# Chapter 8
# Environmental and Health Effects of Pesticide Residues

**Sajjad Ali, Muhammad Irfan Ullah, Asif Sajjad, Qaiser Shakeel, and Azhar Hussain**

**Abstract** Now a days, agroecosystem is largely dependent on pesticides to meet the ever-increasing demand of food and fiber. Tons of synthetic pesticides are deposited to increase the yield. This scenario poses great threat to non-target organisms because 98% sprayed pesticides directly or indirectly affect them. Several studies estimated that 80% of sprayed pesticides directly contaminate the environment. This chapter reviewed the pesticides effects on environment, natural biodiversity, pollinators, food chains and outcome health issues. It was reviewed that soil and water qualities are deteriorated because of pesticide depositions. Due to microbial life threat, soil respiration is decreased by 35% and almost 90% water sources in agro-lands are polluted with pesticides. The aquatic and terrestrial food chains are being endangered because of bioaccumulation and biomagnification of loads of pesticides. Studies revealed that biodiversity and species are endangered because of pesticide exposures. During last few decades, 70% decline in insect biomass and 50% decline in farmland birds is reported in European nations. Similarly, 42% reduction in species richness was also noted in Europe, Australia and North America. Pesticides residues have injurious effects on bees which ultimately decrease their ecological service. United Nations warned that 40% of invertebrate pollinator, particularly bees

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and butterflies, are at risk to global extermination. Almost, 30% honey bee population decline in American and European countries is reported due to extreme use of pesticides. Through food chain contamination, adverse effects reach to human life. These ingestions have resulted serious carcinogenic, endocrine, neurological, reproductive and other ailments. Even, many casualties have been reported due to exposure to poisonous pesticides. Bundle of research indicated that cancer risk and mental health problems are enlarged by 25–30% after exposure to pesticides. Similarly, 50% elevated risk of leukaemia, lymphoma and brain cancer in children is linked with paternal exposure to pesticides. Now, it is time to find out some alternatives focusing the environmental protection and ultimately human health. Integrated pest management can be the one and only option to minimize the use of pesticides.

**Keywords** Air pollution · Biodiversity · Carcinogenic · Diseases · Food chain contamination · Pollinator · Pesticide pollution · Water pollution

## 8.1 Introduction

Application of pesticides to prevent, kill, repel or mitigate the harmful and invasive organisms, has become an integral input in modern agriculture system to meet the ever-increasing demands of food and fiber. Tons of synthetic chemicals, mainly herbicides, insecticides and fungicides, are being deposited into the natural and agroecosystems every year to protect the crop produces from the weeds, insect and pathogens. By 2050, we need to feed 10 billion population of the world (Eddleston 2000). Since 1940, many agricultural practices including pesticides would have become a new trend in modern farming for improved crop yields; eight times better than the previous one. Without pesticide application, losses of fruits, vegetables and cereals due to various pest injuries can reach up to 78, 54 and 32%, respectively (Cai 2008).

Around 2 million tons of pesticides (45% Europe, 25% United States and 25% other countries of the world) are consumed every year worldwide for the crop protection. Worldwide, 40% of the pesticides is confined to herbicides, 17% to insecticides, 10% to fungicides and rest of the pesticides fall into other small usages (Fig. 8.1) (Alavanja 2009; De et al. 2014).

Almost, 98% of the sprayed pesticide chemicals also influence the non-target organisms. Commonly, the pesticide residues through agro-ecosystem, domestic, garden use and spray drifts are accumulating into soil, air, water and food. The workers, who have direct exposure, are at more risks to carcinogenic and mutagenic illnesses but the common people are also not excluded from this danger being exposed to pesticide residues in nature. Besides the use of smart technology in agriculture and increased focus on organic farming, still around 25 million workers of agricultural community are diseased by exposure to pesticides residues exclusive to infection of farm land animals. Environmental scientists are trying to reduce

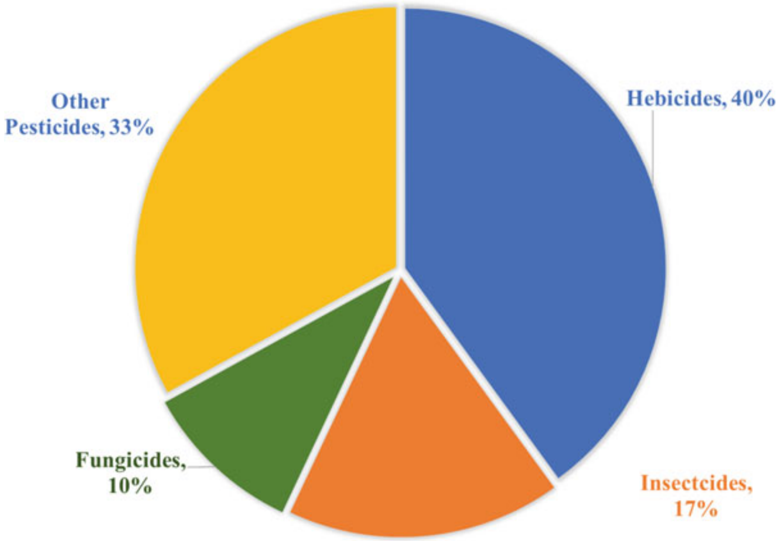


**Fig. 8.1** Global share of different kinds of pesticides application

pesticide application to minimize the poisonous residues exposure (Alavanja et al. 2001; Alavanja 2009).

The monitoring of pesticide residues in food stuff was started in the European Union since 1996. Due to food uncleanness, most of the deaths are noted in hospital reviews (Eddleston 2000). In India, the first pesticides poisoning report was from Kerala in 1958, where over 100 people expired after eating wheat flour with parathion contaminations (Karunakaran 1958). The land can become contaminated during each pesticide application. Likely, 80–90% of pesticides are volatilized into environment within few hours of application (Damalas and Eleftherohorinos 2011). The drift of pesticide causes, not only, the loss of 2–25% of chemical but also causes spread of pesticide residues over longer distances. Large number of pesticide transformation products, from a widespread range of chemicals, were also documented in the past which are entering into our environment every year (Hernández et al. 2008).

