Effect of pesticides on crop, soil microbial flora and determination of pesticide residue in agricultural produce: A Review

ABSTRACT

The review is carried out to represent the effect of pesticide exposure to plant on growth and metabolism. Decades ago, pesticides were introduced aiming to increase the crop yields and protecting crops from pests. Pesticides are highly toxic chemicals and toxicity does not remain restricted to the target organisms only but also affect non-target organisms in the environment. Pesticide reduces the growth, rate of photosynthesis, yield, inhibit seed germination and enzymatic activity. Excessive use of pesticide results in pesticide residue in fruit, vegetable seeds and in soil. Accumulation of pesticide in soil disturbs the microorganisms, soil enzymes such as hydrolases, oxidoreductases, dehydrogenase and phosphatase activities, physicochemical parameters in the soil and in turn affect the soil fertility. Therefore, the thrust of this paper was to review the application of pesticides effect early from germination to growth of the plant, leading to alteration in biochemical, physiological and different enzymatic and non-enzymatic antioxidants which ultimately affect the yield and result in residues in plant, vegetables and fruits.

Key words: *Pesticide, micro-organism, soil enzymes, yield and pesticide residue.*

INTRODUCTION

In agriculture, application of pesticide has become a common trend all over the world and this practice is increasing with the growing population. The use of pesticide is as old as human civilization., dates back 2500 BC when Sumerians rubbed repellent sulfur compounds on their bodies to control insects and mites. Pesticides were introduced in agriculture to meet the demand of growing global population. India is now the second largest manufacturer of pesticides in Asia after China and ranks twelfth globally for the production. The Indian states of Haryana, Punjab and Uttar Pradesh have the largest pesticide consumption, using 45000 tons of (technical grade) pesticides in 2000-2001. About 4.6 million tons of chemical pesticides with about 500 different types are annually used across the world (Zhang et al., 2011). About 85 % of the total pesticides used in the world are applied on agricultural crops while the remaining 15 % are used for other purposes (CEPIS/PAHO, 2005). Pesticides are among the most widely used chemicals to control weeds, insects, fungi and other unwanted pests potentially damaging high crop yield levels and quality (Siddiqui and Ahmed, 2006). Among pesticides, herbicides account for 42%, insecticides 27%, fungicides 22% and disinfectants and other agrochemicals 9% of global pesticide sales. In India 76% of the pesticide used is insecticide, use of herbicide and fungicide is comparatively less common. Farmers are not aware of pesticide poisoning and use pesticides unwisely in higher concentration than the recommended dose (Asogwa and Dongo, 2009). The controlled use of pesticides does not affect the environment but indiscriminate and unskillful use of pesticides affects the growth of plant and animal, accumulates residue in fruits and vegetables, increases pest resistant to pesticides, causes biodiversity losses and declines natural habitats (Baig et al., 2012). Pesticides are highly toxic and toxicity does not remain restricted to the target organisms only but can also affect non-target organisms in the environment (Rachid et al., 2008). Pesticide affects non target organism by reducing the growth, rate of photosynthesis, yield, inhibiting seed germination and enzymatic activity. Accumulation of pesticide have an impact on soil microbial populations also which play important role in degradation of plant and animal residue (Zhang et al., 1984) that may lead to stimulation, decrease, or modification of soil biological and other processes essential for soil fertility, health, productivity, and crop yield (Tanskj et al., 1985). It is estimated that a very small part (<0.1%) of total amount of applied pesticides reach to the sites of action (Pimental, 1995), with the larger proportion being lost via spray drift, off-target deposition, runoff, photodegradation, and so on. A large part of the pesticides applied to crops are either taken up by the plants and animals or are degraded by microbial or chemical pathways. Many pesticides are not easily degradable, they persist in soil, leach to groundwater, surface water and contaminate wide environment. Degradation of the pesticide depends upon the type of the soil, soil property, moisture content of the soil and pH (Li X et al., 2008, Xu G et al., 2008). Degradation of pesticide occurs by mainly two processes one is phytoremediation and other is bioremediation. Biodegradation of organic pollutants is a natural process whereby, bacteria and other organisms breakdown organic molecules into simple substances, eventually producing carbon dioxide and water or methane. The ultimate aim of the biodegradation is to degrade the organic contaminants completely into harmless constituents such as the carbon dioxide and water. Phytoremediation is a process to clean up contaminants by making use of plants. Certain pesticides, which are more resistant to degradation by abiotic (physical, chemical and other factors) and biotic (living organisms i.e. the micro-, meso- and macroorganisms of the soil food web) agencies, leach into the lower strata of the soil, are absorbed by plant roots, accumulate in the food chain and are ultimately biomagnified in the food web.

