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Reviews

Impact of synthetic pesticides utilization on humans and the environment: an overview

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Abstract. *Pesticides are chemicals that kill or manage the population of pests. There are many different types of pesticides on the market today, but the most common are herbicides and insecticides, which kill or manage unwanted plants and insects. The benefits of pesticides include increased food production, increased profits for farmers and the prevention of diseases. Although pests consume or harm a large portion of agricultural crops, without the use of pesticides, it is likely that they would consume a higher percentage. More food is produced by farmers, thereby increasing profit. Pesticides also increase farm profits by helping the farmer save money on labor costs. Using pesticides reduces the amount of time required to manually remove weeds and pests from the fields. In addition to saving crops and livestock, pesticides have also had direct benefits to human health. It is estimated that since 1945, the use of pesticides has prevented the deaths of around seven million people by killing pests that carry or transmit diseases. Although there are benefits to the use of pesticides, there have also been many problems associated with their use. Pesticides do not always stay in the location where they are applied. They are mobile in the environment and often move through water, air and soil. The problem with pesticide mobility is that when they travel, the pesticides come in contact with other organisms and can cause harm. Pesticides have also been shown to disrupt the balance of an ecosystem. In many situations when a pesticide is used, it also kills non-pest organisms. This can drastically alter the natural balance of the ecosystem. By removing non-pest organisms, the environment can be changed to favor the pest. In addition to causing harm to wildlife, pesticides that travel from their original location are known to cause harm to humans. Human exposure to pesticides has caused poisonings, the development of cancer and the deaths of between 20000 and 40000 people worldwide each year. Another major problem associated with pesticide use is bioaccumulation and biological magnification. Bioaccumulation is when a substance builds up in the body because the body does not have the proper mechanisms to remove it. Many synthetic pesticides are not able to be broken down. Once they enter the body of an organism, they are permanently stored in the body tissue.*

Keywords: animals, environment, benefits, human, pollution, syntetic pesticides

Introduction

Agriculture was developed to produce crops and livestock for human consumption. As the human population increases, the amount of food produced is very important. Unfortunately, there are other organisms out there that want to consume the crops that are meant for humans. It is estimated that nearly 37% of all crops produced in the United States each year are destroyed by agricultural pests, which results in an economic loss of around $122 billion a year (Oaya, 2016). The term pesticide covers a wide range of compounds including insecticides, fungicides, herbicides, rodenticides, molluscicides, nematicides, plant growth regulators and others (Rockets, 2007; AL-Ahmadi, 2019). Among these, organochlorine (OC) insecticides used successfully in controlling a number of diseases such as malaria and typhus were banned or restricted after the 1960s in most of the technologically advanced countries (Lorenz, 2009). The introduction of synthetic insecticides – organophosphate (OP) insecticides in the 1960s, carbamates in 1970s and pyrethroids in 1980s and the introduction of herbicides and fungicides in the 1970s-1980s contributed greatly to pest control and agricultural output (Cone, 2000). Ideally a pesticide must be lethal to the targeted pests but not to non-target species, including man (Kellogg et al., 2000). Unfortunately, this is not the case, the controversy of use and abuse of pesticides has surfaced. The rampant use of these chemicals, under the adage, "if little is good, a lot more will be better" has played havoc with human and other life forms (Science Daily, 2006).

Over the next 20 years, crop production will have to increase significantly to meet the needs of a rising human population and this has to be done without damaging the other public goods, environment and social benefits that farming brings (Bingham, 2006). There will be no 'silver bullet' solution to the impending food production challenge. Rather a series of innovations must be developed to meet the different needs of farmers according to their local circumstances (Palmer et al., 2007).

One way to increase food availability is to improve the management of pests. There are estimated to be around 67000 different crop pest species including plant pathogens, weeds, invertebrates and some vertebrate species and together they cause about a 40% reduction in the world's crop yield (Wells, 2007). Crop losses caused by pests undermine food security alongside other constraints such as inclement weather, poor soils and farmers' limited access to technical knowledge (Fox et al., 2007).

Since the 1960s, pest management in the industrialized countries has been based around the intensive use of synthet-

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ic chemical pesticides alongside advances in plant varieties, mechanization, irrigation and crop nutrition which have helped increase crop yields by nearly 70% in Europe and 100% in the USA (Yashmin and Souza, 2006). However, the use of synthetic pesticides is becoming significantly more difficult owing to a number of interacting factors.

