Annals of
Reviews and Research

Review Article
Volume 7 Issue 2 - March 2022
DOI: 10.19080/ARR.2022.07.555709

Ann Rev Resear

A Review of Pragmatic Approaches to Pesticide Application, Microbiological Pest Control and Their Multiplier Effects

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Submission: February 26, 2022; **Published:** March 21, 2022

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Abstract

This report explicitly reviews pesticides, their types, usefulness and the environmental concerns related to them. The majority of pesticide formulations are diluted in water and applied under pressure through hydraulic nozzles, while some specialized formulations are used with a petrochemical diluent, undiluted as ultra-low volume sprays, or dry as granule or dust treatments. Pollution as a result of overuse pesticides and the long-term impact of pesticides on the environment is equally germane. Farmers are routinely exposed to high levels of pesticides, usually much greater than those of consumers. Farmers' exposure mainly occurs during the preparations and application of the pesticide spray solutions and during the cleaning-up of spraying equipment. Farmers who mix, load, and spray pesticides can be exposed to these chemicals due to spills and splashes, direct spray contact as a result of faulty or missing protective equipment, or even drift. Pesticides are used to kill the pests and insects which attack crops and harm them. Different kinds of pesticides have been used for crop protection for centuries. Pesticides benefit the crops however, they also impose a serious negative impact on the environment. Consequently, excessive use of pesticides may lead to the destruction of biodiversity. Many birds, aquatic organisms and animals are under the threat of harmful pesticides for their survival. Therefore, pesticides are a concern for sustainability of environment and global stability; thus, biorational and microbiological tactics are implicated as the last resort.

Keywords: Pesticides; Formulations; Pests; Pollution; Environment; Microbiological Tactics

Abbreviations: POPs: persistent organic pollutants; DDT: dichlorodiphenyl-trichloroethane; BHC: β-Benzene Hexachloride; IPM: Inte-grated pest management; EU: European Union; OPs: Organophosphate compounds; ME: Metabolites; DAPs: dialkylphosphates; DEET: diethyltoluamide; DNOC: dinitroorthocresol; EC: Emulsifiable concentrate; ULV: Ultra-low volume; WP: Wettable powder; DF: Dry FlowableWDG: Water-Dispersing Granules; BT: Bacillus thuringiensis; ICP: Insecticidal Crystal Protein; NPV: nuclear Polyhedrosis virus

Introduction

According to FAO [1], about 5.2 billion pounds of pesticides are used worldwide per year. Therefore, pesticide importation rose steadily from about 13 million dollars in 2001 to 28 million dollars in 2003 with insecticides accounting for about 32% of the imports FAO [1]. The use of pesticides has risen in developing countries with the fastest growing markets in Africa, Asia, South and Central America, Eastern Mediterranean EPA especially on the major cash crops grown for export WHO, personal communication. Although developing countries use only 25% of the pesticides produced worldwide, they experience 99% of the deaths. Thus, indiscriminate use of pesticides tends to be more intense and unsafe, and regulatory, health and education systems are weaker in developing countries. Consequently, pesticides are frequently found in the food commodities in addition to their presence in the air Global Pesticide Use. The major problem of farmers in Nigeria and other developing countries is the use of unapproved pesticides because most of the chemicals used in Nigeria are imported through either the statutory channels or illegal means. Additional problems include use of adulterated and banned insecticides, non-availability of suitable application equipment, supply uncertainties, high costs and inadequate knowledge by farmers about proper use of pesticide products Lale [2]; Adedire & Ajayi.

Poor nations have been led to believe that the only alternative to combat pests agricultural or otherwise effectively is only by using pesticides. Though a few believe pesticides are like medicines, however they kill pests selectively and are therefore less harmful to humans, animals and plants. Governments save budgets to purchase pesticides on regular basis though constantly plead to donors and organizations for assistance either for direct supply of pesticides or for contributions of financial support for purchasing them. Recipient countries anxious to minimize pest damages to the minimum or, being less aware of the negative consequences, usually receive pesticides from every possible source and direction. This leads to uncoordinated influx of pesticide donations and trading, subsequently giving rise to excessive supply. While some of the donations are genuine, others take the opportunity to dump unwanted and illegal pesticides on the poor and unsuspecting countries. Pesticides reach individual farmers or household dwellers that value pesticides dearly because pesticide vendors take the opportunity to promote pesticides aggressively. A pesticide is a toxic chemical substance or a mixture of substances or biological agents that are intentionally released into the environment to control and/or kill and destroy populations of insects, weeds, rodents, fungi or other harmful pests. Otherwise known as biocides and designed to kill, reduce or repel insects, weeds, rodents, fungi or other organisms that can threaten public health and the economy. Pests can be broadly defined as "the plants or animals that caused havoc or destroy our food, health and / or comfort".

Though pesticides are ubiquitous in the environment, and most are synthetic, the use of pesticides for pest prevention and eradication become a common practice all around the world. In developed economy like USA, synthetic pesticide was firstly used in 1940 and this was responsible for substantially increased in consumption over time. Most pesticides are used in agriculture, but in 1999 about 74% of households in USA were reported to use at least one pesticide in the home. Their use is not only restricted to agricultural fields, but they are also employed in homes in the form of sprays, poisons and powders for controlling cockroaches, mosquitoes, rats, fleas, ticks and other harmful bugs. The use of pesticides has increased many folds over the past few decades. However, pesticides provide primary as well as secondary benefits which entails direct usage of pesticides such as the killing of insects that feed on crops. Their mode of action is by targeting systems or enzymes in the pests which may be identical or very similar to systems or enzymes in human beings and therefore, they pose risks to human health and the environment WHO.

Professional application of pesticides both indoors and outdoors is used increasingly commonly for the control of rodents, cockroaches, ants, termites, earwigs and other pests. These include crop protection, preservation of food and materials and prevention of vector-borne diseases, which has harmful on human health and the environment. However, the crop saving substances applied not only protect the crops from damage rendered by pests, but they also increase the yields of crops considerably. According to Webster et al. [3] who indicated that there was a significant increase in crop production due to pesticide usage and stated that economic losses without pesticide use would be much more significant. Pesticides also prevent disease outbreaks through the control of rodent and insect vectors hence they contribute to improved human health. Deaths of about seven million people all around the world have been prevented through insecticide mediated killing of disease vectors. The most significant example is of malaria control that was responsible for an average of 5000 deaths per day Ross [4]. Pesticides protect forests and other wildlife habitats from invasive species of plants and non-native insects and other pests. Improved agricultural yields help the farmers to produce more food without expanding their agricultural land which consequently protects biodiversity.