Types of pesticides

Organophosphate pesticides: Organophosphate are the compounds which works by inhibiting an enzyme, acetyl cholinesterase at cholinergic junctions of the nervous system. Organophosphate are highly toxic to insects as compare to humans and domestic animals Examples of organophosphates include the following

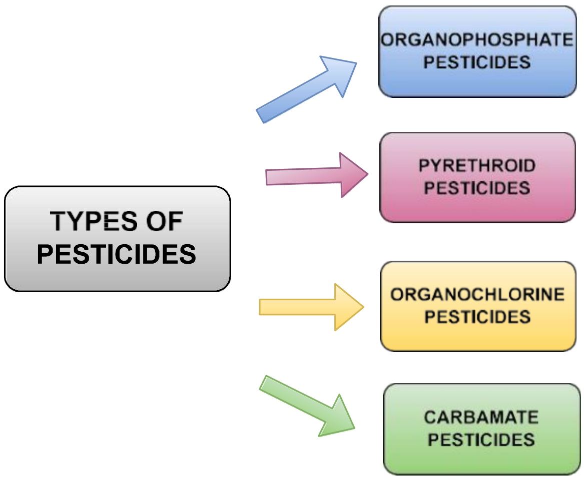

Image 1: Types of pesticides

Insecticides: Malathion, parathion, diazinon, fenthion, dichlorvos, chlorpyrifos, ethion, coumaphos.

Organochlorine insecticides: Organochlorine compounds are chlorinated hydrocarbons. It includes pesticides like DDT, chlordane, aldrin, dieldrin, heptachlor etc. compounds. Organochlorine insecticide are a group of pesticides that are not easily degradable so most of them have been banned but few are still registered for use.

Carbamate pesticides: Carbamate insecticides are derivative of carbamic acids and the first carbamate insecticide was carbazyl (Thacker, 2002). They inhibit acetyl cholinesterase enzyme and cause over stimulation of nervous system. Several subcategories within the carbamates are Aldicarb, carbofuran, carbaryl, carbosulfan etc. Carbamate and OP insecticides are often used in combination to achieve synergistic interaction and controlling a wide range of insects, including those that are resistant.

Pyrethroid pesticides: Pyrethroids are synthetic derivates of pyrethrins, which are natural organic insecticides produced from the flowers of Chrysanthemum flowers. Some of the commonly used pyrethroid are Deltamethrin, cypermethrin, permethrin.

TREND IN PESTICIDE PRODUCTION AND CONSUMPTION IN INDIA AND ASIAN COUNTRIES

With an annual production of 90,000 tonnes, India is one of the leading producers of pesticides in Asia and holds the 12th position globally in terms of pesticide production, having begun producing them in 1952 (Khan et al.,2010). The Standing Committee on Chemicals and Fertilizers of India (2013) estimates that 68490 tonnes of pesticides were produced in India during 2011 and 2012. Pesticides are produced in the country on an annual basis in amounts of roughly '8000 crore, of which '6000 crore worth of pesticides are used domestically and the remainder is exported. According to the government, the amount of technical grade chemical pesticides consumed has decreased from 72,130 tonnes in 1991-1992 to 56,090 tonnes in 2012-2013. This extensive fluctuation over time could be due to weather parameters and availability in the market.

The pesticides usage in Pakistan started in 1954 year, and the pesticides production in Pakistan increased to 78,132 tonnes per annum in 2003 (Khan et al.,2010). In Sri Lanka, the DDT was the first pesticide used after World War II for malaria eradication.

Pesticides were introduced in Thailand and Vietnam around the middle of the 1950s. Pesticide use in Vietnam increased in the middle of the 1980s with the country's economic liberalisation (Table1).

Table 1. Annual pesticide consumption in different Asian Countries.