The arrival of humans in an area to live or to conduct agriculture doubtlessly has environmental impacts. These range from simple crowding out of wild plants in favor of more desirable cultivars to larger scale impacts such as reducing biodiversity by reducing food availability of native species, which can propagate across food chains (Science Daily, 2006). The use of agricultural chemicals such as fertilizer and pesticides magnify those impacts. While advances in agro-chemistry have reduced those impacts, for example by the replacement of long-lived chemicals with those that reliably degrade, even in the best case they remain substantial. These effects are magnified by the use of older chemistries and poor management practices (Lamberth et al., 2013). Public concern over the undesirable environmental effects of chemicals arose in the early 1960s with the publication of Rachel Carson's book, *Silent Spring*. Shortly thereafter, DDT, originally used to combat malaria, and its metabolites were shown to cause population-level effects in raptorial birds. Initial studies in industrialized countries focused on acute mortality effects mostly involving birds or fish (Kohler et al., 2013).

Data on pesticide usage remain scattered and or not publicly available. The common practice of incident registration is inadequate for understanding the entirety of effects (Kohler et al., 2013). Since 1990, research interest has shifted from documenting incidents and quantifying chemical exposure to studies aimed at linking laboratory, mesocosm and field experiments. The proportion of effect-related publications has increased. Animal studies mostly focus on fish, insects, birds, amphibians and arachnids (Damalas et al., 2011). Since 1993, the United States and the European Union have updated pesticide risk assessment, ending the use of acutely toxic organophosphate and carbamate insecticides. Newer pesticides aim at efficiency in target and minimum side effects in non-target organisms. The phylogenetic proximity of beneficial and pest species complicates the project (Kohler et al., 2013). One of the major challenges is to link the results from cellular studies through many levels of increasing complexity to ecosystems (Damalas et al., 2011).

The need to know the impacts of pesticides in terms of their benefits and detriments and also to shift emphasis from the excessive use of conventional synthetic insecticides for the control of pest organisms prompted this work. Moreover, the need to phase out ozone depleting pesticides has open a new window for searching alternative pesticides to control pests of agricultural sector (Ahmedani et al., 2007; Jada et al., 2013). Several methods of pests control employed by farmers and researchers have identified some efficient and effective control of the pests (Adebowale and Adedire, 2006). Some of these methods range from store hygiene, physical and cultural control methods and the use of inert materials. Chemical control appeared to be the most effective and efficient control method (Jackai and Daoust, 1986; Adedire and Lajide, 2001; Oaya et al., 2011) but it has tremendous adverse effect on man, the livestock and the environment (Makanjoula, 1989; Adedire and Lajide, 2000; Bernardes et al., 2015). Chemical related pesticides against pests are not only limited because of the health and environmental concern related to them but also due to their high costs and scarce availability in rural areas (Adda et al., 2011).

Against this background, a curious search for natural-product based agrochemicals which are biodegradable, eco-friendly and safe to humans and the environment has intensified (Jadhau and Jadhau, 2006; Mahmood et al., 2015). There is also the need for cheaper and safer alternative control practices. The potential advantages of non-chemical pesticides over synthetic ones have been highlighted by Prakash et al. (2008) and Oaya and Malgwi (2014).

This review will among other things determine the impact of pesticides, their benefits and detriments to man and his environment.

Benefits of pesticides utilization

Increased yield

The primary benefits are the consequences of the pesticide effects – the direct gains expected from their use. For example, the effect of killing caterpillars feeding on the crop brings the primary benefit of higher yields and better quality of cabbage. The three main effects result in 26 primary benefits ranging from protection of recreational turf to saved human lives. The secondary benefits are the less immediate or less obvious benefits that result from the primary benefits. The benefits of pesticides include increased food production, increased profits for farmers and the prevention of diseases. Although pests consume or harm a large portion of agricultural crops, without the use of pesticides, it is likely that they would consume a higher percentage.