Similarly, application of pesticide on plants, contaminate the surface and ground water by leaching down of pesticide residues from soil. A complete survey of at least 43 states in United States was reported by United State Department of Geo Sciences; in which 143 pesticides and 21 transformation products from all major pesticide classes were noticed in ground water (Waskom 1995). Approximately, 90% water samples from all rivers, stream and fish contain one or several pesticides in a study conducted in India. Additionally, 58% water of human consumption was polluted with Organo-Chlorine insecticides above the Environmental Protection Agency values (Kole et al. 2001). If ground water is polluted with toxic chemicals once, naturally it may take several years for purification from these toxic chemicals. In most of the cases, cleanup is very costly with complex processes, if not impossible (Waskom 1995).

The use of pesticides is increasing day by day. For example, during 1990–2006, the total area treated with pesticides and herbicides increased by 30 and 38% in the United Kingdom (Fera 2009). The excessive use of pesticides may induce different health problems to human after they are exposed to these toxins at various levels. The main problem is the duration of the exposure to pesticide residues. Some people like children, pregnant women, sick or aged persons are more sensitive to the residual effect of pesticide. Now-a-days, pesticides have passed into natural food chains and tend to be bioaccumulated in the higher tropic levels (Mostafalou and Abdollahi 2013). So, there is utmost need for scientists to make strategies to reduce the pesticide residue exposure to save the environment and living beings.

## 8.2 Soil and Water Contaminations by Pesticide Residues

Agro-ecosystem is being contaminated directly or indirectly through plenteous use of pesticides. In addition to reducing the harmful insects, pathogen or weeds; pesticides can be lethal to a range of non-target organisms including beneficial insects, birds, fish, and non-target plants. Insecticides are generally the most acutely toxic group of pesticides, but herbicides can also exert hazards to non-target living organisms. Agricultural systems are disturbed because of pesticide residues after they enter into ecosystem through surface water, ground water and contaminate the soil (Fig. 8.2) (Wasim et al. 2009).

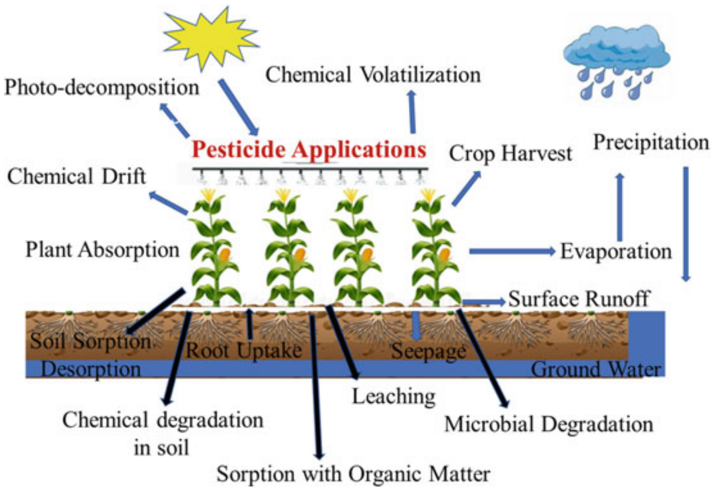


**Fig. 8.2** Pesticide application, decomposition and residues entry into ecosystem through soil, surface and ground water

Similarly, pesticides transformation products are also accumulated in the soils and may disturb the soil microbial life benefitting our crop system. The beneficial micro fauna is declining because of heavy deposits of pesticides in the agricultural soils and their surrounding areas. For example, nitrogen fixing bacteria are disturbed by the heavy applications of herbicides and insecticides into the soil. Similar effects have also been noted in case of mycorrhizal fungi (Lu and Lu 2018). Due to declined populations of beneficial microbes after long exposures of pesticides; the crop productivity might be lowered in future.

A larger fraction of pesticides amasses in the soil due to unselective and frequent use of pesticides. Afterwards, properties and microbiome of soil regulate the destiny of the applied pesticides and their residues, through many degradation processes, transformation products, and adsorption-desorption courses (Weber et al. 2004; Hussain et al. 2009). Degrading pesticides tend to change the soil textures and microorganism activities by changing its microbial biodiversity, biochemical and enzyme activities in the soil (Hussain et al. 2009) which may lead to worrying soil-ecosystem and soil fertility loss. Additionally, repeated applications of pesticides pose impact on the function of helpful root-colonizing soil microorganisms like bacteria, fungi, arbuscular mycorrhiza and algae by manipulating their growth, colonization ability and metabolic events (Tien and Chen 2012). For example, herbicides like chlorsulfuron, sulfonyl-urea, metsulfuron and thifensulfuron methyl decrease the growth of *Pseudomonas* strains in agricultural soil which is key player in soil fertility (Boldt and Jacobsen 1998). Likewise, benomyl, chlorothalonil and captan tend to lower the soil respiration process (a microbiota indicator) by 30–50% (Tien and Chen 2012). Pesticides residual masses also disturb the soil biochemical reactions i.e. nitrogen-fixation, ammonification and nitrification by manipulating certain soil microbial organisms or their enzyme activities (Hussain et al. 2009). Pesticides may influence soil mineralization and organic matter, key soil property to regulate soil productivity. For example, herbicides application including atrazine, glyphosate, primeextra, and paraquat significantly reduce the soil organic matter (Sebiomo et al. 2011). It is vital to assess the responses of soil microbes and numerous enzyme activities to pesticide depositions so their deleterious effects can be minimized.

Pesticide runoff from treated plants and soil can pollute the surface water bodies which may disturb the water life in the long run. According to United States geological survey; urban water resources are polluted with pesticides than the agricultural water bodies. Pesticide leaching from the soil surfaces is accumulated into ground water system (Kole et al. 2001). In the United States, 90% of the wells water samples were found contaminated with pesticides during a study by the US Geological Survey (Gillion et al. 2006).

Accidental spillages, waste effluents, surface run-off and shifting from pesticide applied soils, cleaning of spray machinery after spraying, leaching into water bodies and aerial sprays to kill water-dwelling pests can be ways for pesticides to get into water resources. Pesticides not only affect the fish fauna, but also disturb the food-webs afterwards. Many persistent pesticides like organochlorines and polychlorinated biphenyls were noticed in the chief Arctic Ocean food-webs. The residual effects of pesticides, on aquatic environment, are governed by their solubility in water and penetration into an organism. The hydrophilic or lipophobic nature of the pesticide residual mass makes it less available in the fatty tissues of aquatic organisms which mat later its toxicity (Pereira et al. 2013). If pesticide application remains continued it will be a prodigious threat for agro-ecosystem so, now it is right time to be aware all about this issue and find alternative and environmentally friendly strategies.