Insecticides also improve home sanitary conditions by keeping the population of bugs in control Delaplane [5]. Moreover, pesticides also preserve the beauty of recreational spots by controlling weeds and also prevent structural damage associated with termite infestations. Moreover, herbicides and insecticides are used to preserve the turf on grounds, pitches and golf course Aktar et al. [6]. Playgrounds, playing fields, lawns and gardens may be routinely sprayed in order to keep insects away. However, insecticides may persist in house dust, in soil tracked in from outdoors, in carpets, toys, food and furniture. Such products may contain up to 2% of pesticide. Forrester et al. reported that pesticides are found in recreational waters (lakes, rivers and in pools (algaecides)). Persistent wood preservatives such as arsenic/ copper/chromium mixtures have been used on play structures. The persistent organic pollutants (POPs) include nine pesticides Lemus, et al.; WHO.

Origin and history of pesticide

The use of pesticides dates back to the times of Ancient Romans where people used to burn sulphur for killing pests and used salts, ashes and bitters for controlling weeds. Consequently, a Roman naturalist urged the use of arsenic as an insecticide. In 1600s, the conscious of protection was engendered by a mixture of honey and arsenic that was used for controlling ants. By late 1800s, there was improvement on the method of control when farmers in the USA started using inorganic chemicals like nicotine sulphate, calcium arsenate and sulphur for field related pests though their efforts were not as fruitful as planned because of the primitive methods of application Delaplane [5]. In 1867, an impure form of copper known as arsenic was used to control the outbreak of Colorado potato beetle in the USA. The major breakthrough in pesticide development occurred in the post period of World War-II, when several effective and inexpensive pesticides were synthesized and produced. According to several scientists, this period marked by the advent of Aldrin, dichlorodiphenyl-trichloroethane (DDT) in 1939, Dieldrin, β-Benzene Hexachloride (BHC), 2,4-Dichlorophenoxyacetic acid (2,4-D), Chlordane and Endrin Jabbar & Mallick [7]; Delaplane [5]. In 1867, Paris Green (form of copper arsenite) discovered was used to control Colorado potato beetle outbreak in 1885. Introduction of a copper mixture by Professor Millardet to control mildew in1892, while Potassium dinitro-2-cresylate was produced in Germany.

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In 1939, DDT was discovered by Swiss chemist Paul Muller; organophosphate insecticides and phenoxyacetic herbicides were discovered in 1950s. However, Fungicides, captain and glyodin and organophosphate insecticide e.g., Malathion were introduced between 1950 and 1955 followed by the discovery of triazine herbicides in the years 1955–1960 Jabbar & Mallick [7]. An experimental wartime herbicide named Agent Orange was developed by Monsanto from 1961–1971 but was used during the Vietnam War. However, DDT was officially banned in 2001 Stockholm Convention. However, public attention was drawn to the environmental hazards associated with indiscriminate pesticide use.

There is also growing concern about user's exposure to pesticides and their special susceptibility. Children of the users may have higher exposures and greater vulnerability at both high and low levels of exposure Jeyaratnam, 1990). In 1962, an American scientist Rachel Carson reported that spraying DDT in the field causes sudden death of non-target organisms Jabbar & Mallick [7]; Delaplane [5] either by direct or indirect toxicity. However, in the late 1960s, it opened a new arena in which "inte-grated pest management" (IPM) was introduced which deployed biological predators or parasites for controlling the pests. Although the pest population can be reduced to significantly low levels, especially in pest outbreak situations, but unfortunately IPM was not a substitute for chemical pesticides Delaplane [5]. In 1970–1980s, pyrethroids, sulfonylureas, synthetic fungicides triadimefron and metaxyl were introduced. In 1972, DDT was completely banned in the USA followed by the placement of restriction on the use of Endosulfan, Dieldrin and Lindane. The list of banned pesticides has increased ever since as shown in Table 1. In 2001, 179 nations signed an international treaty known as Stockholm Convention that was intended to completely ban twelve Persistent Organic Pollutants (POP's) including DDT. Later in 2013, the European Union (EU) supported to banning the use of neonicotinoid pesticides (Jacobs, 2015). It has been observed that the overuse of pesticides on aquatic ecosystems has led to a serious threat to species of fish including salmon. Pesticides are also seen to affect primary producers and macro-invertebrates Macneale et al. [8]. Registration of a pesticide is renewed sporadically, which ensures the safety of used pesticides Jabbar & Mallick [7].

Table 1: Pesticides currently approved for use on Kola/Cocoa farms.

S/N	Trade name	Active ingredient	Distribution company in Nigeria	Target pest
	Insecticide			
1	Actara 25 WG	Thiamethoxam	SYNGENTA	Mirid
2	Esiom 150 SL	Acetamiprid + Cypermethrin	INSIS	Mirid
3	Proteus 170 - Tec	Thiacloprid 150 g/l + Delta methrin 20 g/l	SARO	Mirid
	Fungicide			
1	Funguran - OH	Copper hydroxide	INSIS	Black pod
2	Champ DP	Copper hydroxide	SARO	Black pod
3	Ridomil gold 66 WP	Cuprous oxide + metalaxyl-M	SYNGENTA	Black pod
4	Copper Nordox 75 WP	Cuprous oxide	DIZZENGOFF	Black pod
5	Ultimax plus	Metalaxyl + Copper hydroxide	HARVESTFIELD	Black pod
6	Kocide 101	Cuprous Oxide	SARO	Black pod
7	Kocide 2000	Cuprous hydroxide	DUPONT	Black pod
	Herbicides			
1	Touch down	Glyphosate	SYNGENTA	Weed
2	Clear weed	Glyphosate	HARVESTFIELD	Weed
3	Round up	Glyphosate	CANDEL	Weed
	Fumigants			
1	Phostoxin	Aluminum phosphide	GONGONI	Storage pest

Pesticide registration and safety

Registration entails a complex, legal and administrative process that requires considerable amount of time and resources including expertise and skills of registration authority, thus pesticide manufacturers. This affords assessment of potential effects associated with the use of pesticide on human health and the environment Monaco [9] in order to ensure the safety of active including inert ingredients used in the manufacturing of pesticide. Consequently, this is an important aspect of pesticide management that ensures that the pesticide product released in the market is approved and strictly used for the intended purpose. It also empowered to supervise control over quality, pricing,

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packaging, labeling, safety and advertisement of pesticides to assure protection of users' interests WHO [10]. In the process of registration, the manufacturer is required to conduct research and analyze different tests associated with the product chemistry before final submission of the application and data report. These results ascertained the potential pesticide risks on humans, animals and non-target species including the effect of pesticide once it is released in the environment FAO [11]; WHO [10]. Data report or application of registration include several aspects related to pesticide such as physical and chemical properties of active ingredient including formulated product, analytical methods, proposed environmental toxicity and human health hazards, recommended uses and labels, safety data, effectiveness for the intended use, container management, and disposal of waste products. Application is reviewed and analyzed by the scientist in registration authority and after environmental, human and biodiversity risks assessment, the authority approves the pesticide as safe to be use or rejects it if it does not meet the standards as set by the regulatory and registration authorities. Furthermore, the registration authority ensures that each registered pesticide continues to meet the highest safety standards. Hence, previously registered pesticides are being reviewed to ensure that they meet up with the standard of Research by manufacturer before registration decision. Consequently, submission of data report to registration authority by manufacturer and further review of the data report by registration authority is called re- registration Damalas & Eleftherohorinos [12].