Due to the use of pesticides, it is possible to combat pests and produce larger quantities of food. For instance, use of pesticides increased crop yield in Europe by 70% and almost 100% in the US (Yashmin and Souza, 2006). By producing more crops, farmers are also able to increase profits by having more produce to sell. Pesticides also increase farm profits by helping the farmer save money on labor costs. Using pesticides reduces the amount of time required to manually remove weeds and pests from fields. They may be subtle, less intuitively obvious, or of longer term. It follows that for secondary benefits it is therefore more difficult to establish cause and effect, but nevertheless they can be powerful justifications for pesticide use. For example, the higher cabbage yield might bring additional revenue that could be put towards children's education or medical care, leading to a healthier and better educated population. There are various secondary benefits identified, ranging from fitter people to conserved biodiversity.

Improving productivity

Tremendous benefits have been derived from the use of pesticides in forestry, public health and the domestic sphere and of course in agriculture. For instance, in India, food grain production, which stood at a mere 50 million tons in 1948-49, had increased almost fourfold to 198 million tons by the end of 1996-97 from an estimated 169 million hectares of permanently cropped land. This result has been achieved by the use of high-yield varieties of seeds, advanced irrigation technologies and agricultural chemicals (Indian Labour Statistics, 1994). Similarly, outputs and productivity have increased dramatically in most countries, for example wheat yields in the United Kingdom, corn yields in the USA. Increases in productivity have been due to several factors including use of fertilizer, better varieties and use of machinery. Pesticides have been an integral part of the process by reducing losses from the weeds, diseases and insect pests that can markedly reduce the amount of harvestable produce. Warren (1998) also drew attention to the spectacular increases in crop yields in the United States in the twentieth century. Webster et al. (1999) stated that considerable economic losses would be suffered without pesticide use and quantified the significant increases in yield and economic margin that result from pesticide use. Moreover, in the environment most pesticides undergo photochemical transformation to produce metabolites which are relatively non-toxic to both human beings and the environment (Kole et al.,1999).

Protection of crop losses/yield reduction

In medium land, rice even under puddle conditions during the critical period warranted an effective and economic weed control practice to prevent reduction in rice yield due to weeds that ranged from 28 to 48%, based on comparisons that included control (weedy) plots (Behera and Singh, 1999). Weeds reduce yield of dry land crops (Behera and Singh, 1999) by 37-79%. Severe infestation of weeds, particularly in the early stage of crop establishment, ultimately accounts for a yield reduction of 40%. Herbicides provided both economic and labour benefit.

Vector disease control

Vector-borne diseases are most effectively tackled by killing the vectors. Insecticides are often the only practical way to control the insects that spread deadly diseases such as malaria, resulting in an estimated 5000 deaths each day (Ross, 2005). In 2004, Bhatia wrote that malaria is one of the leading causes of morbidity and mortality in the developing world and a major public health problem in India. Disease control strategies are crucially important also for livestock (Nilsson and Gripwall, 1990).

Food quality

In countries of the first world, it has been observed that a diet containing fresh fruit and vegetables far outweighs potential risks from eating very low residues of pesticides in crops (Brown, 2004). Increasing evidence (Dietary Guidelines, 2005) shows that eating fruit and vegetables regularly reduces the risk of many cancers, high blood pressure, heart disease, diabetes, stroke, and other chronic diseases.

Lewis et al. (2005) discussed the nutritional properties of apples and blueberries in the US diet and concluded that their high concentrations of antioxidants act as protectants against cancer and heart disease. Lewis attributed doubling in wild blueberry production and subsequent increases in consumption chiefly to herbicide use that improved weed control.

Other areas-transport, sport complex, building

The transport sector makes extensive use of pesticides, particularly herbicides. Herbicides and insecticides are used to maintain the turf on sports pitches, cricket grounds, football pitches and golf courses. Insecticides protect buildings and other wooden structures from damage by termites and wood boring insects.

Detriments of pesticides utilization

Air pollution: Pesticides can contribute to air pollution. Pesticide drift occurs when pesticides suspended in the air as particles are carried by wind to other areas, potentially contaminating them (Cornell University, 2007). Pesticides that are applied to crops can volatilize and may be blown by winds into nearby areas, potentially posing a threat to wildlife (National Park Services, 2006). Weather conditions at the time of application as well as temperature and relative humidity change the spread of the pesticide in the air. As wind velocity increases so does the spray drift and exposure. Low relative humidity and high temperature result in more spray evaporating. The amount of inhalable pesticides in the outdoor environment is therefore often dependent on the season (Damalas et al., 2011).