S.no	country	pesticide used (tonnes)
1	China	1807000
2	India	56120
3	Malaysia	49199
4	Pakistan	27885
5	Thailand	21800
6	Vietnam	19154
7	South Korea	19788
8	Bangladesh	15833
9	Myanmar	5583
10	Nepal	454
11	Bhutan	12

Source: FAO, 2017

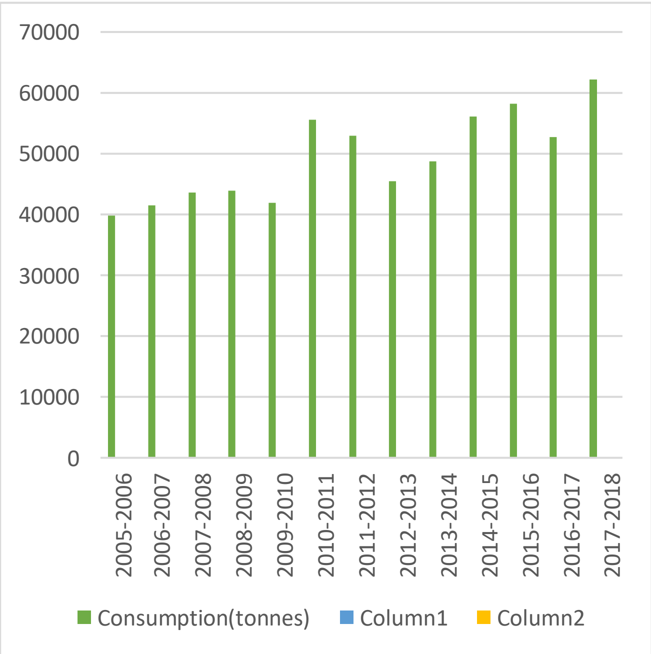

Figure 1. Trend in consumption of pesticides in India: 2005-2006 to 2017-18

State-level consumption of chemical pesticides in India in 2012-13, Uttar Pradesh, Maharashtra, Andhra Pradesh, Punjab, and Haryana account for 70% of the nation's overall pesticide usage. Each twelve states utilise more than 1000 tonnes. The largest user, with 9035 tonnes, is Uttar Pradesh. Pesticide use is relatively low in Sikkim, Mizoram, Goa, Meghalaya, Nagaland, Manipur, and Arunachal Pradesh (less than100 tonnes each). The remaining states (Madhya Pradesh, Chattisgarh, Jharkhand, Bihar, Uttarakhand, Himachal Pradesh, Assam, Odisha, and Kerala can be categorised as medium users, where the consumption of pesticides ranges from 100 to 1000 tonnes (fig.1)

Effect of pesticides on plants

The ultimate aim of pesticide is to kill or control the growth of target organism by various mechanism such as inhibition of photosynthesis, cell division, enzyme function, root and shoot growth, leaf formation; interference with the synthesis of pigments, proteins or DNA; destruction of cell membranes; or the promotion of uncontrolled growth (William et al., 1995). Plants responses differently to the stress induced by different pesticides. Pesticide application can affect early from germination to growth of the plant, causing changes in various enzymatic and non-enzymatic, physiological and biochemical processes and excessive dose of pesticide leads residues in plant, vegetables, fruits and other non-target organism.