## 8.3 Pesticide Bioaccumulation and Bio-magnification in Living Systems

Pesticide chemicals can enter into living systems from the environment directly or through agricultural runoff. They pass through different trophic levels in food web from bottom (algae, oysters and fish) to top (eagle, bears and humans) level and tend to accumulate in living organisms' tissues at each trophic level because most of the chemicals have half-lives between 1 and 4 years (Mostafalou and Abdollahi 2012). At each following food chain level, pesticide residues increase in the tissues of living organisms due to their non-biodegradable nature which is known as biomagnification. This fact was described by studying many food chains and it was noted that higher trophic level possesses elevated levels of the toxins as compared to primary exposures. For example, Fig. 8.3 is depicting the biomagnification ability of Dichloro-Diphenyl-Trichloroethane (DDT) insecticide at different trophic levels (Deribe et al. 2013; Katagi and Tanaka 2016).

This phenomenon poses greater threat to higher trophic levels. The hostile effects of pesticides residues on non-target organisms like aquatic fauna and humans, occurred due to biomagnifications of these toxins. For instance, population declines

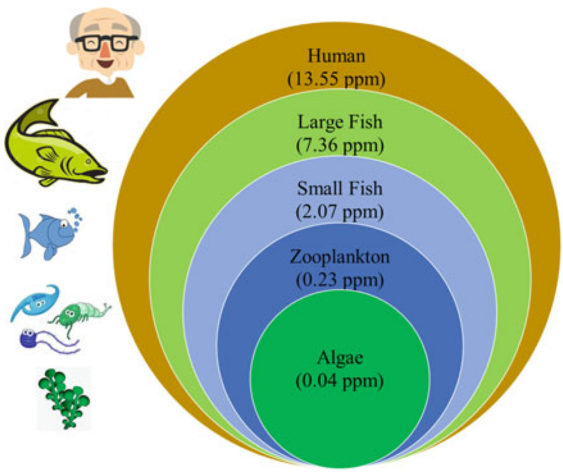


**Fig. 8.3** Biomagnification of pesticides (DDT) at different trophic levels in a food chain

and reproductive disabilities in many fish-eating birds like gulls, terns, and herons etc. were observed as a consequence of Dichloro-diphenyl-dichloroethylene induced eggshell weakening (Grasman et al. 1998). It is observed that biomagnifications increase with increasing lipophilic features and persistence of the pesticide residues in living organisms. Due to this reason, organochlorines are ranked as chemicals with higher biomagnification rates and are persistent in a broader array of living organisms as compared to organophosphates. That's why, they are banned with time (Favari et al. 2002).

Pesticides can affect living organisms, in two ways. Firstly, they become the source of sudden death of directly exposed organisms or secondly, these toxicants accumulate in the living organisms or in sediments of aquatic environments and cause death chronically afterwards. Usually the bio-degradation process of pesticides and polychlorinated biphenyls is very slow as the residues in sediments below water surface cannot degraded by UV light or microorganism activity. Fish species can be exposed to these sediments through skin or gills contact or by direct consumption (Walczak and Reichert 2016). In a study, Striped weakfish (*Cynoscion guatucupa*) was used as a biomonitoring agent of environment. Nineteen pesticides standards were used to detect the pesticides and isomers of endosulfan, chlordanes and hexachlorocyclohexane were found in fish tissues and food contents of *C. guatucupa* showing extreme bioaccumulation and biomagnification of these chemicals at different trophic levels (Lanfranchi et al. 2006). Similarly, sulfotep, demeton-O, dimethoate, disulfoton, fenitrothion and malathion pesticide residues were also detected from coconut oil at higher concentrations. It was concluded that pesticides were bioaccumulated in commercial coconut trees through the rough use of agrochemicals in the fields (dos Anjos and de Andrade 2014). As most of the pesticides are non-biodegradable in nature so, their residual effect cannot be eliminated easily. Even UV light is unable to degrade the pesticide residues in sediments.

## 8.4 Impact of Pesticide Residues on Biodiversity

Pesticides are regarded as one of main constituent of 'Green Revolution'. Mainly, the function of a pesticide is to help the users to avoid pest losses. In addition to controlling pests, the declining biodiversity in nature is obvious now. Pesticide residues are often persistent in nature, remain stable in environment and are causing a serious threat to non-target and non-pest organisms. (Venter et al. 2006). Many of these compounds are extremely toxic to exposed insects, birds, mammals, amphibians and fish. During last few decades, 70% decline in insect biomass in Germany, 50% decline in farmland birds in Europe was recorded due to pesticide applications. Removal of weed can modify the habitat type by discarding of vegetation and eventually leading to insect population reduction. Elimination of some arable weeds was caused by the usage of fungicides which allows farmers to stop 'break crops' such as grass and roots (Storkey et al. 2012). Arial spraying was a major problem prevailing in Canada related to biodiversity loss and 62% of species decline was associated directly or indirectly with pesticide usage. A study investigated that average specie loss was 10% in common bird species from 1980 to 2006 but the decline was recorded up-to 50% in common farmland bird species in 2006 in United Kingdom leaving no option for recovery and suggesting the harmful effect of pesticides in environment (Gibbs et al. 2009). On the same lines, the currently used pesticides in Europe and Australia, are major reason for 42% regional diversity losses of invertebrates in streams and rivers. Similarly, in Europe, 42% species richness was reduced due to pesticide exposures even at environmentally safe doses (Beketov et al. 2013). It is estimated that yearly 72 million birds are killed due to pesticides applications in the United States (Fimrite 2011).

Collectively, 1211 species of birds was regarded as threatened species and among these 86% are endangered due to demolition and deprivation of habitat because of discriminating usage of pesticides and other synthetic compounds (Mitra et al. 2011). Pesticides can accumulate in the tissues of prey and can cause toxic effect to top predators. Particular rodenticides are very toxic and can accumulate in the body of rodents. These can cause secondary poisoning to predators like dogs, foxes, non-target mammals and raptors by eating pesticide exposed prey (Brakes and Smith 2005). Herbicides damage the vegetation and can affect the life of common shrew, wood mouse and badger due to the shortage of food and alteration in microclimate (Hole et al. 2005).