Classification of pesticides

Pesticides can be natural compounds, or they can be synthetically produced and universally divided into different categories depending upon their target. Some of these categories include herbicides, insecticides, fungicides, rodenticides, molluscicides, nematicides and plant growth regulators (WHO, 2002). Therefore, Insecticides, Herbicides, Fungicides, Rodenticides, and Fumigants such as Insect repellents and wood preservatives are chemicals designed to kill, reduce or repel pests. Organochlorines, carbamates, organophosphates, pyrethroids and neonicitinoids are major classes to which most of the current and widely used pesticides belong Global Pesticide Use. There is a large variety of pesticides designed to kill specific pests that are most widely used, ditto insecticides like organophosphate compounds (OPs), endosulfan, Op's organophosphates, organochlorine, dicarboximide fungicides, carbamates, and pyrethroids Aprea [13]. However, residues of organochlorine pesticides and POPs have been detected in breast milk (including DDT, HCB and HCH isomers) in contaminated areas Pronczuk [14]. About nine of the 12 persistent organic pollutants (POPs) included in the Stockholm Convention, are pesticides (aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, mirex, toxaphene and hexachlorobenzene). Organophosphates metabolize into Oxones and specific inactive metabolites (ME) while non-specific metabolites included dialkylphosphates (DAPs) Wessels [15]. DAPs are used as biomarkers of environmental exposure to all kinds of organophosphate pesticides because DAPs are metabolites of all these pesticides. Schmolke et al. [16] reported that the use of neonicotinoid pesticides is increasing, and these pesticides are associated with different types of toxicities Van Djik [17]. Nerve targets of insects which are known for development of neuroactive insecticides include acetylcholinesterase for organophosphates and methylcarbamates, nicotinic acetylcholine receptors for neonicotinoids, gamma-aminobutyric acid receptor channel for polychlorocyclohexanes and fiproles and voltage gated sodium channels for pyrethroids and dichlorodiphenyltrichloroethane Casida & Durkin [18]. This category also includes insect repellents such as diethyltoluamide (DEET) and citronella (of natural origin) for the control of insects. Fumigants are pesticides that exist as a gas or a vapour at room temperature and may be used as insecticides, fungicides or rodenticides, especially in closed storage places as they kill every living organism. They are extremely toxic, due to their physical properties, rapid environmental dissemination and human or animal absorption (examples include cyanide, aluminium phosphate and methyl bromide). Fumigants included Aluminium and zinc phosphide, Methyl bromide and Ethylene dibromide, dinitroorthocresol (DNOC), thus Diethyltoluamide are however regarded as Insect repellents. Fungicides (to kill mould or fungi) thus when applied to wood, they are called wood preservatives and could be as well used for control of moulds. Examples included Thiocarbamates, Dithiocarbamates, Cupric salts, Tiabendazoles, Triazoles, Dicarboximides, Dinitrophenoles and Organotin compounds. Rodenticides (to kill mice, rats, moles and other rodents) for the control of rats, mice, moles such as Warfarines and Indanodiones. Herbicides or weedkillers (e.g., paraquat, glyphosate and propanil), Bipyridyls, Chlorophenoxy, Glyphosate, Acetanilides and Triazines, simazine including 2-4D for the control of weeds.

Other pesticides include algaecides (to kill algae), miticides (to kill moths) and acaricides (to kill ticks).

Pesticide application methods

Once a compound proves to be toxic to insects and therefore in ideal conditions, it is necessary to devise means of applying it efficiently to pests in the field. Hence, pesticide formulation is the act of formulating or making the pesticide, this consists of a pure material which is the technical grade material, or the active ingredient carried on an inert material called a carrier. Therefore, formulation is the processing of a pesticidal compound by any method that will improve its property of storage, handling, application, effectiveness of safety. Pesticide formulations contain active ingredients along with inert substances, contaminants and occasionally impurities. Once released into the environment, pesticides break down into substances known as metabolites that are more toxic to active ingredients in some situations. The majority of pesticide formulations are diluted in water and applied under pressure through hydraulic nozzles, while some

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specialized formulations are used with a petrochemical diluent, undiluted as ultra-low volume sprays, or dry as granule or dust treatments. Some domestic, agricultural or veterinary products may contain more than one chemical belonging to the same or a different chemical group (WHO, 2002). They may belong to any one of the several pesticide classes (Global Pesticide Use 2001).

According to the physical forms characterized, pesticide formulations are classified into two general types viz

i. Liquid formulation types

ii. Dry formulation types

Liquid formulation types

Oil concentrates: These are liquid formulations containing a high concentration of active ingredient (a.i.). They are generally used after dilution to a particular convenient low concentration with an inexpensive hydrocarbon solvent e.g., Xylene, fuel oil or diesel oil. The concentration may be expressed either in term of percent by weight of active ingredient (a.i.).

Emulsifiable concentrate (E.C): These are concentrated oil solution of the technical grade materials enough surfactant or emulsifier added to make the concentrate mix readily with water for spraying. The emulsifier is a detergent-like material which makes possible the suspension of microscopial small oil droplets in water to form an emulsion. Hence, when an emulsifiable concentrate is added to water the emulsifier causes the oil to disperse immediately and uniformly distributed throughout the water; if agitated, given it an opaque or milky appearance. However, this oil in water suspension is called a normal emulsion. Therefore, most popular terms in which most pesticides are used include Abate 200 EC, Aldrex 40EC, Kokotine, Supoma, Ultracide 40 EC etc.