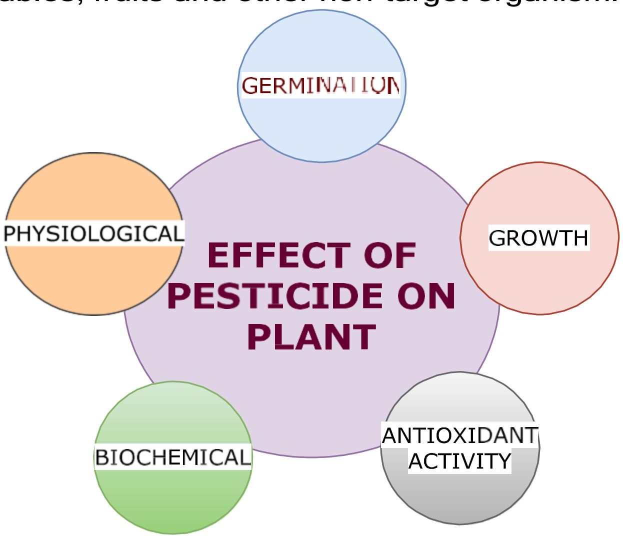

Image 2: Effect of pesticide on plant

A.) Germination

Several workers have studied the adverse effects of pesticides on seed germination. When seeds were treated with insecticides such as Emamectin benzoate, Imidacloprid, Alpha-cypermethrin, Lambda-cyhalothrin, a stimulatory effect at low concentration was observed in *Lycopersicon esculentum*, tomato (Shakir et al., 2015). Similarly grain of *Triticum aestivum* (wheat) showed improved germination when soaked in thiamthoxam, difenoconazole and metalaxyl at concentration 325ml/100kg seed (Larsen and falk, 2013). Some insecticides were found to effect negatively as in *Cenchrus setigerus*, *Pennisetumn pedicellatum*., when seeds were treated with chlorpyrifos, cypermethrin, fenvalerate, a significant reduction in seed germination at concentration 0-100 mg/Kg was found (Dubey and Fulekar, 2011).

B.) Growth

Pesticide effect on growth vary according to different concentration and generally stimulate the growth at low concentration and inhibit at high concentration. Dhanamanjuri et al. (2013) reported increase in radical and plumule growth when seeds of *Cicer arietinum* were treated with a fungicide Carbendazim (bevistin) at 10ppm and seeds of *Zea mays* were treated at 1ppm. Likewise, A study was carried out by Hassan et al. 2018 in which grain of *Triticum aestivum* (ARRI-2011, Millat-2011) were treated with insecticide (Imidacloprid, Thiamethoxam) and fungicide (Tebuconazole) alone as well as in combination and found significant increase in root and shoot length of both varieties treated with Imidacloprid+ Tebuconazole and Thiamethoxam + Tebuconazole compared to seeds treated with Imidacloprid and Thiamethoxam alone.

C.) Antioxidant activity

It has been observed in many studies that accumulation of pesticides produces Reactive oxygen species (ROS) such as superoxide anion O^{2-} and damage the membrane lipids but also stimulates the production of antioxidant enzymes, including superoxide dismutase, catalase, peroxidase, ascorbate peroxidase, glutathione reductase and glutathione S-transferase. When Tomato (*Lycopersicon esculentum*) was exposed to insecticides Emamectin benzoate, Imidacloprid and alpha cypermethrin by foliar spray, higher concentrations significantly increased ROS levels, caused membrane damage and reduced cell viability both in root and shoot tissues. To cope with oxidative stress shoot tissues produced more antioxidants as compared to root tissues (Shakir et al., 2018). This effect was also observed by application of herbicides as simetryne in *Triticum aestivum* caused accumulation of ROS and leads to membrane damage but also stimulated the production of antioxidant enzymes.

D.) Biochemical and physiological changes

The herbicide pendimethlin treated seeds at concentration 0-10 ppm resulted in high content of seed reserves as total protein, carbohydrate, starch and reducing sugar in the endosperms of *Zea mays* (Rajashekhar et al., 2012). In a similar study (Parween et al., 2011a) seeds of *Vigna radiata* were treated with insecticide chlorpyrifos at concentrations 0-1.5mM and found that 0.6 and 1.5 mM showed more toxic effect by decreasing nitrate, NR activity, soluble sugar, and protein content whereas at low concentration (0.3 mM) chlorpyrifos act as stimulant for same parameters. Many pesticides have been found to inhibit the physiological processes such as photosynthesis, chlorophyll and carotenoid content.

Table 2. Study of effect of pesticide on germination, growth and various physiological parameters of plants.

Chemical used	Pesticide type	Class	Crop/plant	Mode of application	Conc. /dosage	Effect	Reference
Chlorpyrifos, Cyper-methrin, Fenvalerate.	Organophosphate Pyrethroids	Insecticide	*Cenchrus setigerus Pennisetumn pedicellatum*	Soil	0-100 mg/Kg	Reduction and delay in seed germination at higher concentrations (75 and 100 mg/kg) of Chlorpyrifos compared to cypermethrin and fenvalerate	Dubey and Fulekar. (2011)
Chlorpyrifos	Organophosphate	Insecticide	*Vigna radiata*	Foliar	0-1.5mM	Increase in plant height, number of branches, leaves per plant, total leaf area, plant biomass. Further increase in insecticide level showed negative effect upon all the above parameters.	Parween et al. (2011b)
Chlorpyrifos	Organophosphate	Insecticide	*Vigna radiata*	Foliar	0-1.5mM	0.6 and 1.5 mM showed more toxic effect by decreasing nitrate, NR activity, soluble sugar, and protein content whereas at low concentration (0.3 mM) chlorpyrifos act as stimulant for same parameter.	Parween et al. (2011a)
Pendime-thalin	_	Herbicide	*Zea mays*	In Hoagland Solution	0-10ppm	Significant decrease in Germination, length of radical and plumule with increase in conc.. of pendimethalin and treated seed showed high content of seed reserves as total protein, carbohydrate, starch and reducing sugar in the endosperms	Rajashekhar et al. (2012)
Thiam-thoxam, Difeno-conazole Metalaxyl	Neonicotinoid	Insecticide	*Triticum aestivum* (wheat)	Treated seeds in plots	325ml/100kg seed	Improved germination and freezing tolerance of spring wheat	Larsen and falk. (2013)