Also, droplets of sprayed pesticides or particles from pesticides applied as dusts may travel on the wind to other areas, (US Environmental Protection Agency, 2007) or pesticides may adhere to particles that blow in the wind, such as dust particles (Environment Canada, 2001). Ground spraying produces less pesticide drift than aerial spraying does (Palmer et al., 2007). Farmers can employ a buffer zone around their crop, consisting of empty land or non-crop plants such as evergreen trees to serve as windbreaks and absorb the pesticides, preventing drift into other areas (Science Daily, 1999).

Pesticides that are sprayed on to fields and used to fumigate soil can give off chemicals called volatile organic compounds, which can react with other chemicals and form a pollutant called tropospheric ozone. Pesticide use accounts for about 6 percent of total tropospheric ozone levels (IPM, 2006).

Effect on water: In the United States, pesticides were found to pollute every stream and over 90% of wells sampled in a study by the US Geological Survey (Golliom et al., 2007). Pesticide residues have also been found in rain and groundwater (Kellogg et al., 2000). Studies by the UK government showed that pesticide concentrations exceeded those allowable for drinking water in some samples of river water and groundwater (Bingham, 2007).

Pesticide impacts on aquatic systems are often studied using a hydrology transport model to study movement and fate of chemicals in rivers and streams. As early as the 1970s quantitative analysis of pesticide runoff was conducted in order to predict amounts of pesticide that would reach surface waters (Hogan et al., 1973). There are four major routes through which pesticides reach the water: it may drift outside of the intended area when it is sprayed, it may percolate, or leach, through the soil, it may be carried to the water as runoff, or it may be spilled, for example accidentally or through neglect (State of Jersey, 2007). They may also be carried to water by eroding soil (Papendick et al., 1986). Factors that affect a pesticide's ability to contaminate water include its water solubility, the distance from an application site to a body of water, weather, soil type, presence of a growing crop, and the method used to apply the chemical (Pederson, 1997). Maximum limits of allowable concentrations for individual pesticides in public bodies of water are set by the Environmental Protection Agency in the US (Pederson, 1997).

Similarly, the government of the United Kingdom sets Environmental Quality Standards (EQS), or maximum allowable concentrations of some pesticides in bodies of water above which toxicity may occur (Bingham, 2007). The European Union also regulates maximum concentrations of pesticides in water (Bingham, 2007).

Impact on soil: Many of the chemicals used in pesticides are persistent soil contaminants, whose impact may endure for decades and adversely affect soil conservation (US Environmental Protection Agency, 2007). The use of pesticides decreases the general biodiversity in the soil. Not using the chemicals results in higher soil quality (Johnson, 1986) with the additional effect that more organic matter in the soil allows for higher water retention (Kellogg et al., 2000). This helps increase yields for farms in drought years, when organic farms have had yields 20-40% higher than their conventional counterparts (Lotter et al., 2003)). A smaller content of organic matter in the soil increases the amount of pesticide that will leave the area of application, because organic matter binds to and helps break down pesticides (Kellogg et al., 2000).

Degradation and sorption are both factors which influence the persistence of pesticides in soil. Depending on the chemical nature of the pesticide, such processes control directly the transportation from soil to water, and in turn to air and our food. Breaking down organic substances, degradation, involves interactions among microorganisms in the soil. Sorption affects bioaccumulation of pesticides which are dependent on organic matter in the soil. Weak organic acids have been shown to be weakly sorbed by soil, because of pH and mostly acidic structure. Sorbed chemicals have been shown to be less accessible to microorganisms. Aging mechanisms are poorly understood but as residence times in soil increase, pesticide residues become more resistant to degradation and extraction as they lose biological activity (Arias-Estevez et al., 2008).

Impact on plants: Nitrogen fixation, which is required for the growth of higher plants is hindered by pesticides in soil (Rockets, 2008). The insecticides DDT, methyl parathion, and especially pentachlorophenol have been shown to interfere with legume-rhizobium chemical signaling (Rockets, 2008). Reduction of this symbiotic chemical signaling results in reduced nitrogen fixation and thus reduced crop yields. Root nodule formation in these plants saves the world economy $10 billion in synthetic nitrogen fertilizer every year (Fox et al., 2007).