Organochlorine belongs to the most important group of insecticide which is the most persistent and stable compound in the environment and its application causes a huge loss to biodiversity. According to a study by (Newton 1976), it was estimated that the usage of compounds such as Dichlorodiphenyltrichloroethane and dieldrin from organochlorines group of insecticides resulted a heavy loss to many bird species like fish eating birds and Peregrine Falcon *(Falco peregrinus)* in some regions of Europe and Americas. It was concluded that applications of granular formulation of carbofuran has an effectual impact on the populations of songbird exposed to insecticide when they were breeding alongside the edge of contaminated fields (Stinson et al. 1994). Carbofuran in liquid form was also reported for its lethal effects on Burrowing Owl (*Speotyto cunicularia*), a bird species with was recalled as endangered (Gervais et al. 2000). The negative impact of diazinon applied on the grasslands showed maximum mortality in the population of Brant geese (*Branta bernicla*) which used to harbour their nests at that place to lay eggs (Stinson et al. 1994).

The negative impact of pesticides on fish have been widely documented. According to a study, the insecticidal residues of Hexachlorocyclohexane and Dichlorodiphenyltrichloroethane was found in four different species of fish in freshwater in China. Residual scale of Hexachlorocyclohexane contents was found comparatively higher in grass carp and chub while that of Dichlorodiphenyltrichloroethane was examined higher in snakehead species of fish (Wu et al. 2013).

According to a research, the predator-avoidance behaviour of guppy fish (*Poecilia reticulata*) in response to the effect of pentachlorophenol in the presence of a predator largemouth bass (*Micropterous salmoides*). The findings of this study suggested that the groups of guppies treated with higher level of chemical exhibit sluggish response and could not maintain an optimal flux of speed to get escaped after the attack of predator (Brown et al. 2009).

There are approximately 6000 species of amphibians documented in literature to date world widely. One-third of this amount is endangered due to various reasons like overexploitation, introduction of predator species and habitat destruction by using pesticides. The prominent factor in this context is the water pollution caused by runoff and leaching of pesticide residues (Brühl et al. 2013). In addition to the insecticides, herbicide like diclofop-methyl and fungicide like difenoconazole also indicated toxic effects of these chemicals on albino rats. These compounds had altered the enzymatic and metabolic activities of tested rats. These chemicals possess higher potential to cause toxic effect to humans as well as environment (Abd-Alrahman et al. 2014).

Cereal yield loss was widely documented and inspected that it was affected due to one-half reduction in plants, one-third loss in insects and about one-fifth decline in bird species in the United Kingdom (Robinson 2016). Residues of Dichlorodiphenyltrichloroethane, chlordane and Hexachlorobenzene was found in blubber of franciscana dolphins in Brazil from 1994 to 2004 (Leonel et al. 2010). A study was arranged from 1992 to 2006 determining the concentration of pesticides (Dichlorodiphenyltrichloroethane, Hexachlorocyclohexane and Dieldrin) residues in blubber of bycaught female common dolphins (Law et al. 2013).

Hazardous impact of pesticides residues to non-target organisms were documented by several specialists. Yadav (2017) highlighted the risk of biodiversity to the toxicants of pesticides. In this study, it was described that the physiological activity of pesticides has a similarity between both pest and non-target species. For example, Carbofuran, Chlorpyrifos and Terbufos are very efficient and well-known pesticides to control the corn rootworm immatures present in the soil but these insecticides impose extremely lethal effects to populations of earthworms.

Aerial application of some pesticides was responsible for total extinction of arthropods in different crops such as cotton. Systemic insecticides caused secondary poisoning in predator species like *Chrysoperla carnea* which fed on pesticide exposed insects which are threatened by agrochemicals in farmland ecosystems (Mansoor et al. 2015). Similarly, lethal and sublethal effects of some insecticides were tested against a predatory bug *Orius insidiosus.* According to results of studies, it was derived that insecticides such as abamectin, cartap, imidacloprid, and flubendiamid was seemed to be safe and those pyriproxyfen and rynaxypyr were characterized as non-injurious and pymetrozine was categorized as somewhat damaging the bugs (Moscardini et al. 2013).

Pesticides exert very devastating effects to honey bees. Impact of imidacloprid, diafenthiuron and ethofenprox was observed in response to metabolic changes in larvae and adults of wild honey bees (*Apis dorsata).* Haemocytes of bees were badly affected resulted in the loss of immunity against diseases and other abnormalities such as agglutination, denucleation and cell shape distortion. It was concluded that pesticide exposure was the key factor in the destruction of immune system in honey bees (Perveen and Ahmad 2017).

The impact of neonicotinoids was observed affecting the immunocompetence of honey bees (*Apis mellifera*). Thiacloprid and imidacloprid reduced the number of haemocytes, encapsulation response, and antimicrobial activity. Clothianidin was responsible for carrying out these abnormalities at somehow large concentrations (Brandt et al. 2016). Sublethal effects of clothianidin, imidacloprid and thiamethoxam against the foraging behaviour of honey bees were also recorded. Neonicotinoids were associated with multisensory disruptors and had a damaging role counter to feeding activity of pollinators (Démares et al. 2018).

After green revolution, agrochemicals became an integral part of modern crop production technologies to fulfil the dietary demands of rapidly increasing populations but in current scenario, their toxic and deadly effects to living organisms demand restricted use of these agrochemicals. Organic farming is much important to specie richness and abundance of living organisms. Though, more quickly degradable chemicals are invented which exchange the persistent ones, but their residues are still capable of putting an organism's health at risk by contaminating food, environment and water. Increment in food production in present and future point of view, must oblige with production of good class of food and with less lethal contaminants (Carvalho 2017). Data recorded from various countries showed that due to pesticide toxic effect biodiversity is declining day by day.

## 8.5 Impact of Pesticides Residues on Pollinators and Bees

Pollinators facilitate the transfer of pollen between flowers. Almost, 90% wild plants are reliant on insect pollination (Ollerton 2017). One third of global food production is materialized due to insect pollinators, mainly because of bees which have more than 20,000 species worldwide. Honey bees add about US $200 billion to the world economy each year through crop pollination (Eilers et al. 2011).

In 2016, the United Nations warned that 40% of invertebrate pollinator, particularly bees and butterflies, are at risk to global extermination. During past few years, decline of bee species and downfall of honeybee colonies, due to continuous pesticides applications to agricultural crops, have worried the apiculturists and ecologists About, 25–30% honey bee population decline in American and European countries is due to extreme use of pesticides. More than half of native bee species are in endangered in North American regions (Sanchez-Bayo and Goka 2014).