Chemical used	**Pesticide type**	**Class**	**Crop/plant**	**Mode of application**	**Concentration /dosage**	**Effect**	**Reference**
TOPIK, EC (active ingredient is Clodinafop-propargyl).	_	Herbicide	*Triticum aestivum L. Zea mays L. Secale cereale L.*	Foliar	8–800 μg/L.	Increases in lipid peroxidation (LPO) intensity, superoxide anion O^{2-} generation, total antioxidant activity (AOA), and catalase (CAT) and ascorbate peroxidase (APOX) activity, The highest level of generation of O^{2-} was observed in the leaves of maize and winter wheat treated by 800 lg/L CP. Antioxidant enzymes were most active in winter rye and wheat, and least active in maize	Lukatkin et al. (2013)
Carben-dazim (bevistin)	_	Fungicide	*Cicer arietinum, Zea mays*	Seeds treated in petri plates	10ppm 1ppm	Stimulated germination, growth of radical and plumule	Dhanamanjuri et al. (2013)
Emamectin Benzoate, Imidacloprid Alphacypermethrin, Lambda-cyhalothrin	Neonicotinoidsz Pyrethroids	Insecticide	Tomato (*Lycopersicon esculentum*)	Seeds soaked in pesticide solution	10-60mg/L, 125- 2000 mg/L 30-500mg/L	At low conc. have stimulatory effect on germination, root and shoot biomass and length but inhibitory effect at high conc.	Shakir et al. (2015)
Simetryne (s-triazine herbicide)	_	Herbicide	*Triticum aestivum*	Soil	0.8 to 8.0 mgkg_1	Suppressed growth and decreased chlorophyll content. Accumulation of simetryne produced ROS which injured the membrane lipids but also stimulated the production of antioxidant enzymes, including superoxide dismutase, catalase, peroxidase, glutathionereductase and glutathione S-transferase.	Jiang et al. (2016)
Glyphosate and Aminomethylphosphonic acid (AMPA)	_	Herbicide	*Salix miyabeana*	Foliar spray	0- 2.8 kg ha−1	Both chemicals showed accumulation of ROS, decrease in chlorophyll content and rate of photosynthesis.	Gomes et al. (2016)

Chemical used	Pesticide type	Class	Crop/plant	Mode of application	Concentration /dosage	Effect	Reference
Malathion	Organo-phosphate	Insecticide	*Allium cepa*	In Hoagland's nutrient solution	50- 375 ppm	Malathion-induced mitotic alterations as breakage and laggard formation. Malathion at 375 ppm showed higher levels of malondialdehyde content, superoxide dismutase and catalase than the control, while the activity of peroxidase was low. The effective concentration for root growth was 250 ppm, whereas the stronger inhibition was observed at 375 ppm	Singh and roy. (2017)
Imidacloprid Thiame-thoxam Tebuc-onazole	Neonicotinoids	Insecticide Fungicide	*Triticum aestivum* (ARRI-2011, Millat-2011)	Seed	Imidacloprid+Tebuconazole@ 4 ml/kg seed Actara +Tebuconazole @ 0.6 g + 1.57 ml/kg seed Imidacloprid @ 2.5 g/kg seed Actara (Thiamethoxam) @ 0.6 g/kg seed	Significant increase in germination of seeds, root and shoot length and yield of both varieties treated with Imidacloprid+ Tebuconazole and Thiamethoxam + Tebuconazole compared to seeds treated with Imidacloprid and Thiamethoxam alone.	Hassan et al. (2018)
Emamectin Benzoate, Imidacloprid Alpha-cyper-methrin	Neonicotinoids Pyrethroids	Insecticide	*Lycopersicon esculentum*	Foliar spray	Emamectin -10-160mg/L, Cypermethrin-30-500mg/L Imidacloprid- 125-2000 mg/L	Higher concentrations significantly elevated ROS levels and caused membrane damage by the formation of TBARS, increased cell injury and reduced cell viability both in root and shoot tissues. To cope with oxidative stress shoot tissues produced more antioxidants as compared to root tissues	Shakir et al. (2018)
DDTs (DDT + DDE + DDD)	Organochlorine	Insecticide	*Lycopersicon esculentum* and *Cucurbita pepo*	Soil	63.5–101.3 ng g−1 dry weight of DDT and 381.4–455.3 ng g−1 dry weight of DDE	No effect on protein content or CAT activity in any of the species. DDTs exposure in tomato showed increased GR and GPX activity in stems and leaves and decrease in the GST activity in roots. No effect in zucchini observed.	Mitton et al. (2018)

