and nuts and field cropping areas	grass weeds and many broad-leaved weeds		
Profenofos	EC, SL	50	Insecticide, Acaricide/Miticide	III	Class II	maize, vegetables, and other crops	lepidoptera and mites		
Profenofos + Cypermethrin	EC	Profenofos 40% + Cypermethrin 4%							

Propamocarb hydrochloride				Fungicide	III		vegetables, ornamentals, glasshouse tomatoes, cucumbers, tulips, and in forestry seedbeds, turfs, lettuce, cucurbits, cabbage, tomatoes, seed strawberries, seed treatment	Phycomycetous diseases, Phythium blight, phytophthora infestans, pytophthora cactorum
Propineb	WP	70	Fungicide, Microbiocide	III	U	vines, apple, pears, stone fruit, tomatoes, ornamentals, vegetables, citrus fruit, berry fruit		downy mildew, black rots, red fire disease, grey mould, scab, brown rot, leaf spot disease, Alternaria blight, phytophthora blight, septoria leaf spot, leaf mould and rust
Propoxur	EC	18.7, 2	Insecticide	I, II, III	Class II	food storage areas, houses, animal houses, fruit, vegetable, ornamentals, vines, maize, sugar cane, and forestry		cockroaches, flies, fleas, mosquitoes, bugs, ants, millipedes, chewing insects, sucking insects, migratory locusts and grasshoppers
Propoxur + Tetramethrin + Piperonyl butoxide	AE	Propoxur 2% + Tetramethrin 0.2% + Piperonyl butoxide 1%						

Propyrisulfuron				Herbicide			non-food crops and forest areas	
Prothiofos				Insecticide	III	Class II	vegetables, fruit, maize, sugar cane, and ornamentals	leaf-eating caterpillars, pseudococcus spp, thrips, cockchafer larvae and cutworms
Pyrametostrobin				Fungicide				
Pyraoxystrobin				Fungicide			Vegetables	
Pyrasulfotole				Herbicide			grass crops and fruits, turf and nonfood growing areas	
Pyrethrins		Liquid	0.5, 5	Insecticide	III	Class II	public health, Stored products, animal house, domestic animal, farm animal, fruit, vegetables, field crops, ornamentals, glasshouse crops and house plant	mites, chewing insects, sucking insects, spider mites
Pyrethrins + Beauveria bassiana			Pyrethrins 0.75% + Beauveria bassiana 0.06%					
Pyrethrins + Piperonyl butoxide			Pyrethrins 4% + Piperonyl butoxide 16%					
Pyrifluquinazon				Insecticide			greenhouse tomatoes	
Pyriproxyfen		EC	100	Insect Growth Regulator, Insecticide	III	U	Breeding sites	white fly, thrips, and public health insect pests

Pyriproxyfen + Beauveria bassiana		Pyriproxyfen 70% + Beauveria bassiana 7%						
Pyroxasulfone				Herbicide			corn	
Pyroxulam				Herbicide			non food growing areas, turf	
Quinalphos				Insecticide	II	Class II	fruit tree, vegetable, beet, vines, ornamentals, nuts	lepidoptera, coleoptera, diptera, hemiptera, aphids, bollworms, borers, leafhoppers, mealybugs, mites, planthoppers and thrips
Saflufenacil				Herbicide			fruit crops, forestry and ornamentals	
S-bioallethrin				Insecticide	II, III		field crop, fruit, nuts , vegetables, ornamentals and turf	flying insects and crawling insects
S-Bioallethrin + Permethrin	EC	S-Bioallethrin 0.78 + Permethrin 18.70%						
Spinetoram	SG	0.5, 5.87		Insecticide (Organic)		U	field crop, fruit, nuts , vegetables, ornamentals	codling moth and leafminers
Spinetoram				Insecticide			pome fruit, tree nut, vegetables	codling moth, leafminers
Spirotetramat				Insecticide			citrus, grapes, pome fruit, stone fruit, tree nut, vegetables	