These beneficial insects are exaggerated by sub-lethal effects of pesticides which are often ignored. Due to repeated and long-term exposure to pesticides, physiology, neurobiology, behavior and other mechanisms of survival of pollinator insects can be changed. Pesticides residues may be carried back to hive and fed to the young ones thus imposing an extra risk and pressure to bee populations which are on continuous decline in agricultural lands (Connolly 2013).

Toxicity of pesticides may vary to honey bees. Most of the miticides, fungicides and herbicides are nontoxic to the honey bee. The biological insecticide *Bacillus* *thuringenesis* shows very low toxicity to bees. Different formulations of the same pesticides vary significantly in their toxicity to bees. Dust formulations are more dangerous for bees than others because they can stick to their hairs. However, granular formulations are less dangerous to bees. Residual characteristic of a pesticide is an important factor in defining its safety for pollinators. An insecticide which has low residual activity and degrades within few hours can be applied with less risk when bees are not foraging actively on plants (Sponsler et al. 2019).

Bee killing, due to pesticide use, have been known since the late nineteenth century but the discovery huge declines in wild and managed pollinators indicated reduction in crop productivity and honey yields (Berenbaum 2016). The pyrethroid insecticides can kill more bees when used in combination with fungicides and their toxicity is increased by 10 to 100 times. In Europe, almost 9% bee and butterfly species are endangered to be lost due to pesticides. A decline of 37% of bee species and 31% of butterfly species is reported in European regions. Similarly, beekeepers in the United States also testified 50% hive losses yearly with some grief losses up-to 100%. Since 2006, about 10 million bee hives have been reported to be lost, with a value of about $200 per hive. These sufferings are magnified due to neonicotinoids application at large scale (Whitehorn et al. 2012).

Unfortunately, mix of pesticides is a common practice among the farmers to save time and labour. Many pesticides like pyrethroids, imidacloprid and clothianidin produce a great reduction in foraging and navigation abilities of bees and other pollinators (Schneider et al. 2012; Feltham et al. 2014). In addition to behavioral degradation, colony collapse disorder in honeybees is also reported frequently, worldwide. Several studies narrated that the declining of bee colonies is a consequence of exposure to pesticides or their residues in cropping areas.

Organophosphate, Pyrethroid and systemic neonicotinoid insecticides like thiamethoxam and imidacloprid are mainly responsible for bee declining in exposed areas due to reduced colony initiation, lowered colony growth, and lesser reproductive outcome after exposure to certain pesticides (Fig. 8.4). Imidacloprid trace dietary residues through nectar have no lethal effects, however, can cause 6–20% reduction in the expected performance of honey bees. Overall, up-to 50% colony collapse disorders are occurring due to pesticide applications (Baron et al. 2017). Many neonicotinoids were present in plant nectar and pollen of insecticide treated crop area and nearby wild flowers also and therefore, taken into bee colony food-storage which pose serious danger to the immatures (Alaux et al. 2010).

In addition to bee damages, pesticide residues have also been reported in honey and bee-wax samples around the globe which is threatening for the end consumers (Noori et al. 2012). Eventually, agricultural production and source of revenue of small farmers will be greatly affected due to loss of beneficial insects like pollinators and specially honey bees. This challenge can be overcome by formulating the strict rules and regulations for pesticides use (Connolly 2013). Due to repeatitive application of pesticides, the physiology and other mechanisms of pollinaters become modified or altered. So, it is need of an hour to protect the pollinaters and other lives either by limiting the use of pesticides or by making strict rules and regulations about its application.

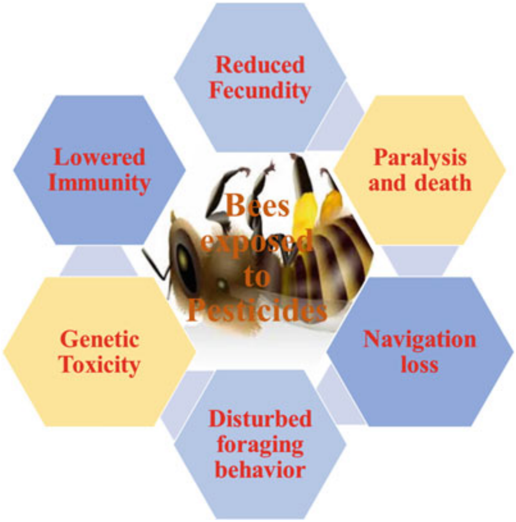


**Fig. 8.4** Effect of pesticide exposures on honeybees and their life activities

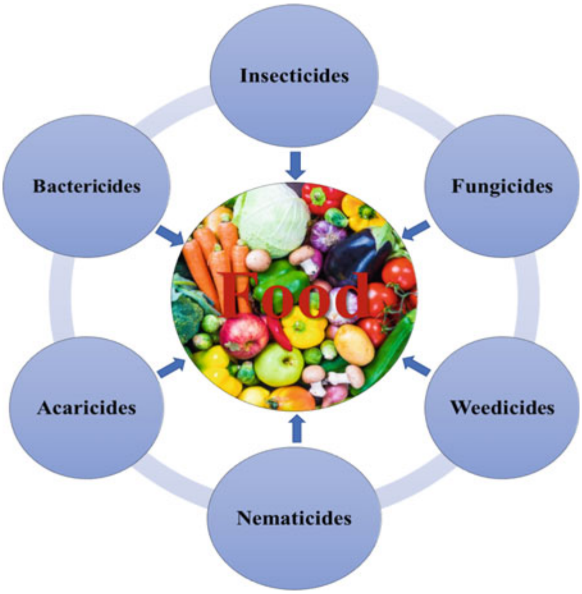


**Fig. 8.5** Application various kinds of pesticides for food production leading to residual accumulation in food

## 8.6 Pesticides Residues and Food Chain Contamination

Pesticide contamination is a worldwide food safety issue. The magnitude and effect of pesticide exposures through food is of great concern for food consumers. Environmental contaminants like pesticides possess potential to be accumulated in both terrestrial and aquatic food chains (Fig. 8.5).

Many studies have reported pesticide buildups in soils, terrestrial and aquatic frameworks, and their lethal consequences on human and non-human biota. Innovations are utilized first and their undesired impacts appear later on. Pesticides are one of the best examples in this case (Clarkson 1995). Synthetic pesticides chemicals were presented to improve crop yields by shielding crops from pests. Because of crop yield security new pesticides products are utilized for higher crop production. The Pesticide utilization remains a typical practice particularly in Tropical and South nations (Carvalho 2017).