According to E V Zheryakov and Yu I Zheryakova, 2021 the amount of chlorophyll a and b pigments was 4% higher than when herbicides were applied without micro-fertilizers and in contro the content of chlorophyll in the leaves was 0.350% by weight. Inhibitory effect of dimethoate was observed by (Mishra et al., 2008) in which dimethoate inhibited photosynthetic reaction by acting on PSII. The stimulatory dose of dimethoate 50ppm also caused inhibition in PSII and complete chain reaction that may be due to the damage of oxygen evolving complex (OEC). Further increase in dimethoate concentration to 100 and 200ppm leads to interruption of reduction site of PSII, plastoquinone. Similarly, Kana et al. (2004) treated *Hordeum vulgare* L. with Clomazone (0.25 and 0.5 mM) and observed reduction in chl a and b, carotenoid content and increase in chl a/b ratio. In a recent study (Gomes et al., 2016) a negative effect of herbicide treatment was reported where application of Glyphosate and aminomethylphosphonic acid (AMPA) caused reduction in chlorophyll content and process of photosynthesis.

Effect of pesticide on soil microbial flora

Soil quality maintenance depends on the functions of soil microorganisms for organic matter decomposition, residue degradation, and nutrient transformations (Álvarez-Martín et al., 2016; Crouzet et al., 2016; Ling et al., 2016). The residual pesticide in soil disturbs the microorganisms, soil enzymes such as hydrolases, oxidoreductases, dehydrogenase and phosphatase activities (Menon et al., 2005), physicochemical parameters in the soil and in turn affect the soil fertility. Pesticide like monocrotophos and quinalphos (organophosphates), and cypermethrin (pyrethroid), tend to increase the activities of cellulase and amylase enzymes. Thus, Pesticide residue negatively affect soil microbial flora, activity and affect various process such as nitrogen fixation, ammonification, nitrification (driven by the ammonia-oxidizing archaea [AOA] and ammonia-oxidizing bacteria [AOB], and microbial nitrogen-fixation processes (driven by N2-fixing bacteria), compromising the normal nitrogen supplying capacity of the soil (Nettles et al., 2016; Zhang et al., 2015).

In soil various microbes belonging to different class such as bacteria (eubacteria, archaebacteria), cyanobacteria, actinomycetes, fungi and algae are present. The effect of pesticides on soil microorganisms varies depending on the chemical dosage, the properties of the soil and various environmental factors. Mehjin et al. (2019) studied the effect of herbicide glyphosate and insecticide cypermethrin and found the inhibitory effect on growth and activities of micro-organism such as ammonifying, nitrifying, denitrifying bacteria, algae, fungi and actinomycetes.