Streptomycin	SP	90	Bactericide/ Antibiotic, Fungicide	III		field crop, fruit, nuts , vegetables, ornamentals and turf	
Sulfoxaflor			Insecticide				
Sulfur	WP, DF, WG	80	Fungicide, Insecticide	III		field crop, fruit, nuts , vegetables, forestry, ornamentals and turf	scab, powdery mildew, shot hole, mites
Sulfur + Ethoxylated Alcohol + Polyoxyethylene dodecyl mono ether + Water		Sulfur 45% + Ethoxylated Alcohol 3% + Polyoxyethylene dodecyl mono ether 2% + Water 55%					
Tebuconazole	EW	25	Fungicide		Class II	field crop, fruit, nuts , vegetables, ornamentals and turf	smut and bunt disease, rust, powdery mildew, scab, powdery mildew fungi
Tebufenozide			Insect Growth Regulator	III	U	field crop, fruit, nuts , vegetables, ornamentals and forest crops	lepidopteran larvae
Tebufluoquin			Fungicide				
Tefuryltrione			Herbicide			fruits, turn and ornamentals	
Tembotrione			Herbicide			fruits, turn and ornamentals	

Temephos	AB, GR	1	Insecticide/Larvicide	III	Class III	public health, Agriculture, Humans and domestic animals	larvae of anopheles, aedes, culex, simulium spp, flea and lice
Tetramethrin			Insecticide	III	U	public health and home garden use	flies, cockroaches, mosquitoes, wasps and other insect pests
Tetramethylfluthrin			Insecticide				
Thiamethoxam	WG	10, 20, 25	Insecticide, Seed treatment/P rotectant	III	Class II	seed treatment, field crop, fruit, nuts , vegetables, ornamentals and turf	
Thiencarbazon-methyl			Herbicide			fruits, turn and ornamentals	
Thiocyclam	SP	50	Insecticide	II	Class II	field crop, fruit, nuts , vegetables, ornamentals	lepidoptera, coleoptera, diptera, thysanoptera, colorad beetle, stemborers, corn borer, tanymecus, weevil and sugarcane stemborer

Thiophanate-methyl	SP	70	Fungicide	III	U	field crop, fruit, nuts , vegetables, ornamentals and turf	eyespot, scab, monilia disease, gloeosporium rot, canker, powdery mildew, botrytis, sclerotinia, leaf spot disease, club root, dollar spot, corticium, fusarium, pyricularia oryzae and sigatoka disease
Thiophanate-methyl + Thiram	WP	Thiophanate- methyl 50% + Thiram 30%					
Thiram	WP	75, 80	Fungicide	III	Class II	seed treatment, field crop, fruit, nuts , vegetables, ornamentals and turf	botrytis spp, rust, scab, leaf curl, monilia, damping off disease
Trichoderma viride	WP	1	Fungicide	III			downy mildew, powdery mildew, fusarium wilt, verticillium wilt, leaf spot, root rot, stem rot
Triclopyr			Herbicide	I, III	Class II	forests, industrial sites, turf, permanent grass pastures, rangeland, non- irrigation ditchbanks	
Trifloxystrobin	WG	50	Fungicide	III	U	banana, cucurbits, grape, pome fruit, turf, ornamentals	

Biopesticide								
Common Name / Active Ingredient	Formulations	Concentration (%)	Pesticide/ Chemical Class	Pesticide Type	US EPA Toxicity Class	WHO Hazard Class	Host Plant/Area	Target Pest
1-Methylcyclopropene				Plant Growth Regulator	III		fresh cut and potting flowers	
6-Benzyladenine			Plant derived	Plant Growth Regulator	III		fruits, vegetables, ornamentals and forestry	
Abamectin	EC, TK	0.01, 1.8, 3.6	Macrocyclic Lactone, Botanical	Acaricide/Miticide, Insecticide	II	Class Ib	Ornamentals, citrus fruit, nut crops, vegetables, and other crops	Mites, leafminers, suckers, Colorado potato beetle, fire ants, pinworms
Agrobacterium radiobacter			Microbial, Beneficial bacterium	Fungicide			nurseries, orchards, and bare-root seedlings	crown gall infection
Amblyseius californicus			Beneficial insect (Predatory mite)	Insecticide			greenhouse, corn, ornamentals and interiorscapes	Willamette mites
Amblyseius cucumeris			Beneficial insect (Predatory mite)	Insecticide			greenhouse, vegetables and ornamentals	thrips
Amblyseius degenerans			Beneficial insect (Predatory mite)	Insecticide			fruit, vegetables, ornamentals	thrips