Pesticides can kill bees and are strongly implicated in pollinator decline, the loss of species that pollinate plants through the mechanism of Colony Collapse Disorder as published by Hackenburg (2007) and Wells (2007) in which worker bees from a beehive or western honey bee colony abruptly disappear. Application of pesticides to crops that are in bloom can kill honeybees (Cornell University, 2007) which act as pollinators. The USDA and USFWS estimate that US farmers lose at least $200 million a year from reduced crop pollination because pesticides applied to fields eliminate about a fifth of honeybee colonies in the US and harm an additional 15% (George, 2004). On the other side, pesticides have some direct harmful effect on plant including poor root hair development, shoot yellowing and reduced plant growth (Walley and Lupwayi, 2006)).

Impact on animals: Many kinds of animals are harmed by pesticides, leading many countries to regulate pesticide usage through Biodiversity Action Plans (Haefeker, 2000). Animals including humans may be poisoned by pesticide residues that remain on food, for example when wild animals enter sprayed fields or nearby areas shortly after spraying (Palmer et al., 2007).

Pesticides can eliminate some animals' essential food sources, causing the animals to relocate, change their diet or starve. Residues can travel up the food chain; for example, birds can be harmed when they eat insects and worms that have consumed pesticides (Cornell University, 2007). Earthworms digest organic matter and increase nutrient content in the top layer of soil. They protect human health by ingesting decomposing litter and serving as bio-indicators of soil activity. Pesticides have had harmful effects on growth and reproduction on earthworms (Yashimin and Souza, 2010). Some pesticides can accumulate or build up to toxic levels in the bodies of organisms that consume them over time, a phenomenon that impacts species high on the food chain. (Cornell University, 2007).

Impact on birds: The US Fish and Wildlife Service estimate that 72 million birds are killed by pesticides in the United States each year (Fimrite, 2011). Bald eagles are common examples of non-target organisms that are impacted by pesticide use. Rachel Carson's book *Silent Spring* dealt with damage to bird species due to pesticide bioaccumulation. There is evidence that birds are continuing to be harmed by pesticide use (Cornell University, 2007).

In the farmland of the United Kingdom, populations of ten different bird species declined by 10 million breeding individuals between 1979 and 1999, allegedly from loss of plant and invertebrate species on which the birds feed. Throughout Europe, 116 species of birds were threatened as of 1999. Reductions in bird populations have been found to be associated with times and areas in which pesticides are used (Kerbs et al., 1999). DDE-induced eggshell thinning has especially affected European and North American bird populations (Vos et al., 2000). In another example, some types of fungicides used in peanut farming are only slightly toxic to birds and mammals, but may kill earthworms, which can in turn reduce populations of the birds and mammals that feed on them (Palmer et al., 2007). According to them, some pesticides come in granular form. Wildlife may eat the granules, mistaking them for grains of food. A few granules of a pesticide may be enough to kill a small bird. The herbicide paraquat, when sprayed onto bird eggs, causes growth abnormalities in embryos and reduces the number of chicks that hatch successfully, but most herbicides do not directly cause much harm to birds. Herbicides may endanger bird populations by reducing their habitat (Palmer et al., 2007).

Impact on aquatic life: Fish and other aquatic biota may be harmed by pesticide-contaminated water (Helfrich et al., 1996). Pesticide surface runoff into rivers and streams can be highly lethal to aquatic life, sometimes killing all the fish in a particular stream (Toughil, 1999). Application of herbicides to bodies of water can cause fish kills when the dead plants decay and consume the water's oxygen, suffocating the fish. Herbicides such as copper sulfite that are applied to water to kill plants are toxic to fish and other water animals at concentrations similar to those used to kill the plants. Repeated exposure to sub-lethal doses of some pesticides can cause physiological and behavioral changes that reduce fish populations, such as abandonment of nests and broods, decreased immunity to disease and decreased predator avoidance (Helfrich et al., 1996). They further stressed that the application of herbicides to bodies of water can kill plants on which fish depend for their habitat.

Pesticides can accumulate in bodies of water to levels that kill off zooplankton, the main source of food for young fish (Pesticide Action Network North America, 1999). Pesticides can also kill off insects on which some fish feed, causing the fish to travel farther in search of food and exposing them to greater risk from predators (Helfrich et al., 1996). According to them, the faster a given pesticide breaks down in the environment, the less threat it poses to aquatic life. Insecticides are typically more toxic to aquatic life than herbicides and fungicides.