As the persistent synthetic chemicals have been eliminated and limited by progressively biodegradable synthetic compounds, contamination by pesticide deposits and late buildups still affect the natural human nourishment, for example, dichlorodiphenyltrichloroethane, hexachlorocyclohexane and lindane, are long-lasting chemicals. Now a days, these pesticides are prohibited for farming use in most nations. As an outcome, residues of these synthetic compounds cause contamination to the environment by scattering in the ecosystem (Reeves et al. 2019). Agriculture needs to additionally create better practices to secure general well-being, which requires progressively safe utilization of pesticides through earlier testing, cautious hazards, and additionally through training of farmers and clients, measures for better insurance of biological systems, and great practices for the reasonable improvement of agribusiness, fisheries, and aquaculture (Green et al. 2016).

Pesticide chemicals enter into the natural food chains, and lastly are ingested by people consuming such food and water. Due to pesticide resistance development, pesticide companies persistently develop new synthetic compounds. In the European Union, there are more than 800 synthetics are enlisted as pesticides. We know slightly about the ecological effects of these synthetic compounds and their negative impacts on living organisms (Köhler and Triebskorn 2013). As they are toxic and deliberately mixed in the environment, their production, distribution, and use necessitate purposeful and regular monitoring of their residues in food. The acceptable daily intakes are being established and used by governments and international risk managers, to set maximum residue limits for pesticides in food items to facilitate safer food (FAO 2010).

Numerous instances of pesticide intoxication in farmers, workers, and their families occurred during pesticide application. Pesticides application in agriculture is derived with the assistance of a few systems, from the manual services by laborers by walking to truck-and plane-based application methods. It is assumed that accidental pesticide poisoning kills an estimated 0.35 million people every year, globally. Such, poisonings are strongly related to unnecessary exposures and inappropriate use of toxic chemicals (Carvalho 2017). Dispersion of pesticide residues in the environment and large killings of human and non-human biotas, such as amphibians, bees, birds, fish and minor mammals were reported in the literature (Köhler and Triebskorn 2013).

Throughout the years, extensive research was conducted, additionally, to know the behavior of these synthetic compounds in nature to understand their decomposing cycles and fate with respect to their lethality to biota. The dichlorodiphenyltrichloroethane used to save crops was regularly noticed to be transported to the water bodies where it is quickly processed to dichlorodiphenyldichloroethylene and tend to be bio-accumulated in the oceanic food-chains and returned to end consumers in the long run (Carvalho 2006).

The organochlorine pesticides, long before were revealed as steady products, stay longer times in soils and silt, accumulating in non-human creatures with devastating impacts at the population level. Ultimately, they move in food chains with adverse effects on human health (Carvalho 2006; Köhler and Triebskorn 2013). Organochlorine synthetic compounds were queried and replaced by less persistent synthetic substances, like organophosphate, carbamate and pyrethroids based on research with respect to their degradation rates in soil and aquatic situations (Carvalho 2006). For instance, toxaphene is not used in cotton fields anymore in Nicaragua but years after end of its applications, the deposits in agricultural soils is still a contaminant source transported to marine environment with a huge danger to food farming in coastal areas (Carvalho 2006).

Soils are serving as the fundamental source of constant organochlorines. Soil erosion, surface runoff, and river bodies convey a large number of detrimental organochlorines to the ecosystem and contaminating natural food chains. Pesticide residues, conveyed to the ocean, pose higher risks to enormous marine biological systems, for example, coral reefs and other biota in the deep sea (Jamieson et al. 2017). Poisonous remains of pesticides in water systems may eradicate marine species, decrease biodiversity, and disturb the natural ecosystem functioning. Massive research in aquatic toxicology helped to comprehend pesticide bioaccumulation mechanisms to set toxicity levels for certain representative species (crustacean, fish, plants) and intricate strategies to control pesticide pollution under tolerated limits (Carvalho 2017).

The pesticides residues in food, on ingestion interact with the human gastrointestinal microbiota consisting of certain bacteria, fungi, viruses and protozoa. These pesticide residues cause disruption in the composition of microbiome, which could have lethal effects on intestinal homeostasis and overall systemic immunity (FAO 2010). The consumption and ingesting contaminated food weaken the human immunity. So, the food at MRL (maximum residual level) should be consumed that will be tolerant by the human body.

## 8.7 Pesticide Resdues and Health Concerns

Exposure to agrochemicals is posing serious concerns to human health. The dermal exposures account for almost 90% of the pesticide exposures (Ross et al. 2001). Toxicities by pesticide exposure are expressed in a variety of ways, ranging from mild symptoms, like slight skin irritation or allergic indications to severe symptoms, like strong headache, dizziness, or nausea. Longer exposures can cause chronic abnormalities in human ranging from cancer to other serious diseases (Fig. 8.6). The most important ailments raised by pesticide exposures are discussed here in this section.

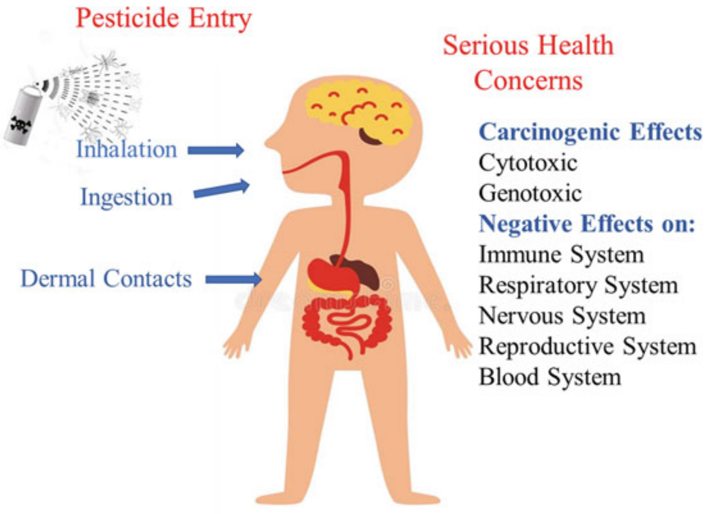


**Fig. 8.6** Exposure routs and effects of pesticide exposure on human health

### *8.7.1 Carcinogenic Effects of Pesticide Residues*

Many kinds of cancer have been produced in human due to pesticide residues exposures. Even, if a pregnant woman is exposed to the pesticide residues then there is a possibility that her child may be sensitive towards the brain cancer, leukemia, and Wilms' tumor. Pesticides exposures from outside is mainly related to the causes of blood cancer in children (Srivastava and Kesavachandran 2019). In 2010, a review found that 19 out of 32 pesticides were linked with at-least one type of cancer, including brain, bladder, colon and rectal, leukaemia, lung, melanoma, multiple myeloma, non-hodgkin lymphoma, and pancreatic cancer (Weichenthal et al. 2010).