Amblyseius fallacis				Beneficial insect (Predatory mite)	Insecticide			greenhouses and nurseries and vegetables and fruits	mites
Amblyseius swirskii				Beneficial insect (Predatory mite)	Insecticide				
Ampelomyces quisqualis				Microbial Fungus	Fungicide			cucurbits, grapes, tomatoes and ornamentals	powdery mildew
Anisopteromalus calandrae				Parasitoid	Insecticide			Stored grain	weevil
Annonin					Insecticide			chillies roses, vegetables, and fruits	
Anthocoris nemoralis				Beneficial insect (Predatory bug)	Insecticide				pear psylla
Anthraquinone					Bird Repellent	III		planted seeds	crows
Aphelinus abdominalis				Parasitoid	Insecticide			Sweet potato	potato aphids
Aphidius colemani				Parasitoid	Insecticide			vegetable crops, strawberry, melon	aphids
Aphidius ervi				Parasitoid	Insecticide			sweet potato	potato aphids
Aphidius matricariae				Parasitoid	Insecticide			fruits, vegetables and forestry	

Aphidoletes aphidimyza						Beneficial insect (Predatory midge)	Insecticide			fruits, vegetables and forestry	aphids
Aphytis malinus						Parasitoid	Insecticide			fruits, vegetables and forestry	second and third instar of red scale, yellow scale, San Jose scale and oleander scale
Aspergillus flavus						Fungus	Fungicide			fruits vegetables and turf, greenhouse	
Atheta coriaria						Beneficial insect (Predatory beetle)	Insecticide			fruits and vegetables	fungus gnats and shore flies
Autographa californica NPV						Baculovirus	Insecticide, Virus			corn, fruit, vegetables, and ornamentals	Lepidopteran larvae
Azadirachtin	EC	0.15, 1.18, 3, 0.03, 70				Botanical	Insecticide, Nematicide	IV		Outdoor food crops	Aphids, beetles, borers, caterpillars, flies, leafhoppers, leafminers, nematodes, scales, thrips, weevils, whiteflies

Bacillus cereus				Bacterium	Plant Growth Regulator			agriculture, horticulture and forestry	
Bacillus firmus				Bacterium	Nematicide			cucumber and tomatoes	root-knot nematodes
Bacillus licheniformis				Bacterium	Fungicide	III		golf courses, lawns, and other ornamental turfgrass	
Bacillus pumilus				Bacterium	Fungicide	III		roses, strawberries, tree fruits, vegetables, vines, corn,	
Bacillus sphaericus				Bacterium	Insecticide	III			mosquito larvae
Bacillus subtilis				Microbial	Fungicide	II, III		seed treatment, field crop, fruit, nuts , vegetables, ornamentals and turf	Organisms which attack the root system
Bacillus thuringiensis	EC, WG, WP	11.61, 4		Bacterium	Insecticide	III	Class III	ornamentals, pome fruit, stone fruit, vines, tomatoes, vegetables and forests	Lepidoptera, diptera, coleoptera insects
Bacillus thuringiensis spp. aizawai				Bacterium	Insecticide	III	Class III	agriculture, horticulture and forestry	lepidopterous larvae