Pesticide residue in agricultural produce

The use of pesticide has been increased due to increasing population and hence demand of food. Excessive use of pesticide leaves harmful residues in grain, fruits and vegetables which has become the part of food chain and now is the major public health concern. When the food contaminated with pesticide is consumed over long period of time, it leads to increase in body fat. Thus, it is essential to determine pesticide residue level and to mitigate the potential health risks from pesticide residues, maximum residue levels (MRLs) on particular crops have been established by the European Union in Regulation of European Commission (EC 2005) and the current MRLs for all crops and all pesticides can be found in the MRL database on the Commission website (EU Pesticides database 2017). The Maximum Residue Limits (MRLs) for the same pesticide differ widely even on the same commodity between countries as well as with the international Codex Committee standards (Codex, 2010). However, it cannot be said for sure that there is ever a “safe” level of pesticide residues in food because most of the chemical messengers function at precisely minute quantities of ppm or even ppb in our bodies (Boobis et al., 2008). Few pesticides such as OCP have been banned since the 1970s because they are extremely persistent in the environment and accumulate in sediments, plants, and animals. The determination of pesticide residues is generally performed by HPLC, GC using specific detectors, such as ECD and MS (Aguado, 2008). Fernandes et al.,2011 studied pesticide residue in strawberries when pesticide sprayed in the range of 0.005-0.250 mg/kg. They found Lindane and β-endosulfan above the MRL in Organic farming and Integrated Pest Management while other OCP (aldrin, o,p 0-DDT and their metabolites, and methoxychlor) were found below the MRL. In another study Cypermethrin was applied separately in three different concentrations i.e. 50ppm, 75ppm, 100ppm on okra crops and the residue were determined 0,1,3,5, 7,9,11,13,15,17,19 and 21 days after application (Shinde et al., 2012). The results indicate that the residue below the detectable level were found after 17 days. The residue of different pesticides such as Organophosphates (OP), Organochlorines (OC), Synthetic pyrethroids (SP) and carbamate were monitored by Jagadish et al. (2015).

Table 3. Effect of pesticide on soil microbial flora.

Chemical used	Class	Micro-organism	Concentration /dosage	Effect	Reference
Chlorpyrifos	Insecticide	Bacteria, fungus	Dilution 10^{-1}-10^{-4}	In presence of pesticide, the bacterial population in *Canna* rhizosphere crashed while there was no substantial impact or lowering of bacterial population in marigold rhizospheric soil.	Hindumathy and Gayathri. (2013)
Chlorpyrifos, Cypermethrin and Azadirachtin	Insecticide	Bacteria, fungus	For chlorpyrifos and cypermethrin 3.6 mg/kg-18 mg/kg for azadirachtin 0.26 mg/kg-1.13g/kg	At high concentration azadirachtin mimics chlorpyrifos and cypermethrin. Adverse effect was observed on bacterial and fungal communities at different plant growth stages. Number of genes and transcripts of nifH (nitrogen fixation); amoA nitrification); and narG, nirK, and nirS (denitrification) also showed adverse effect.	Singh et al. (2015)
Hexaconazole	Fungicide	Soil microbes	0.6 – 6 mg kg−1	At 6 mg/kg microbial biomass carbon (MBC) and soil basal respiration (RB) was negatively affected but NO−3-N concentration and ammonia-oxidizing bacteria populations was transitorily increased.	Chao Ju et al. (2017)
Imidacloprid	Insecticide	Phosphate solubilizing bacteria, Actinomycetes, Biological nitrogen fixers and fungus Soil enzymes	RD i.e. 25 g a.i. ha−1 to 10 RD 250 g a.i. ha−1,	Higher dose (10RD) leads to great reduction in population of bacteria and fungus. Number of actinomycetes and asymbiotic biological nitrogen fixers varied as control had highest number BNF population, whereas, 2RD treated soil reported to have the lowest BNF population. But reduction in BNF population was maximum in 5RD and 10RD treatments when comparison was made with the initial population of respective treatments.	Mahapatra et al. (2017)
Carbendazim, Imidacloprid Glyphosate	Fungicide Insecticide Herbicide	*Pseudomonas putida* and *Bacillus amyloliquefaciens*	Imi(10 to 2.09 %) Gly(10 to 0.15 %) Car (1 to 0.15 %)	These bacteria showed the ability to tolerate the pesticide at as Carbendazim (0.512%), Imidacloprid (3.27%) and Glyphosate (3.27%). Increase in PGP activities like IAA production, exopolysachchride production, biofilm synthesis, phosphate solubilization and siderophore production was observed.	Kumar et al. (2017)
Glyphosate Alphacype-rmethrin Malathion	Herbicide Insecticide	Bacteria, actinomycetes, Fungi, algae	0-200ppm	The microbial activities and the number of bacteria, actinomycetes and fungi were inversely proportional to the concentration of pesticides added to the soil. The number of micro-organism were decreased in all the concentration of pesticides but highest reduction was observed at 200ppm.	Mehjin et al. (2019)

Table 4. Effect of pesticides exposure on residues of different plant species.