Aqueous concentrates (Water soluble concentrate): The technical grade material may be initially water miscible or alcohol miscible and formulated with an alcohol to become water miscible. Therefore, water soluble concentrates are concentrates of pesticidal chemicals dissolved in water. However, this formulation resembles the emulsifiable concentrate in viscosity and colour but do not become milky when diluted with water. The most common type is the salt of herbicidal acid e.g., 2-4-D; since the herbicidal acid is the normal a.i. concentrates are generally expressed in terms of gm per dm^3 e.g., Azodrin 60% WSC, Bladex 20% WSC =0.2 gm a.i./dm^3.

Oil solution: These are ready to use formulation containing generally a low odour, colourless solvent (e.g., odourless kerosene) and a pesticide chemical in low concentration, usually less than 5% by weight. Oil solutions of insecticides are generally used for household or institutional insect control. In addition to low odour, the formulation is non-staining and have a high flesh point to minimize fire hazard e.g. liquid shelltox, ultra-low volume (ULV) concentrates formulations (e.g. Ensodil, Endosulphan 25% ULV).

Invert Emulsifiable Concentrates: These differ from the normal emulsion concentrate by the fact that their dilution with water results in an emulsion in which external or continuous phase of the emulsions is the oil portion whereas the internal or discontinuous phase of the emulsion is water. These concentrates are used principally in the formulation of oil soluble herbicidal esters. Characteristically, invert emulsions form significant larger droplets than conventional emulsifiable concentrates when emitted from special application equipment. The external phase contains an oil of relatively low vapour pressure; thus, evaporation of the continuous phase is minimized and useful in ULV applications where reduction of drift is essential.

Dry formulation types

All dry formulations except wettable powders are intended for further dilution to field strength before final application using low-cost diluents such as clay and talc for dust bases and water for wettable powders which has to be applied as a spray.

Dust bases or dust concentrates

Dry free flowing powders containing a high concentration of a.i. varying generally from 25-75% pesticide. Fertilizer mixtures are often made by mixing the dust concentrates with the dry fertilizer, a sticker being added in the case of granular fertilizer to prevent segregation of the fine pesticides of pesticidal base.

Wettable powder (WP)

These are similar to dust bases except that they are formulated for dilution with water into a final spray. Quality is judged by the rapidity of wetting when mixed with water and the suspendability in water when mixed in practical dilutions. Hence, WP is essentially concentrated dust containing a wetting agent to facilitate the mixing of the powder with water before spraying. The technical grade material is added to the inert diluents (solvent) in this case, a finely ground talc or clay in addition to a wetting agent or surfactant and mix thoroughly in a ball mill. However, without the wetting agents the powder will float when added to water and the two will be almost impossible to mix because wettable powder usually contain from 50-75% of clay or talc. They sink rather quickly to the bottom of tank unless the spray mixture is agitated constantly. Many of the insecticide sold for garden user are in form of WP because there is very little chance that this formulation will burn foliage even at high concentration.

Dusts

Dusts are usually fine powder dry pesticides usually formulated to field strength varying from 1-10% a.i. according to the potency of the pesticide and the rate of application. Dusts must be free flowing so that they can be accurately metered in application requirement, pesticide size may vary but is usually below 200 meshes (74 mm).

There are different types of dust viz

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a) One in which the toxic agent is undiluted e.g., Sulphur dusts use on ornamentals and Sodium fluoride (Naf) which is one of the oldest insecticides used.

b) When the active ingredient or toxic agent is diluted with an active diluent e.g., garden pesticide having Sulphur dusts as the carrier or diluents.

c) One in which the toxic agent or active ingredient is carried on an inner diluent, this is most common type formulation in use today both in home garden and in agriculture, insecticide, fungicide combination is applied in this manner, the carrier being an inert clay such as pyrophyllite.

Granules

The granules have been formulated as an improvement of the dust which can easily be blown away under windy condition. Therefore, granular pesticides are distinguished from powdered pesticides according to mesh size range which for granules lies between mesh 4 and 80. Granules are small pellets formed from varied inert clay and sprayed with a solution of the toxicant to give the desire content. The disintegrated characteristic of granules in the presence of moisture after entering the soil directly affects the rate of release of pesticides. The concentration of a.i. in granular pesticides varies from as low as 1 % to as high as 42% depending upon the properties of the a.i., the characteristics of the carriers, the potency of the insecticide and the desired rate of application of the finished product e.g., Birlane 10% granules, dieldrin 20 %, 5% granules.

Pellets

Pesticide pellets are dry pesticide formulations in which the particle size is larger than that of granules i.e., greater than 4 meshes. There are no fixed minimum sizes but in practice diameters maybe as large as 0.6 cm and possible 1.5 m. Pellets are generally formed by mixing the a.i. with a suitable inert ingredient plus a binder followed by pan granulating to the desire size. Concentration of a.i. may range from a fraction of a percent as in the case of baits in which an attractant inert ingredient is used, to as high as 20% or 25% if fertilizer is added.

Mixing pesticides

Although mixing pesticides can be a mundane task, it should be performed with extreme caution. After all, pesticide injuries are most likely to occur while chemicals are being mixed. Why? First, pesticide containers are opened during mixing, and pesticide formulations are usually highly concentrated. Second, people who work with pesticides tend to be less safety conscious when they are mixing pesticides than when they are actually spraying them. People climb on equipment carrying pesticides, lift and pour open containers of pesticide, and often work alone with pesticides; all of which can be dangerous.

Proper mixing procedures

Mixing Order: Pesticide labels usually provide directions for mixing different materials, often describing the sequence of mixing. Whenever a label provides such directions, you should follow them. In general, follow the W-A-L-E-S PLAN when adding herbicides to a tank mix W - Wettable Powders (WP) then Flowables (F, DF). A - Agitate, then add adjuvants such as anti-foaming compounds, buffers. L - Liquid and Soluble products, E - Emulsifiable Concentrates (EC) and S – Surfantants. Prior to mixing you should fill your spray tank with half of the carrier you intend to use, usually water. Then start the sprayer and check to make sure that all valves and gauges work and that you have proper tank agitation. Compability agents are adjuvants that reduce the risk of incompability in pesticide/fertilizer combinations. If you use a compatility agent, it should be the first thing you put in the tank.