Bacillus thuringiensis spp. israelensis				Bacterium	Insecticide, Larvicide	III	Class III	fruits, vegetables, forestry and turf	mosquito and blackfly larvae
Bacillus thuringiensis spp. kurstaki				Bacterium	Insecticide	III	Class III	agriculture, horticulture and forestry	lepidopterous larvae
Bacillus thuringiensis spp. Tenebrionis				Bacterium	Insecticide	III	Class III	eggplant, tomatoes, and ornamental trees	colorado potato beetle, elm leaf beetle
Bacteriophages				Virus	Fungicide				
Beauveria bassiana				Microbial Fungus	Insecticide	III		Fruit, vegetables, turf and ornamentals and nurseries	Aphids, Mealybugs, psyllids, thrips, weevils and white flies
Bee Attractant				Attractant	Attractant, Pheromone				
Blastocidin-S					Fungicide	III	Class Ib		rice blast
Bracon hebetor				Parasitoid	Insecticide			stored grains	
Burkholderia cepacia				Bacterium	Fungicide				
Candida oleophila				Microbial fungus	Fungicide				
Capsaicin				Botanical	Repellent	III		fruits, vegetables, ornamentals and forestry, non- agricultural lands	rabbits, squirrels and soft bodied insects

Carcinops pumilio				Beneficial insect (Predatory beetle)	Insecticide			Poultry farm and livestock areas	flies
Chenopodium ambrosioides				Plant derived	Acaricide/Miticide, Insecticide			fruits, vegetables, ornamentals and forestry nuts	aphids, leafhoppers, leafminers, plant-feeding mites, thrips and white flies
Chitosan				Crustacean derived	Fungicide	III		fruits, vegetables, ornamentals and forestry greenhouse and nursery plants	Botrytis and powdery mildew
Chondrostereum purpureum				Microbial fungus	Herbicide			fruits, forests and hardwood trees	
Chrysoperla carnea				Beneficial insect (Predatory Bug)	Insecticide			field crops, orchards and greenhouses, fruits, nurseries and vegetables	aphids, caterpillars, leafhoppers, mealybugs, spider mites, scales, thrips, whiteflies
Chrysoperla rufilabris				Beneficial insect (Predatory Bug)	Insecticide			field crops, orchards and greenhouses, fruits, nurseries and vegetables	aphids, mites, and phytophagous insect eggs
Cinnamaldehyde				Plant derived	Fungicide, Repellent	III		Greenhouse and horticulture crops	

Clonostachys rosea f. catenulate				Microbial fungus	Fungicide		herbs, spices, vegetables, ornamentals, trees, shrub seedling and production of horticultural plants	damping-off, seed rot, stem rot, root rot and wilt diseases
Clove Oil				Plant derived	Fungicide, Herbicide		field crops, orchards and greenhouses, fruits, nurseries and vegetables	weeds, silver scurf and sprout
Codlemone				Synthetic female sex hormone	Attractant/ Pheromone		field crops, orchards and greenhouses, fruits, nurseries and vegetables	codling moth
Colletotrichum gloeosporioides				Fungus	Herbicide	III		
Coniothyrium minitans				Microbial fungus	Fungicide	III	field crops, orchards and greenhouses, fruits, nurseries and vegetables	Sclerotinia sccklerotorum and Sclerotinia minor
Corn Gluten Meal				Botanical	Attractant/ Pheromone, Herbicide, Insecticide		field crops, orchards and greenhouses, fruits, nurseries and vegetables	fruit fly

Cotesia plutella				Parasitoid	Insecticide			field crops, orchards and greenhouses, fruits, nurseries and vegetables	Caterpillars
Cryptolaemus montrouzieri				Beneficial insect (Predatory beetle)	Insecticide			Citrus, grape, Ornamentals	mealybug, aphids, white flies, soft scales
Cuelure				Synthetic sex pheromone	Attractant/ Pheromone			melon and curcubits	melon fruit fly
Cybocephalus nipponicus				Beneficial insect (Predatory Beetle)	Insecticide			horticulture, forestry and ornamentals	
Cydia pomonella (GV)				Microbial Baculovirus	Insecticide, virus			fruits, forestry	codling moth
Cytokinins				Botanical	Plant Growth Regulator			field crops, fruits, horticultural crops, ornamentals, trees, turf and vegetables	
Dacnusa sibirica				Parasitoid	Insecticide			Greenhouse crops and nurseries	
Delphastus catalinae				Beneficial insect (Predatory beetle)	Insecticide			Greenhouse crops and sweet potato	sweet potato whitefly and greenhouse whitefly