Carcinogenic effects are still underdiscussing and there is an urgent need of research to explore the association of organochlorines and cancer, but the danger cannot be underestimated (Calle et al. 2002; Witczak and Abdel-Gawad 2014). It was documented that glyphosate was determined in endocrine disruptor (Thongprakaisang et al. 2013). Data was analyzed from ten different Districts of Spain to investigate the association of pesticide with cancer from occupational and non-occupational papulations. It was observed that cancer rated were maximum in areas belonging to intensive usage of agrochemicals compared to those of minimized consumption of such carcinogenic compounds. The study strengthened and supported the evidences of involvement of pesticides to threat of cancer (Parrón et al. 2014). Organochlorine residues, in blood stream from adipose tissues, might be mixed up with breast milk and injurious to infants (Mrema et al. 2013).

Several case-control studies analyzed rates of cancer among youngsters exposed to pesticides and inflated rates of all kinds of cancer were found higher in folks exposed to pesticides within the garden and on indoor plants and whose mothers had been exposed during pregnanancy. An outstanding study exhibited that inflated rates of childhood cancer are linked with exposure to pesticides (Srivastava and Kesavachandran 2019). In USA, a study expressed 19 and 28% excess prostate cancer risk among the farmers and commercial pesticide applicators (Koutros et al. 2010). Certain studies, from Canada, Europe and the United States, investigating the association between toxic chemical exposure and brain cancer also disclosed inflated cancer risks among the folks exposed to pesticides. Almost all organochlorines are lipophilic in nature and their bioaccumulation is very high remaining in the adipose tissues for decades (Mrema et al. 2013).

Six studies investigated the links between chemical exposure and carcinoma. Most of these, supported the supposed association. A study of feminine greenhouse employees in Kriti found that exposure to pesticides for quite 4 h daily for a minimum of 10 years inflated the chance of benign breast unwellness (Calle et al. 2002). In the same line, several studies evaluated the connection between chemical exposure and urinary organ cancer, and they found positive associations. The link was found not solely in directly exposed populations, however conjointly in youngsters of exposed folks, and was most consistent once folks had prolonged exposure (Xie et al. 2016). The relation between abdomen cancer and nitrates and some weed killer chemicals indicated that the rate of abdomen cancer was found increased in areas with high levels of weed killer contamination within the water (Sabarwal et al. 2018).

Four studies examined the association between carcinoma and chemical exposure. Results of those studies are somewhat tough to interpret as solely two collected data relating to smoking standing. In the end, pesticide associated elevated risk of carcinoma among girls exposed to pesticides at work was found (Parrón et al. 2014). Few studies were found on chemical exposure and gonad cancer. Gonad cancers are considered as a health impact of interest and evaluated its association with exposure to certain pesticides was found (Alavanja et al. 2004). During the evaluation of the connection between carcinoma and chemical exposure of pesticide residues, and it was found positive associations between pesticides exposures and this sort of cancer (Bassil et al. 2007).

### *8.7.2 Neurological Effects of Pesticide Residues*

Experimental evidences link the hazardous exposure to higher neurologic outcomes. The residual effects of pesticide may result in each general and typical symptom. Direct exposure, as an example, will cause typical indications like contraction of the pupils, fuzzy vision, a supercilium headache, reddening and irritation in the eyes. Symptoms of general poisoning are entirely because of the buildup of neurotransmitter at the nerve ending. Under advanced poisoning, the target is pale with higher sweating, and frothing from the mouth. Alternative symptoms embrace changes in vital signs like muscle weakness, convulsions, disarray with or without coma. The victim might be dead if treatment is not given timely. In-vitro and animal-based studies showed that nanomolar concentrations of organochlorines such as endusulfan and lindane were involved in the blockage of calcium channels resulting in the deficiency of calcium ions in pheochromocytoma cells leading to mental disruptions (Heusinkveld et al. 2010).

Yokoyama (2007) highlighted Tokyo subway sarin poisoning cases along with the pesticide users (tobacco farmers) in association with Green Tobacco Sickness in Malaysia. It was determined that after 6–8 months exposure to pesticides leads to neurobehavioral and neurophysiological abnormalities. Additionally, organophosphates and dithiocarbamate disrupt peripheral nerve conduction and some related disorders (Yokoyama 2007). Similarly, mental health of Brazilian public was assessed through a questionnaire and clinched that pesticides were found in blood cholinesterase and found associated with mental disorders in all participated individuals (Buralli et al. 2019). In Mexico, farmers exposed to pesticides showed 25% elevation in depression and depression–anxiety while 24% inhibited enzymatic activity with generalized anxiety (Serrano-Medina et al. 2019).

### *8.7.3 Endocrine Disruptions and Pesticide Residues*

Endocrine hormones play an imperative role in different body functioning particularly in growth and reproductive function. There were significant evidences of involving of Dichlorodiphenyltrichloroethane and its isomers like Dichlorodiphenyldichloroethylene in disruption of endocrine glands (Turusov et al. 2002). In general, about all classes of organochlorines were found to be associated with abnormal functioning of endocrine with very small concentration of residual contents (Lemaire et al. 2004). Organophosphates like malathion and parathion were also found active in disrupting and malfunctioning of endocrine glands (Gasnier et al. 2009).

Risk association between specific pesticide and incident polygenic disorder ranged from 20 to 200%. Risks were larger once users of specific pesticides were compared with applicators of United Nations agency who had never applied that chemical. Synthetic pesticides can also extinguish cell structure and cell functioning. Previous studies highlighted that at micromolar level of organochlorines like dieldrin, cell propagation and cell capability was declined up to a considerable extent (Slotkin and Seidler 2007). Another investigation revealed that heptachlor and dieldrin are the causal agents of raising advance apoptosis in cell cultures producing mitochondrial damage and oxidative stress (Culbreth et al. 2012).