Premixing: Premixing in a smaller, separate container or tank is necessary for many pesticides' formulations

Wettable Powders (WP): Make slurry in a separate container by adding small increments of water until it forms a gravy-like consistency. Slowly add this slurry to the tank with the spray tank agitator running

Dry Flowable (DF) and Water-Dispersing Granules (WDG): Premix with 1 part flowable to 1-part water (start with the water and add the flowable to it) and then pour the mix slowly into the tank

Liquid Flowables: Premix liquid flowables by adding 1-part liquid chemical to 2 parts water for liquid fertilizer before blending in the tank. Many labels for liquid flowable products describe the proper mixing procedure., Mix pesticides carefully and accurately, using only the recommended amount. Read the label carefully and follow the directions exactly. Wear gloves, splash-proof goggles or face shield, and other required personal protective clothing. Keep hands away from the face, head and neck when mixing. Open liquids on a level surface and below eye level to avoid spilling and splashing. Pour liquids below eye level and as close to ground as possible. Do not try to pour from a container that is too heavy. Open powders with scissors to avoid spreading dust. Use the proper measuring tools when mixing pesticides. Mix pesticides outdoors or in a well-lit and ventilated area.

Steps to take when mixing pesticides:

i. Always be sure the sprayer has been checked for uniform application and calibrated properly for application at the recommended rate

ii. Calculate the amount of pesticide to add to the sprayer tank based on the active material in each gallon of pesticide concentrate, or the percentage of active ingredient of dry pesticide

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iii. Read and follow instructions on the manufacturer's label pertaining to personal hazards in handling

iv. Fill the sprayer tank with at least half the volume of water or fertilizer solution you ultimately will need. Start moderate agitation and keep it going throughout the process.

v. Add compatibility agents if needed, for maximum benefit, they must be in solution before pesticides are added.

vi. Add, mix, and disperse dry pesticides (wettable powders, dry flowables, or water dispersible granules). These formulations usually contain wetting and dispersing agents that aid in mixing.

vii. Add liquid flowables and allow thorough mixing thus liquid flowables also contain wetting and dispersing agents.

viii. Add emulsifiable concentrates and allow thorough mixing, finish by adding water soluble formulations (2, 4-D, amine etc)

ix. Add any surfactants; crop oil concentrates etc., last, because crop oils especially do not mix and disperse well if added first.

x. Add the remainder of water or liquid fertilizer and maintain agitation while spraying until the tank is empty

Caution: Never pour concentrated herbicides into an empty tank. Never allow a sprayer containing mixed chemicals to stand without agitation, as heavy wettable powders may clog nozzles or settle into corners of the sprayer tank.

Read the label: Always, the first step in the safe mixing of pesticides is to read the pesticide label. A pesticide label may indicate if two products can be mixed together and provide guidance as to the proper order in which they need to be mixed. A pesticide can be tank mixed if the label does not prohibit its application with other products and the pesticides in the mix must be registered individually on the crop you are treating.

Pesticide combinations and interactions

Pesticide combinations usually alter plant absorption and translocation as well as metabolism and toxicity at the site of action of one or more of the mixed products. However, all changes are for the better Anonymous [19]. There are basically five different types of interactions that change the efficacy of pesticide combinations

Additive effects

Occur when two pesticides mixed provide the same response as the combined effects of each material when applied alone

Synergistic responses

Occur when two pesticides provide a greater response than the added effects of each material when applied separately Azeez [20]. With true synergism, one can often reduce pesticide application rates without sacrificing controls.

Antagonism

occurs when two pesticides applied together produce less control than when each material is applied separately

Enhancement

This is mixed with an additive to provide a greater response than if the pesticide applied alone

Potentiation - occurs when ability of one pesticide increases the effect of another pesticide which hitherto, is less toxic

Several formations were proposed to control mosquitoes and flies, some of them associated essential oils to pyrethroid Liang [21]; Kono et al. [22] although eucalyptus essential oil was used as a synergistic insecticide in addition to growth inhibitors Narasaki et al. [23]. Also, more complex preparations such as combinations of substances present in botanicals are less likely to become ineffective because of the development of resistance by insect pests Regnault-Roger & Hamraoui [24].

Testing for incompatibility

Two or more pesticides, or a pesticide and a fertilizer, are compatible if no adverse effects occur as a result of mixing them together. The deactivation of an active ingredient often occurs with chemical incompatibility. This is most affected by temperature, tank pH, and length of time that you hold a spray mixture in the tank before use. Physical in compatilibilities usually involve the inert ingredients of a formulation. The mixture may become unstable, forming crystals, flakes, or sludge that may clog spray equipment. For herbicides, incompatibility most often occurs when you mix an emulsifiable concentrate formulation with wettable powders. Similarly, you should not mix EC insecticide with fungicides or herbicides. Liquid fertilizers can also cause compatibility problems, mainly due to their strong electrochemical nature. When attempting pesticide combinations that are unfamiliar to you, use a jar test to check for in compability. In addition, test the combination on a few plants or a small area before larger scale treatments. Wait at least 2 to 3 days for any problems to become apparent. Keep accurate records on compatible, safe combinations for future reference. Always wear personal protective equipment (PPE) when pouring or mixing pesticides, Perform this test in a safe area away from food and sources of ignition. Pesticides used in this test should be put into the spray tank when completed and applied to a labeled site. Rinse all utensils and jars and pour the rinse water (rinsate) into the spray tank. Do not use utensils or jars for any other purpose after they have contacted pesticides.

a) Step 1 – Measure 1 pint of water into a clear quart jar. Use the same water (or other diluents) that you will use when making up the larger mixture.

b) Step 2 – Add ingredients in the following order, accordingly, stir each time a formulation has been added. Firstly, to compatibility agents and thereafter activators, add 1 teaspoon

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for each pint per 100 gallons of final spray mixture for each of the Wettable powders and dry flowables, Water soluble concentrates or solutions, Emusifiable concentrates, Soluble powders, and Remaining adjuvants and surfactants.

c) Step 3 – After mixing, let the solution stand for 15 minutes. Stir well and observe the results. Feel the sides of the jar determine if the mixture is giving off heat. If so, the mixture may be undergoing a chemical reaction and the pesticides should not be combined. Let the mixture stand for about 15 minutes and feel again for unusual heat. If scum forms on the surface, if the mixture clumps, or if any solids settle to the bottom (except for wettable powders), the mixture probably is not compatible. Finally, if no signs of incompatibility appear, test the mixture on a small area of the surface where it is to be applied Anonymous [19]. Pesticides are considered to be more water soluble, heat stable and polar which makes it very difficult to reduce their lethal nature.