Delphastus pusillus					Beneficial insect (Predatory beetle)	Insecticide			Greenhouse , fruits and vegetables	sweet potato whitefly and greenhouse whitefly
Diallyl sulfide						Fumigant				
Dicyphus hesperus					Beneficial insect (Predatory bug)	Insecticide			vegetables, fruits and ornamentals	white flies
Diglyphus isaea					Parasitoid	Insecticide			Greenhouse tomatoes, chrysanthemum, cucumber, celery, ornamentals	leafminers
Disparlure					Pheromone	Attractant/ Pheromone			field crops, fruits, horticultural crops, ornamentals, trees, turf and vegetables	gypsy moth
Emamectin Benzoate					Macrocyclic Lactone	Insecticide	III		non-food crops	
Encarsia formosa					Parasitoid	Insecticide			Greenhouse cucumbers, peppers and tomatoes	Whiteflies
Eretmoceris eremicus					Parasitoid	Insecticide			sweetpotato	Sweetpotato whiteflies, silverleaf
Eretmoceris mundus					Parasitoid	Insecticide			Greenhouse	Sweetpotato whiteflies
Ethoxylated alcohol						Larvicide				mosquito

Eugenol					Plant derived	Insecticide				
Feeding Stimulant						Insect feeding stimulant			field crops, fruits, horticultural crops, ornamentals, trees, turf and vegetables	Lepidoptera larvae
Feltiella acarisuga						Insecticide	III		vegetables and fruits	red spider mite
GABA						Plant Growth Regulator			field crops, fruits, horticultural crops, ornamentals, trees, turf and vegetables	
Galendromus occidentalis						Insecticide			tomato, corn, grapes and ornamentals	russet mite
Garlic Extract						Repellent, Insecticide			field crops, fruits, horticultural crops, ornamentals, trees, turf and vegetables	

Gibberellic Acid				Botanical	Plant Growth Regulator	III		field crops, fruits, horticultural crops, ornamentals, trees, turf and vegetables	
Goniozus legneri				Parasitoid	Insecticide			nuts, fruit trees	navel orangeworm, pink bollworm and codling moth
Gossypure				Pheromone	Attractant/ Pheromone			field crops, fruits, horticultural crops, ornamentals, trees, turf and vegetables	pink bollworm
Grandlure				Pheromone	Attractant/ Pheromone			field crops, fruits, horticultural crops, ornamentals, trees, turf and vegetables	boll weevil
Harpin Protein					Plant Growth Regulator			field crops, fruits, horticultural crops, ornamentals, trees, turf and vegetables	

Helicoverpa armigera NVP				Baculovirus	Insecticide, Virus			vegetables and ornamentals	bollworm, corn earworm, tobacco budworm
Helicoverpa zea NPV				Baculovirus	Insecticide, Virus			vegetables and ornamentals	bollworm, corn earworm, tobacco budworm
Heterorhabditis bacteriophora				Parasitoid	Insecticide			turf, nurseries	black vine weevil and grubs
Heterorhabditis megidis				Parasitoid	Insecticide			horticulture crops and forestry	Vine weevil marvae
Heterorhabditis spp.				Parasitoid	Insecticide			field crops, fruits, horticultural crops, ornamentals, trees, turf and vegetables	Lepidopterous larvae
Hippodamia convergens				Beneficial insect (Predatory ladybird)	Insecticide			field crops, fruits, horticultural crops, ornamentals, trees, turf and vegetables	aphids, thrips, whiteflies and other soft bodied insects