Plant species	Pesticide Detected	Class	Range of detected residues	References
Bhindi	Cypermethrin	Insecticide	0.001 ppm	Shinde, et al. (2012)
Rice	Chloripyrifos Ethion Triazofos Bifenthri Fenpropathrin Profenofos Malathion Aldrin	Insecticides	0.05 mg/kg 0.01 mg/kg 0.02 mg/kg 0.01 mg/kg Not available 0.01 mg/kg 0.02 mg/kg 0.01 mg/kg	Jagadish et al. (2015)
Wheat	Chlorpyrifos Triazofos Profenofos Malathion Aldrin Cypermethrin Dichlorovos Cyhalothrin-L	Insecticides	0.05 mg/kg 0.02 mg/kg 0.01 mg/kg Not available 0.01 mg/kg 2.0 mg/kg Not available 0.05 mg/kg	Jagadish et al. (2015)
Red gram	Chlorpyrifos Ethion Triazofos Profenofos Malathion Cypermethrin	Insecticides	0.05 mg/kg 0.01 mg/kg 0.01 mg/kg 0.01 mg/kg Not available 0.05 mg/kg	Jagadish et al. (2015)
Ch. Cabbage	Acetamiprid Azoxystrobin Cypermethrin Deltamethrin Dimethoate Diflubenzuron	Insecticides and fungicides	1.5 mg/kg 6 mg/kg 1.0 mg/kg 0.5 mg/kg 0.2 mg/kg 1.0 mg/kg	Kocourek et al. (2017)
Cauliflower	Acetamiprid Azoxystrobin Cypermethrin Deltamethrin Dimethoate Diflubenzuron	Insecticides and fungicides	0.4 mg/kg 5 mg/kg 0.5 mg/kg 0.1 mg/kg 0.2 mg/kg 1.0 mg/kg	Kocourek et al. (2017)
Cowpea	Dieldrin aldrin γ-benzene hexachloride pp-DDE Endrin Endosulfan	Insecticides	20.14 mg/kg 7.81 mg/kg 0.24 mg/kg 1.23 mg/kg 1.82 mg/kg 13.49 mg/kg	Olutona., 2019
Beans	Diel-drin Endosulfan II Endrin CHO	Insecticides	0.99 mg/kg 1.02 mg/kg 1.66 mg/kg	Olutona.,2019
Orange	Chlorpyrifos, Diazinon Malathion	Insecticides	7.05 mg L^{-1} 6.66 mg L^{-1} 12.38 $\mu g L^{-1}$	Kashi et al. (2021)
Apple	Chlorpyrifos, Diazinon Malathion	Insecticides	0.74 mgL^{-1} 0.70 mgL^{-1} 1.10 $\mu g L^{-1}$	Kashi et al. (2021)
Tomato	Chlorpyrifos, Diazinon Malathion	Insecticides	0.60 mgL^{-} 0.57 mgL^{-1} 0.89 $\mu g L^{-1}$	Kashi et al. (2021)
Chilli	Chlorpyrifos Dimethoate	Insecticides	0.74 mg kg-1 0.61 mg kg-1	Megawati et al. (2021)

They studied 250 samples, among them 80 samples were found to be contaminated with different groups of pesticides. Pesticide residues were found to be above the Maximum Residue Limit (MRL) in 22 samples and below MRL in 58 samples.

Conclusion and future Perspective:

It can be concluded from the present review that pesticide application represents viable solution to pest control, however application of pesticide above the recommended dose adversely affects the growth of target as well as non-target crops. Keeping in mind, the side effect of pesticide there is need to educate pesticide dealers and farmers about the proper and optimal applications pesticides. The edible part of crop has been found to be contaminated with multi pesticide residue above the MRL and hence more efficient methods should be developed for dissipation of pesticide residues in food grains. Use of organic chemicals, such as: biopesticides and integrated pest management can be the alternative to pesticide. These poses lower or no risk to the environment and human health. Further, the effects of these pesticides on non-target host plants should be investigated at biochemical, anatomical and molecular level to identify the mechanism by which they cause toxicity.

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