Impact on amphibians: In the past several decades, amphibian populations have declined across the world, for unexplained reasons which are thought to be varied but of which pesticides may be a part (Cone, 2000). Pesticide mixtures appear to have a cumulative toxic effect on frogs. Tadpoles from ponds containing multiple pesticides take longer to metamorphosize and are smaller when they do, decreasing their ability to catch prey and avoid predators (Science Daily, 2006). Exposing tadpoles to the organochloride, endosulfan at levels likely to be found in habitats near fields sprayed with the chemical kills the tadpoles and causes behavioral and growth abnormalities (Ralloff, 1998). The herbicide atrazine can turn male frogs into hermaphrodites, decreasing their ability to reproduce. Both reproductive and non-reproductive effects in aquatic reptiles and amphibians have been reported. Crocodiles, many turtle species and some lizards lack sex-distinct chromosomes until after fertilization during organogenesis, depending on temperature. Embryonic exposure in turtles to various PCBs causes a sex reversal. Across the United States and Canada disorders such as decreased hatching success, feminization, skin lesions, and other developmental abnormalities have been reported (Vos et al., 2000).

Impact on Humans: Many workers and residents in the rural regions are in contact with pesticides on a daily basis, so they are at high risk of poisoning by these compounds. This exposure can cause neuropsychiatric sequelae, because many pesticides affected changes in the function of the central, peripheral, and autonomic nervous system (Freire and Koifman, 2013).

Pesticides can enter the body through inhalation of aerosols, dust and vapor that contain pesticides; through oral exposure by consuming food/water; and through skin exposure by direct contact (California Department of Pesticide Regulation, 2008). Pesticides secrete into soils and groundwater which can end up in drinking water and pesticide spray can drift and pollute the air.

The effects of pesticides on human health depend on the toxicity of the chemical and the length and magnitude of exposure (Lorenz, 2009). Farm workers and their families experience the greatest exposure to agricultural pesticides through direct contact. Every human contains pesticides in their fat cells.

Children are more susceptible and sensitive to pesticides (California Department of Pesticide Regulation, 2008) because they are still developing and have a weaker immune system than adults. Children may be more exposed due to their closer proximity to the ground and tendency to put unfamiliar objects in their mouth. Hand to mouth contact depends on the child's age, much like lead exposure. Children under the age of six months are more apt to experience exposure from breast milk and inhalation of small particles. Pesticides tracked into the home from family members increase the risk of exposure. Toxic residue in food may contribute to a child's exposure (Du-Toit, 1992). The chemicals can be accumulated in the body over time.

Exposure effects can range from mild skin irritation to birth defects, tumors, genetic changes, blood and nerve disorders, endocrine disruption, coma or death (Lorenz, 2009). Developmental effects have been associated with pesticides. Recent increases in childhood cancers in throughout North America, such as leukemia, may be a result of somatic cell mutations (Crawford and Fiedler, 1992). Insecticides targeted to disrupt insects can have harmful effects on mammalian nervous systems. DDT and its breakdown product DDE disturb estrogenic activity and possibly lead to breast cancer. Fetal DDT exposure reduces male penis size in animals and can produce undescended testicles. Pesticide can affect fetuses in early stages of development, in utero and even if a parent was exposed before conception. Reproductive disruption has the potential to occur by chemical reactivity and through structural changes (Hodgson and Levi, 1996).

Persistent organic pollutants

Persistent organic pollutants (POPs) are compounds that resist degradation and thus remain in the environment for years. For example some pesticides, including aldrin, chlordane, DDT,dieldrin, endrin, heptachlor, hexachlorobenzene, mirex and toxaphene, are considered POPs. Some POPs have the ability to volatilize and travel great distances through the atmosphere to become deposited in remote regions. Such chemicals may have the ability to accumulate and can also concentrate (i.e. become more concentrated) up to 70000 times their original concentrations (Ritter et al., 2007). POPs can affect non-target organisms in the environment and increase risk to humans (Centre for Disease Control and Prevention, 2007) by disruption in the endocrine, reproductive, and immune systems (Ritter et al., 2007).

Pest resistance

Resistance is the complete ability of an organism to withstand the toxic effects of a pesticide or the complete capacity of a plant to withstand attack. Pests may evolve to become resistant to pesticides. Many pests will initially be very susceptible to pesticides but following mutations in their genetic makeup, they become resistant and survive to reproduce. Resistance is commonly managed through pesticide rotation, which involves alternating among pesticide classes with different modes of action to delay the onset of or mitigate existing pest resistance (Graeme, 2005).