Hypoaspis spp.				Beneficial insect (Predatory mite)	Insecticide			field crops, fruits, horticultural crops, ornamentals, trees, turf and vegetables	fungus gnats and soil dwelling insect larvae
Indianmeal Moth Granulovirus (IMMGV)				Baculovirus	Insecticide			stored commodities	Indian meal moth
Indole 3-butyric acid	DP	0.1, 30			Plant Growth Regulator	III		cutting of herbaceous and woody ornamentals	
Indole-3-acetic Acid				Botanical	Plant Growth Regulator			field crops, fruits, horticultural crops, ornamentals, trees, turf and vegetables	
Iron Phosphate				Inorganic	Molluscicide			field crops, fruits, horticultural crops, ornamentals, trees, turf and vegetables	slugs and snails
Karanjin					Acaricide/Miticide, Insecticide			chillies, flowers and vegetables	mites, scales, thrips and whiteflies

L-cysteine					Plant Growth Regulator				field crops, fruits, horticultural crops, ornamentals, trees, turf and vegetables	
Lecanicillium lecanii					Microbial Fungus	Insecticide	III		field crops, fruits, horticultural crops, ornamentals, trees, turf and vegetables	aphids, mealy bugs, mites, scales, thrips and whiteflies
Leptomastix dactylopii					Parasitoid	Insecticide			field crops, fruits, horticultural crops, ornamentals, trees, turf and vegetables	mealybugs
Macrolophus caliginosus					Beneficial insect (Predatory mite)	Insecticide			field crops, fruits, horticultural crops, ornamentals, trees, turf and vegetables	spider mites and whiteflies
Mamestra configurata NPV					Baculovirus	Virus			non agriculture crops, forstry and nursery	bertha armyworm

Mesoseiulus longipes					Beneficial insect (Predatory mite)	Insecticide			field crops, fruits, ornamentals, trees,	
Metaphycus spp.					Parasitoid	Insecticide			field crops, fruits, horticultural crops, ornamentals, trees, turf and vegetables	scales
Metarhizium anisopliae					Fungus	Insecticide			field crops, fruits, horticultural crops, ornamentals, trees, turf and vegetables	black vine weevil, tick, grub, spider mites, whiteflies and thrips
Methyl Anthranilate						Repellent				
Milbemectin					Macrocyclic Lactone	Acaricide/Miticide, Insecticide	II		citrus, fruit, ornamentals, nurseries, strawberry	red mites, spider mites, two spotted spider mites
Muscidifurax spp.					Parasitoid	Insecticide			field crops, fruits, horticultural crops, ornamentals, trees, turf and vegetables	flies

Myrothecium verrucaria					Fungus	Nematicide				citrus, leafy vegetables, nuts, pineapples, pome fruit, stone fruit	nematodes
Natamycin						Fungicide				daffodils and ornamentals	basal rot
Neem oil					Plant derived	Fungicide, Insecticide				fruits, melon. Nuts, vegetables, ornamentals	fungal diseases, mites and insect pests
Nosema locustae					Microsporidian	Insecticide				grasshopper nymphs and mormon cricket	
Orius insidiosus					Beneficial insect (Predatory bug)	Insecticide				greenhouse vegetables and ornamentals	thrips
Orius spp.					Beneficial insect (Predatory bug)	Insecticide				greenhouse vegetables and ornamentals	thrips
Oxytetracycline						Antibiotic/Bactericide				peaches and pears, fruits	bacterial spot and fire blight
Paecilomyces fumosoroseus					Microbial Fungus	Insecticide				ornamental plants	whiteflies, thrips, mites
Paecilomyces lilacinus					Microbial Fungus	Nematicide				banana, pineapple, citrus, vegetables	

Paenibacillus popilliae				Bacterium	Insecticide			field crops, fruits, horticultural crops, ornamentals, trees, turf and vegetables	
Pantoea agglomerans				Microbial Fungus	Fungicide			field crops, fruits, horticultural crops, ornamentals, trees, turf and vegetables	
Pediobius foveolatus				Parasitoid	Insecticide			beans and vegetables	Mexican bean bottle
Periplanone B					Attractant/ Pheromone				
Phasmarhabditis hermaphrodita				Parasitoid	Insecticide			field crops, fruits, horticultural crops, ornamentals, trees, turf and vegetables	Slug
Pheromone					Attractant/ Pheromone				
Phlebiopsis gigantea				Fungus	Fungicide			conifers, forest	root rot and butt rot
Phytophthora palmivora				Fungus	Herbicide				