Risks associated with pesticide use

Risks associated with pesticide use have surpassed their beneficial effects. Non- selective pesticides kill non-target plants and animals along with the targeted ones. Pesticides have drastic effects on non-target species and affect animal and plant biodiversity, aquatic as well as terrestrial food webs and ecosystems. Pesticides enter the natural ecosystems by two different means depending upon their solubility. When a pesticide is applied directly to a target pest (plant or animal) the whole site is affected including crop plants, soil organisms and, potentially, humans and wildlife in the immediate area. In addition, part of it goes to the air or to surface waters, due to emission or drift. Once on the target site, the pesticide may "drain" into surface waters or volatilize into the air. From the air it may deposit on humans, wildlife or plants or on the soil. From the animals or plants where it was applied the pesticide may leak into groundwater. Pesticides in surface water may go into aquatic organisms and by sedimentation into other organisms that remain in the sediment. The persistence of the pesticide depends on its physical and chemical properties (partition coefficients, degradation rates, deposition rates) and the characteristics of the environment Anonymous [25].

According to Majewski & Capel [26], it is quite common that about 80–90 % of the applied pesticides can volatilize within a few days of application while using sprayers. The volatilized pesticides evaporate into the air and subsequently may cause harm to non-target organism. Some pesticides are volatile and can be inhaled over a period of hours or days because of the volatilization from contaminated surfaces. Particulate material under 10 micrometres is breathable, and the smaller particles are more dangerous because they can reach the alveoli. Additionally, air, water and soil bodies have also been contaminated with the uncontrolled use of chemicals to toxic levels which has resulted in reduction of several terrestrial and aquatic animal and plant species. Among all the categories of pesticides, insecticides are considered to be most toxic whereas fungicides and herbicides are second and third on the toxicity list. Water soluble pesticides get dissolve in water and enter ground water, streams, rivers and lakes hence causing harm to untargeted species. Once used or spilled pesticides may contaminate nearby groundwater and surface water used for drinking or bathing. On the other hand, fat soluble pesticides enter the bodies of animals by a process known as "bioamplification". They get absorbed in the fatty tissues of animals hence resulting in persistence of pesticide in food chains for extended periods of time.

The process of bioamplification can be described as follows:

i. Small concentration of pesticide enters the bodies of animal that are in low level in the food chain such as grasshopper (primary consumer).

ii. Shrews (secondary consumer) eat many grasshoppers and therefore the concentration of pesticide will increase in their bodies.

iii. When the high-level predator such as owl eats shrews and other prey, the pesticide concentration eventually increases many folds in its body.

Therefore, the higher the trophic level, the greater will be the pesticide concentration which is known as bioamplification. This process disrupts the whole ecosystem as more species in higher trophic levels will die due to greater toxicity in their bodies. This will eventually increase the population of secondary consumers (shrews) and decrease the population of primary consumers (grasshoppers). Some pesticides persistent and bio-concentrate persistent organic pollutants (pops) low water solubility persist in the environment. Accumulate in the food-chain lypophilic, travel long distances, concentrate in marine animals, may produce toxic effects from Aldrin, Dieldrin, Chlordane, DDT, Endrin, Heptachlor, Mirex and Toxaphene. Some pesticides are characterized by being very persistent in the environment. They may represent long-term dangers as they biomagnify up the food-chain.

Threats to biodiversity

Pesticides have different distribution and persistence patterns in the environment, even if all of them are distributed in some way through air, soil and water Anonymous [27]. The threats associated with the use of uncontrolled use of these toxins cannot be overlooked. Accumulation of pesticides in the food chains engendered from the populations of aquatic and terrestrial plants, animals and birds is of greatest concern as it directly affects the predators and raptors. Though pesticides also reduced the quantity of weeds, shrubs and insects on which higher orders feed. Spraying of insecticides, herbicides and fungicide might also cause reduction in the population of rare species of animals and birds. However, pesticides can be applied as liquid sprays on the soil or crop plant, may be incorporated or injected into the soil or applied as granules or as a seed treatment. Once they have reached their target area, pesticides disappear via degradation,

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dispersion, volatilisation or leaching into surface water and groundwater; they may be taken up by plants or soil organisms or they may stay in the soil Hayo & Werf [28]. The major concern of pesticide overuse is their leaching into the soil, which affects the microbes residing in it. Soil dwelling microbes help the plants in many different ways, such as nutrient uptake, breakdown of organic matter and increasing soil fertility.

But indirectly they are also advantageous to humans as we heavily depend on plants. Unfortunately, pesticide overuse may have drastic consequences and a time may come when we would not have any more of these organisms and soil may degrade. Several soil microbes are involved in the fixation of atmospheric nitrogen to nitrates. Chlorothalonil and dinitrophenyl fungicides have been shown to disrupt nitrification and denitrification bacteria dependent processes Lang & Cai [29]. The herbicide, triclopyr inhibits soil bacteria involved in the transformation of ammonia into nitrite Pell [30]. Glyphosate, a non-selective herbicide, reduces the growth and activity of nitrogen-fixing bacteria in soil Santos & Flores [31] whereas, 2, 4-D inhibits the transformation of ammonia into nitrates carried out by the soil bacteria Frankenberger [32]. Herbicides also cause considerable damage to fungal species in soil as pesticides trifluralin and oryzalin both are known to inhibit the growth of symbiotic mycorrhizal fungi Kelley & South [33] that help in nutrient uptake. Oxadiazon has been known to reduce the number of fungal spores (Moorman [34] whereas triclopyr is toxic to certain species of mycorrhizal fungi Chakravarty & Sidhu [35].

Pesticides enter the water via drift, by runoff, leaching through the soil or they may be applied directly into surface water in some cases such as for mosquitoes' control. Pesticide-contaminated water poses a great threat to aquatic form of life. It can affect aquatic plants, decrease dissolved oxygen in the water and can cause physiological and behavioural changes in fish populations. Pesticides which are applied to land drift to aquatic ecosystems and there they are toxic to fishes and non-target organisms. These pesticides are not only toxic themselves but also interact with stressors which include harmful algal blooms. About 80 % of the dissolved oxygen is provided by the aquatic plants and it is necessary for the sustenance of aquatic life. Killing of aquatic plants by the herbicides results in drastically low O_2 levels and ultimately leads to suffocation of fish and reduced fish productivity Helfrich [36]. Generally, levels of pesticides are much higher in surface waters than groundwater probably because of surface runoff from farmland and contamination by spray drift Anon [37]. However, pesticides reach underground through seepage of contaminated surface water, improper disposal and accidental spills and leakages (Pesticides in Groundwater 2014). Aquatic ecosystems are experiencing considerable damage due to drifting of pesticides into the lakes, ponds and rivers. Atrazine is toxic to some fish species, and it also indirectly affects the immune system of some amphibians Forson & Storfer [38]; Rohr et al. [39]. Amphibians are chiefly affected by pesticides contaminated surface waters, in addition to overexploitation and habitat loss The Asian Amphibian Crisis [40]. Carbaryl has been found toxic for several amphibian species, whereas herbicide glyphosate is known to cause high mortality of tadpoles and juvenile frogs Relyea [41]. Small concentrations of malathion have been shown to change the abundance and composition of plankton and periphyton population that consequently affected the growth of frog tadpoles Relyea & Hoverman [42]. The reproductive potential of aquatic life forms also reduces due to herbicide spraying near weedy fish nurseries which eventually reduces the amount of shelter that is required by young fish to hide from predators Helfrich [36]. Pesticide exposure can also cause sub-lethal effects on terrestrial plants in addition to killing non-target plants. Drifting or volatilization of phenoxy herbicides can injure nearby trees and shrubs Dreistadt [43].