### 8.7.4 Effect of Pesticide Residues on Reproduction and Fertility

Pesticide chemical exposures are also linked to birth imperfections, craniate death and changed fetal growth. Figure 8.7 is explaining the mode of action and effects of pesticide exposure on reproductive system on human (Bretveld et al. 2006). A weed killer, a 50:50 mixtures of 2,4,5-Trichlorophenoxyacetic Acid and 2,4-Dichlorophenoxyacetic Acid has been related to dangerous health and hereditary effects in Malaya and Vietnam. Additionally, it was found that descendants who were exposed to pesticides had birth weight and biological process defects (Srivastava and Kesavachandran 2019). A number of pesticides and a couple of 4-D compounds have been reported for impaired male fertility. Toxic chemical exposures resulted in decreased male fertility, genetic variations and reduced variety in spermatozoon, injuries to the germinal animal tissues and disturbed endocrine performance (Srivastava and Kesavachandran 2019). Sabarwal et al. (2018) emphasized that the long-term exposure of pesticides are accountable as causal agents of Parkinson's and Alzheimer's diseases in addition to various other reproductive and respiratory disorders.

### 8.7.5 Pesticides Residues and Child Health

Children are very prone and susceptible of being affected by neurotoxins of pesticides and exposure rates were very high. Scientists suggest that rapidly developing

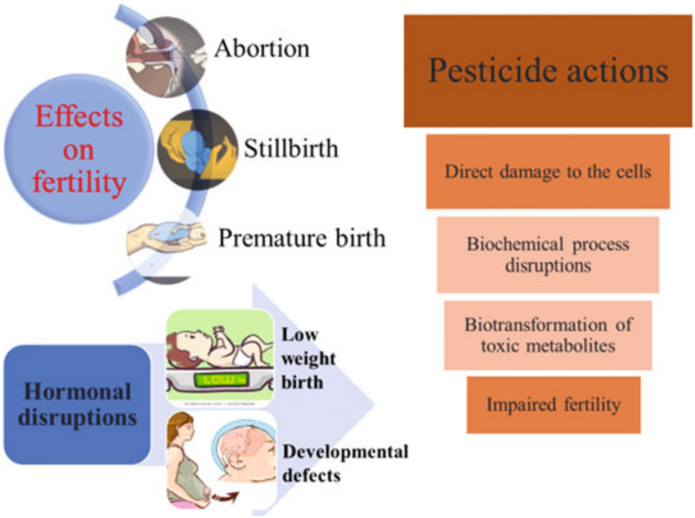


**Fig. 8.7** Pesticide actions and their effects on reproductive function of human

brain tissues and cells become most vulnerable. Nevertheless, the results of pesticides were seen not as much linked with pre and postnatal exposure about neurophysiological effects. It was concluded from a study that parental exposure of pesticides resulted in deprived mental performance level and this factor was observed more in boys than in girls. It was also suggested that postnatal impact of pesticides can adversely affect child's neuropsychological behavior and parental exposure was less associated with neurodevelopmental damages (González-Alzaga et al. 2015). In 2011, a meta-analysis of 40 studies concluded that maternal pesticide exposures before birth is positively associated with 48% elevated risk of leukaemia and 53% increased risk of lymphoma in childhood. While, paternal exposures before or after the birth is linked with 50–65% higher risk of brain cancer in children (Vinson et al. 2011). Such findings are discussed in many other studies also.

### *8.7.6 General Health Aspects and Pesticide Residues*

It is growing belief that carcinogenic activity of pesticides is the main matter of concern with public health. In addition to cancer, 4 non-cancer attributes such as dermatologic, neurologic, reproductive, and genotoxic effects and their relationships with pesticides were investigated by Sanborn et al. (2007). They concluded the positive linkage between 4 above mentioned non-cancer human health issues with pesticides. A comparative study was established to observe the effects of synthetic pesticides in contrast to naturally occurring plant chemicals. The study demonstrated that the toxicological effects of both synthetic and naturally occurring chemicals was equally harmful in context to human cancer risks. It was also observed that with the application of low doses the exposure rate of pesticides residues was insignificant (Ames et al. 1990). The key signs of pesticides boozing can be distinguished into syndromes like muscarinic syndrome; in which acetylcholine the exploitation, heart disturbances and exocrine glands with raised bronchial secretions, sweating and tearing disrupt the gastrointestinal tone. The conditions may cause diarrhea, nausea, vomiting, bronchospasm, bradycardia and elicits urinary incontinence. Some studies have reported accrued risks of eczema in the individuals exposed to pesticides (Paudyal 2008).

As health is the most important thing to survive so, compromise in health can not be afforded. Protective measures can help farm workers to avoid get exposed from agrochemicals. Some preventive measures are such as goggles, mask, gloves, shielding clothes and boots may reduce the chances of exposure. It was also reported that lack of knowledge and skills about the application is the main source of indiscriminating usage of agrochemicals and becoming the possible health hazard foundations. The application of agrochemicals must be at suggested rate and use of bio-pesticides instead of synthetic pesticides can lessen the public health issues related to exposure of these agrochemicals (Elahi et al. 2019). For this purpose, improved monitering programmes should be planed, prefer application of bio-pesticides rather than synthetic chemical pesticides, use of resistant varieties and other alternative and preventive measures should be promoted.

## 8.8 Conclusion

Though, pesticide chemiclas were initiated to rescue human-life by increasing agricultural productions and regualting harmful insects, weeds and diseases but their hostile properties have created great concerns about paybacks related to their uses. Above mentioned facts clearly highlights the negative costs of undiscriminating use of pesticides. Some side-effects are appeared as increased resistance in pest populations, reduced beneficial organisms for example pollinators, endangered soil microbial diversity, water and air contamination in natural ecosystem. The persistency of pesticides has affected our ecosystem to a greater extent and now pesticides have gone into countless food-chains. They are biomagnified into the higher food trophic levels including humans and other mammals. Many human illnesses, acute and chronic, have now become a big health concern because of pesticides contaminated living resources.

Now, it is need of hour, we should focus on the proper and safer pesticide applications to shield our environmental resources and prevent health hazards. Alternate pest management approaches like integrated pest management, a combination of various controling tools such as, growing resistant genotype, cultural, physical and mechanical pest control, must be deployed with rational pesticide use to decrease the frequency and pesticide applications with least amounts. Moreover, progressive cropping approaches including bio and nano-echnology can also simplify the ways for developing pest resistant crop genotypes. Pesticides with low side-effects must be explored and replaced the existing pesticdes with higher health and environmental risks. Community awareness extension programs can be utilized and promoted to teach and encourage the farmers to implement the advanced and innovative integrated pest management approaches as key tool to decrease the harmful effects of pesticides to our agro-ecosystem and natural environment.

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