Phytoseiulus persimilis				Beneficial insect (Predatory mite)	Insecticide		greenhouse, interiorscapes, tomatoes, strawberries	mites
Pine Extracts				Botanical	Plant Growth Regulator		flowers, fruit, ginger, nurseries, nuts, sugarcane, vegetables	
Plant Extract 620				Botanical	Nematicide	III	field crops, fruits, horticultural crops, ornamentals, trees, turf and vegetables	Nematodes
Plant Oils				Botanical	Fungicide, Herbicide, Insecticide			
Podisus maculiventris				Beneficial insect (Predatory bug)	Insecticide		field crops, fruits, horticultural crops, ornamentals, trees, turf and vegetables	mexican bean beetle, cabbage looper, cabbageworm
Polyoxins					Fungicide	III	golf courses, parks, commercial, industrial ground	

Potassium Bicarbonate					Fungicide				fruits, vegetables, herbs and ornamentals	Anthraxnose, black spot, botrytis, powdery mildew
Pseudomonas chloroaphis				Bacterium	Fungicide				grass crops	wilt, root rot, rice blast, sheath blight, downy mildew, powdery mildew, bacterial wilt, fusarium wilt, verticillium wilt, leaf spot, root rot and shoot rot
Pseudomonas fluorescens				Microbial Bacterium	Fungicide		III		banana, vegetables, nursery, greenhouse	
Pseudomonas syringae				Microbial Bacterium	Fungicide				citrus, pome fruit, seed storage	
Rhamnolipid					Fungicide/Biosurfactant					
Rhizobia					Inoculant					
Rhizobium lophanthoe				Beneficial insect (Predatory Beetle)	Insecticide				citrus, interiorscaping, ornamentals	scales
Rodolia cardinalis				Beneficial insect (Predatory Beetle)	Insecticide					

Rumina decollata						Predator			fruits, vegetables, herbs and ornamentals	brown garden snails
Sabadilla					Plant derived	Insecticide	III		citrus, fruits, vegetables, ornamentals	thrips
Seaweed Extract						Plant Growth Regulator	III		fruit, vegetables, field crops, turf and ornamentals	
Spalangia cameroni						Insecticide			fruit, vegetables, field crops, turf and ornamentals	
Spinosad		SG, SC	2.5, 22.5, 25, 48		Spinosyn, Macroyclic Lactone	Insecticide		Class III	field crop, fruit, nuts , vegetables, ornamentals and turf	lepidoptera, diptera, thysanoptera, coleoptera, fire ants and fruit flies
Spodoptera exigua NPV					Baculovirus	Insecticide, Virus			ornamentals, vegetables, glasshouse crops	armyworms
Spodoptera litura NPV					Baculovirus	Insecticide, Virus			ornamentals, vegetables, glasshouse crops	armyworms

Steinernema carpocapsae				Parasitoid	Insecticide			fruit, vegetables, field crops, turf and ornamentals	black vine weevil, borers, cutworms, root maggot, rootworms, strawberry weevil, white grubs
Steinernema feltiae				Parasitoid	Insecticide				
Steinernema kraussei				Parasitoid	Insecticide				
Steinernema riobravisi				Parasitoid	Insecticide			citrus groves and nurseries	larval stages of sugarcane rootstalk borer and bluegreen weevil
Steinernema scapterisci				Parasitoid	Insecticide			turf	mole cricket
Stethorus punctillum				Beneficial insect (Predatory coccinellid)	Insecticide			fruit, vegetables, field crops, turf and ornamentals	red spider mites
Streptomyces candidus				Microbial Bacterium	Fungicide			fruits and vegetables	phytophthora and pythium
Streptomyces griseoviridis				Microbial Bacterium	Fungicide			herbs, vegetables, ornamentals, greenhouse	damping off, seed rot, stem rot, root rot and wilt disease
Streptomyces lydicus				Microbial Bacterium	Fungicide			nurseries and landscape markets	soilborne root rot, damping off