Herbicide glyphosate increases susceptibility of plants to diseases Brammall & Higgins and reduces seed quality Locke [44]. Even low doses of herbicides, sulfonylureas, sulphon-amides and imidazolinones have a devastating impact on the productivity of non- target crops, natural plant communities and wildlife Fletcher [45]. Populations of beneficial insects such as bees and beetles can significantly decline by the use of broad-spectrum insecticides such as carbamates, organophosphates and pyrethroids. Insect population has also been found to be greater on organic farms compared to non-organic ones. Synergistic effects of pyrethroids and triazole or imidazole fungicides are harmful to honeybees Pilling & Jepson [46]. Neonicotinoid's insecticides such as clothianidin and imidacloprid are toxic to bees. Imidacloprid even at low doses negatively affects bee foraging behaviour Yang [47] in addition to reducing learning capacity Decourtye [48]. The greatest havoc wreaked by neonicotinoids was the sudden disappearing of honeybees at the very start of the twenty-first century. This was a major concern to the food industry as 1/3 of the food production depends on pollination by bees. Honey and wax obtained from commercial hives were reported to contain a mixture of pesticides of which neonicotinoids shared a significant portion. Pesticide accumulation in the tissues of bird species leads to their death. Bald eagle populations in the USA declined primarily because of exposure to DDT and its metabolites Liroff [49]. Fungicides can indirectly reduce birds and mammal populations by killing earthworms on which they feed. Granular forms of pesticides are disguised as food grains by birds. Organophosphate insecticides are highly toxic to birds, and they are known to have poisoned raptors in the fields. Sublethal quantities of pesticides can affect the nervous system, causing behavioural changes.

Environmental pollution of pesticide

Obsolete, unwanted and banned pesticides are serious environmental hazards. Leaking and corroding metal drums filled with obsolete and dangerous pesticides dot urban and rural landscapes of developing countries around the world. These chemical leftovers have become villains in the agricultural world they were designed to help, affecting not only a nation's

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agriculture and its environment, but also fundamentally the health of its people and consequently development in general be it in rural areas or under urban conditions. This global environmental tragedy is a direct result of several decades of mishandling and misuse but is most dramatic in the developing world where there is no awareness of the inherent danger of pesticides. The unaware therefore draw water from contaminated site for own survival and that of their animals. Most of the affected countries are under tropical conditions where agricultural and vector pests flourish both in diversity and numbers. Migratory pests such as locusts, grasshoppers, grain eating birds, storage pests, rodents, etc. inflict untold damage to agriculture and bring about hunger or misery when they are at their peak.

Pesticide impact on human health

Pesticides have improved the standard of human health by controlling vector-borne diseases, however, their long term and indiscriminate use has resulted in serious health effects Cristina [50]. As the pesticide use has increased over the past few decades, the likelihood of exposure to these chemicals has also increased considerably. According to World Health Organization, each year, about 3,000,000 cases of pesticide poisoning and 220, 000 deaths are reported in developing countries Lah [51]. About 2.2 million people, mainly belonging to developing countries are at increased risk of exposure to pesticides Hicks [52]. Pesticides enter the human body through ingestion, inhalation or penetration via skin Spear [53]. But the majority of people get affected via the intake of pesticide contaminated food. After crossing several barriers, they ultimately reach human tissues or storage compartments Hayo & Werf [28]. Although human bodies have mechanisms for the excretion of toxins, however, in some cases, it retains them through absorption in the circulatory system Jabbar & Mallick [7]. Toxic effects are produced when the concentration of pesticide in the body increases far more than its initial concentration in the environment Hayo & Werf [28]. The effects of pesticides on human health are highly variable. Probably appear in days and are immediate in nature or they may take months or years to manifest and hence are called chronic or long-term effects Cunningham. Currently, preference is given to biological control of pests. This is a bioeffector- method of controlling pests using biocontrolling agents including other living organisms. These biocontrolling agents are also known as bio-rational pesticides. An example of bio-rational pesticide is Insect growth regulators (IGRs) which are the hormones that regulate insect growth without affecting non-target organisms Delaplane [5].

Microbes to kill pests

According to the United Nations' Food and Agriculture Organization, pests destroy at least 35 percent of the world's harvest a year. Although soil and plants in some areas are saturated by pesticides, pests do not seem to be giving way. The urgency of the problem is understandable if one is to take into consideration that about 300 pests are now immune to pesticides. It is dangerous to increase the dosage because many of the fission products of pesticides are conducted in the plants and water and in the organism of birds and fish, affecting man. According to Olga [54] a Soviet scientist who believes that microbiology offers one of the most advanced methods of protecting plants from pests; whereby biorational and microbiological tactics are implicated in combating pests. Thus, the measures to prevent plant disease and kill the pests in the Soviet Union saved a harvest worth about 6,000 million rubles. Pesticides quickly kill the pests, but they also kill useful insects and birds, whereas microbiological pesticides kill the target pest. According to Olga [54], micro-organisms could either be extracted from sick insects though commercial production does not destroy their capacity to kill a specific pest or through the excretions of micro-organisms which reproduce in great numbers during their commercial breeding. However, the Soviet Union employs bacterial, fungus and virus preparations and particular attention is given to bacterial preparations made of the spore bacteria whose action is well known. Microbiological preparations will replace many chemical pesticides to save useful animals and plants though this does not mean, that chemical pesticides will disappear altogether, but will only have a smaller role to play.