Pest resurgence

The general understanding is that when a broad-spectrum insecticide is used to control or eliminate a pest, the natural enemies of that pest may be killed or reduced to below natural levels while the target pest for elimination may survive (Choffnes et al., 2008). Pesticides on account of their smell may drive away the natural enemies of the pest. After the treatment, the pest population remains at a low level only for a while. However, in the absence of its natural enemy, they multiply rapidly and gradually build up to damaging levels once again, leading to what is known as resurgence (Figure 1).

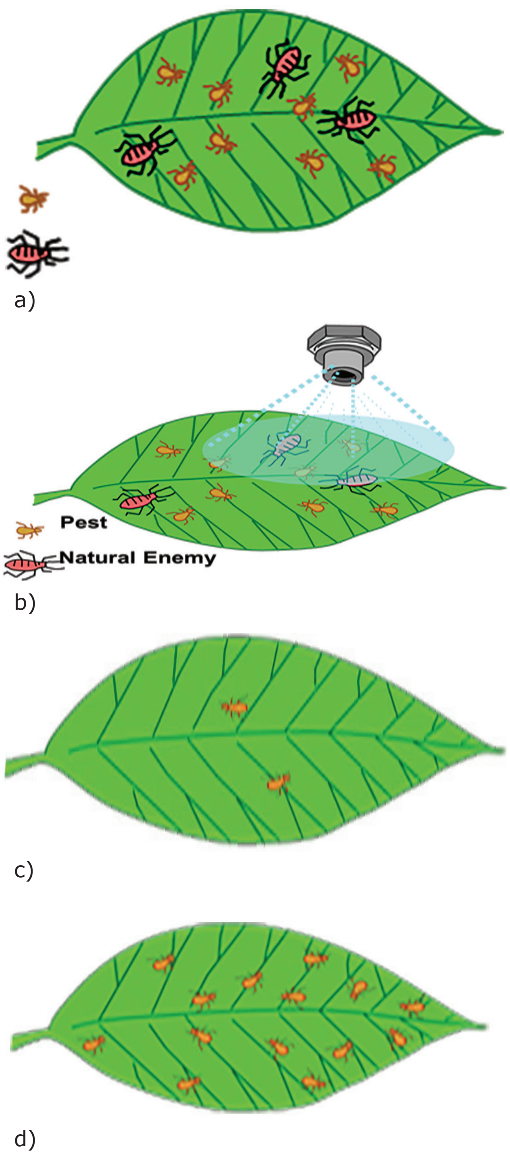

Figure 1. Simple illustration of pest resurgence where pesticide is the major cause (a, b, c, d)

Pest resurgence can be defined as the rapid numerical rebound of a pest population after the use of a broad spectrum pesticide, brought about by the distraction of natural enemies which were otherwise holding the pest in check (Van den Bosch and Messenger, 1973). Hardin et al. (1995) also defined the term resurgence as an increase in target arthropod pest species abundance to a level which exceeds that of a control or untreated population following the application of an insecticide. Resurgence is an abnormal increase in a pest population following insecticide treatment, often far exceeding the economic injury level (Chelliah, 1986). Mafuyai (2014) also defines resurgence as the rapid reappearance of a pest population in injurious number, usually brought about after the application of a broad spectrum pesticide has killed the natural enemies which normally keep a pest in check.

Conclusion

The extensive benefit which man accrues from the use of synthetic pesticides provides the best opportunity to those who juggle with the risk-benefit equations. The economic impact of pesticides in non-target species (including humans) has been estimated at approximately $8 billion annually in developing countries. What is required is to weigh all the risks against the benefits to ensure a maximum margin of safety. The total cost-benefit picture from pesticide use differs appreciably between developed and developing countries. For developing countries, it is imperative to use pesticides, as no one would prefer famine and communicable diseases like malaria. It may thus be expedient to accept a reasonable degree of risk. Our approach to the use of pesticides should be pragmatic. In other words, all activities concerning pesticides should be based on scientific judgment and not on commercial considerations. The long-term effects of low level exposure to one pesticide are greatly influenced by concomitant exposure to other pesticides as well as to pollutants present in air, water, food and drugs.

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