Streptomyces saraceticus					Microbial Bacterium	Nematicide			fruit, vegetables, field crops, turf and ornamentals	root knot nematode
Streptomycin					Microbial	Antibiotic/Bactericide, Fungicide	III		fruit, vegetables, field crops, turf and ornamentals	bacterial diseases
Tea Tree Oil						Fungicide			curcubits, peppers, tomatoes, herbs,	powdery mildew
Thripobius semiluteus					Parasitoid	Insecticide				
Trapping Systems						Trap/Lure			fruit, vegetables, field crops, turf and ornamentals	
Triacantanol						Plant Growth Regulator			Vegetable and field crops	
Trichoderma harzianum					Microbial Fungus	Fungicide			Vegetable and field crops	root diseases
Trichoderma harzianum (strain T-22)					Microbial Fungus	Fungicide			soil, root, seed	botrytis, cylindrocladium, fusarium, pythium, rhizoctonia, thielaviopsis, powdery mildew

Trichoderma harzianum (strain T-39)				Microbial Fungus	Fungicide			fruit, vegetables, field crops, turf and ornamentals	root diseases and foliar fungal diseases
Trichoderma harzianum/polysporum				Microbial Fungus	Fungicide			fruit, vegetables, field crops, turf and ornamentals	
Trichoderma spp.				Microbial Fungus	Fungicide			fruit, vegetables, field crops, turf and ornamentals	
Trichoderma virens				Fungus	Fungicide			greenhouse plants, ornamentals, vegetable transplants	
Trichoderma viride				Microbial Fungus	Fungicide	III		fruit, vegetables, field crops, turf and ornamentals	downy mildew, powdery mildew, fusarium wilt, verticillium wilt, leaf spot, root rot, stem rot
Trichogramma ostrinae				Parasitoid	Insecticide			fruit, vegetables, field crops, turf and ornamentals	european corn borer

Trichogramma spp.				Parasitoid	Insecticide			avocado groves, corn, orchards, tomatoes, other vegetables	moth egg, armyworm, bollworm, caneborer, codling moth, cutworm, fruit worm, leafworm, loopers, lepidopterous pests
Trimedlure					Attractant/ Pheromone			fruit, vegetables, field crops, turf and ornamentals	Mediterranean fruit fly
Validamycin				Antibiotic	Fungicide	III		vegetables, ornamentals, forestry, nursery, greenhouse	rice sheath blight, black scurf, damping off
Xylocoris flavipes				Beneficial insect (Predatory bug)	Insecticide			vegetables, ornamentals, forestry, nursery, greenhouse	
Zeatin				Plant derived	Plant Growth Regulator			fruit, vegetables, field crops, turf and ornamentals	

Abbreviations			
AB	Grain bait	SC	Suspension concentrate (= flowable concentrate)
AE	Aerosol dispenser	SG	Suspo-emulsion
BB	Block bait	SL	Soluble concentrate
DF	Dry flowable	SP	Water soluble powder
DP	Dustable powder	TB	Tablet
EC	Emulsifiable concentrate	TC	Technical material
EW	Emulsion, Oil in water	TK	Technical concentrate
FL	Flowable liquid	UL	Ultra-low volume (ULV) liquid
GR	Granule	WG	Water dispersible granules
PC	Gel or Paste concentrate	WP	Wettable powder
RB	Bait (Ready for use)	WSG	Water soluble granule

Details of WHO Hazard Classes	
Ia	Extremely hazardous
Ib	Highly hazardous
II	Moderately hazardous
III	Slightly hazardous
U	Unlikely to present acute hazard in normal use
O	Obsolete as pesticide, not classified
FM	Fumigant, not classified

NOTE
Updated on 29.12.2022. This list is subjected to revision.



The Small Island Conservancy

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Male', Maldives