Innovative application of microbial agents for biological control

The greatest recent advance is in the area of biotechnology and/or its application particularly in commercial production of genetically more effective or virulent recombinant strains of parasitoids or microbial agents. Notably, the crystallization of insecticidal proteins of some microbial pesticides particularly especially Bacillus thuringiensis (Bt) has caused a significant enhancement of its insecticidal and target activities Surinder [55]. These genetic manipulations particularly in the bacterium, B. thuringiensis have led to the determination at the molecular level of the mode of action of delta-toxins and their specificity; characterization and exploitation of Bt Insecticidal Crystal Protein (ICP) in microbial insecticide development and subsequent construction of recombinant Bt strains as well as cloning of vectors for the lux-gene technology in the control of soil borne diseases Mukerji. Also, isolates of the nuclear polyhedrosis virus (NPV) can now be subjected to structural genetic and biological comparison to select the most suitable isolates for use in biological control especially for lepidopterous pests Escribano, et al. [56]. The principle of synergism is now being employed in the development of compound NPV biocontrol agents. For example, AcNPV (Autographa californica nuclear of polyhedrosis virus), PinPV (Prodenia litura) and the Bt preparations were mixed together to make a biological control compound. The synergism of the mixture increased virulence by 5.1 and 9.5 times compared with that of AcNPV and PiNPV against A. californica and P. litura respectively Hou-Jian Wen et al. [57].

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Even now, genetically modified NPV (GM, Ac NPV) are now undergoing tests in the field for biological control Hernandez-Crespo [58]. The potency of NPV can now be increased by the addition of virus enhancing adjuvant such as Blankophor and Tinopal Webb [59] which are optical/fluorescent brighteners that protect viruses from degradation by ultraviolet lights and thus extend the effectiveness in the field Escribano et al. [56]. Blankophor and Tinopal are chemicals that absorb energy from the ultraviolet lights and emit it as visible light Shapiro & Hamm [60]; Farrar, Ridgway & Dively [61]. There had been landmark development in the use of entomogenous fungi in recent times. A typical example is the use of Bioblast, a commercial formulation of the fungus Metarhizium anisophae for the control of termite. The preparation is used to control active galleries within structures in the U.S.A and as a ground treatment to protect timber in Australia Quarles. It is very effective against both drywood and subterranean termites Quarles. The use of entomo-pathogenic and fungivorous nematodes particularly of the families: Steinermatidae and Heterohaditidae have proved to be as effective as the synthetic chemical insecticides Iahibashi [62]. They are now available in different commercial formulations in the United States Choo et al. [63]; Ishibashi [62].

Precautions for applying pesticides

Wear protective clothing as a matter of habit/routine, hence use foot wears (rubber); simple cut shoe types are preferable to boots and sandals. Do not exceed recommend dosage, usually the degree of infestation and possible loss makes farmer to overreact because they want to ensure immediate control of the pest. Pay attention to correct dosage and harvesting date to prevent presence of pesticide residue above Maximum Acceptable Limit, and safety of sprayers when re-entering sprayed plots. Time application to prevent drift, (windy weather is relevant) particularly in case of drastic strokes (swing frog). Therefore, if you feel ill while spraying, stop work at once and get medical attention

Choice of and caring for equipment

Choose the right equipment, Knapsack and mistblower for sprays and dusts, swing frog for swolves and fogs. For efficient and safe application, keep equipment by checking parts, valves, nuts, rubber hose along its length and joints connection, nozzles. Calibrate the equipment accurately so it will disperse the prescribed amount of pesticide. Under dosage from faulty calibration would be ineffective against pests and diseases or create resistance problems. Over dosage caused illegal residues, probably use separate equipment for different clones of pesticide. Avoid using herbicide equipment for fungicides and insecticides, where this is impracticable for economic reason, wash equipment thoroughly before next use. Pay attention to special procedure of cleaning particular class of pesticides. Thoroughly flush the tank with warm water and detergent. Run some of this through the lance and nozzle. (In large scale tank, use household Ammonia to flush tank, lance and nozzles) of boom sprayers. Allow washing what to remain in the tank for 12 -24 hrs. To ensure that the equipment has been thoroughly cleaned, fill it with water and spray seedlings of sensitive plants (grass, dicotyledonous weeds, cover crops and observe after 2 days). If treated area or seedling remain healthy, then the equipment is safe for further use.

Conclusion

Pesticides have proved to be helpful for the farmers as well as people all around the world by increasing agricultural yield and by providing innumerable benefits to society indirectly. But the issue of hazards posed by pesticides to human health and the environment has raised concerns about the safety of pesticides. Although we cannot completely eliminate the hazards associated with pesticide use, but we can circumvent them in one way or the other. Exposure to pesticides and hence the harmful consequences and undesirable effects of this exposure can be minimised by several means such as biorational and microbiological tactics, appropriate sparing pesticides by using well-maintained spraying equipments. Production of better, safe and environment friendly pesticide formulations could reduce the harmful effects associated with the pesticide usage. If the pesticides are used in appropriate quantities and used only when required or necessary, then pesticide risks can be minimised. Similarly, if a less toxic formulation or low dose of a toxic formulation is used, the havoc can be curbed. There are organochlorines, which are used as pesticides. These pesticides are least biodegradable, and their use is banned in many countries. Besides this fact, organochlorines are highly used in many places.

This results in serious health hazards. Water pollution is on the rise due to these pesticides, even at low concentration, these pesticides have serious threat to the environment Agrawal [64]. The majority of farmers are unaware of the potential toxicities of pesticides. They have no information about types of pesticides, their level of poisoning, hazards and safety measures to be taken before use of those pesticides. Due to this reason, toxic and environmentally persistent chemicals are used to kill pests which can also lead to intentional, incidental or occupational exposure. These compounds have long term effects on human health Sanborn [65]. Awareness should be arranged for these farmers to reduce the uses of toxic pesticides Sharma et al. [66]. In future chemical pesticides can be used in combination with biorational and remedies which result in more sustainable elimination of pests and insects. This combination not only promises environmental sustainability, but also has diverse applications in controlling of urban pests and invasive species Gentz [67]. Pesticides have also posed a serious threat on biological integrity of marine and aquatic ecosystems. It is the need of time to integrate the studies of different disciplines including toxicology, environmental chemistry, population biology, community ecology, conservation biology and landscape ecology to understand direct and indirect effects of pesticides on the environment Macneale [8], [68-81].

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How to cite this article: Azeez OM. A Review of Pragmatic Approaches to Pesticide Application, Microbiological Pest Control and Their Multiplier Effects. Ann Rev Resear. 2022; 7(2): 555709. DOI:10.19080/ARR.2022.07.555709

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DOI:10.19080/ARR.2022.07.555709

How to cite this article: Azeez OM. A Review of Pragmatic Approaches to Pesticide Application, Microbiological Pest Control and Their Multiplier Effects. Ann Rev Resear. 2022; 7(2): 555709. DOI:10.19080/ARR.2022.07.555709