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Global Scenario of Pesticides and Benefits from Pesticide Usage: A Review

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Abstract: Pesticides have contributed significantly in increasing agricultural production and the farmers' income globally. Responsible application of pesticides play a key role in agricultural input and help to protect seeds and safeguard crops from unwanted plants, insects, bacteria, fungi and rodents. Also, pesticides can have negative environmental impacts through contamination of soil, water and non-target plants and animals that can decrease biodiversity and, in some cases, reduce crop yield. Globally, total pesticides use in agriculture remained stable in 2020, at 2.7 million tonnes (Mt) of active ingredients. The worldwide application of pesticides per area of cropland was 1.8 kg/ha. On a per capita and per value of agricultural production basis, pesticides application was 0.69 kg/1000 international dollars and 0.37 kg/person, respectively. Total pesticides trade reached approximately 7.2 Mt of formulated products in 2020, with a value of USD 41.1 billion. Pesticides have contaminated every ecosystem on the earth since pesticide residues have been reported in water, air, soil, crops and non-target plants and animals. They can also be toxic to other organisms, including birds, fish, beneficial insects etc. The chemical residues of pesticides have impacted human health through the environment and food contamination. This review provides scientific information on pesticides about global scenario of production and utilization, present status in India, benefits from usage and use and application considerations. This study recommends use of bio-pesticides by the farmers to achieve more yield from agriculture with minimum effects on ecosystem. This review paper creates awareness among students, general public and scientific community for sustainable management practices for the use of pesticides to safeguard the natural resources and human health.

Keywords: Agriculture, Bio-pesticides, Disease, Global scenario, Insecticides, Pesticides, Pests

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Introduction

Pesticides, fertilizers and improved seed varieties have contributed to increase in crop yields. Pesticides are used to manage pests such as weeds, insects, and plant pathogens along with to

reduce amount of labour, fuel, and machinery used for pest control (Gardner *et al.*, 2009). Properly applied pesticides contribute to higher yields and improved product quality by controlling weeds,

insects, nematodes, and plant pathogens. The herbicides reduce the amount of labour, machinery, and fuel used for mechanical weed control. Most of pesticides possess toxic properties and their use is a concern about human health and environmental consequences (Fernandez-Cornejo *et al.*, 2014).

Pests interfere with the production and utilization of crops and livestock used for food and fibre. Agricultural pests include insects, mites, nematodes, plant pathogens, weeds, and vertebrates. They reduce yield and quality of crop and increases the production costs. Pesticides are either synthetic (developed in laboratories and manufactured) or natural (available in the nature) (Bauder *et al.*, 2020). Biologically active part of the pesticide used to control pests are called pesticide active ingredients. Generally, pesticides are sold as mixtures of active ingredients with inert materials for safety, storage, handling, or application. Toxicity (quality or degree of being poisonous or harmful to plant, animal, or human life) of a pesticide determines its performance for management of the pests (NRC, 1975).

The benefits of pesticide use are accompanied by potential risks to human health and the environment. Human health risks can result from direct exposure of farm workers to pesticides or from consumer exposure to pesticide residues on foods. Environmental risks can result from the movement of pesticides into ground and surface water and into the food chain (Rajveer *et al.*, 2019). The hazard or risk of using a pesticide depends on toxicity and exposure. Agricultural producers use pesticides to prevent or manage pest infestations, to generate economic benefits for farmers and consumers. However, adverse impact on human health and environment is a issue of public concern (Lorenz, 2009).

Padmajani *et al.* (2014) recorded that though pesticides have become inevitable ingredients with green revolution technologies, indiscriminate use of pesticides causes health hazards to humans and long lasting bad effects to the environment. The cost of pesticides imposed damage has to be

borne by the society as a whole. Upcountry vegetable farming is one of the intensive cultivated farming systems which consumes a high volume of pesticides and fertilizers, especially due to short duration of crops and highly favourable humid conditions for rapid spread of pests and diseases.

The pesticides are important components of the plant protection tools across the world in spite of various other practices which are advocated and practiced. Though, many peer reviewed scientific studies, and the consolidated knowledge about the adverse impacts of pesticides at the global level is available, there are still gaps in knowledge and information that need to be addressed (UNEP, 2022). To overcome the knowledge gaps and further research on innovative ideas on less toxic pesticides, present study was undertaken.

Definition of Pesticides:

Table 1 illustrates definition of pesticides as described by various researchers.

Methodology:

This article reviews the pesticides with respect to definition, sources, global scenario of pesticides production and utilization, present status of pesticides consumption in India, role of pesticides/benefits from pesticide usage and use and application considerations for pesticides. Review method adopted was based on the scientific literature survey from databases such as Scopus, Medline, EMBASE, Web of Science and Science Direct. The relevant data and information were collected from the thorough study of the journal articles, research papers, reports and various literatures. The keywords used for reviewing the literature were the ones that refer to the issues concerning the pesticides. For literature search, keyword "pesticides" is combined with definition, global scenario with production and utilization, present status in India, benefits from usage and use and application considerations.

Table 1: Selected definitions of pesticides (Megha *et al.*, 2018)

Reference	Definition of Pesticide
FAO (2002)	Any substance or mixture of substances intended for growing, destroying, preventing or controlling any pest (including vectors of human or animal disease,) unwanted species of plants or animals that cause damage or otherwise interfering in the production, processing, storage, transport or marketing food, agricultural products, wood and wood products or animal feedstuffs or which may be administered to animals for the control of insects, arachnids or other pests in or on their bodies.
Pillay (2017)	Natural or synthetic agents designed to kill all types of pests including insects, rodents, fungi and unwanted plants (weeds).
Megha <i>et al.</i> (2018)	Any physical, chemical or biological agent that will kill an undesirable or troublesome animal, plant or micro-organism.
Hassaan and Nemr (2020)	All compounds that are applied to destroy or regulate pests; this includes insecticides (insects), herbicides (weeds) and fungicides (fungi).
Nayak and Solanki (2021)	Substances (natural or manmade) used to control pests, weeds, and diseases in plants in various agronomic practices.

Global scenario of Pesticides Production and Utilization:

According to Zhang (2018), global croplands are not unlimited and global population grows continually. Therefore, it is necessary to take all measures to increase crop production in order to ensure food safety. Reducing crop loss from pest injury is one of the major tasks to ensure crop production. Worldwide insects, mites, plant pathogens and weeds damage crops of which insect pests caused an estimated 14% of loss, plant pathogens caused 13% loss, and weeds 13% loss, hence use of pesticide is necessary in crop production (Zhang *et al.*, 2011).

De *et al.* (2014) reported that an average of 2 million tons of pesticides was used each year globally to confront weeds, insects and pests. Assad *et al.* (2021) noted that globally, 7 million tons of chemical pesticides are manufactured annually, of which around 4.6 million tons are applied annually across the world. On global scale, of the total pesticides applied, 45% is applied in Europe, 24% in the USA, 3.75% in India and

remaining 27% in rest of the world. Europe is rampant pesticide consumer and is followed by Asia. Brazil, China, France, Japan, and the United States are the leading pesticide producers globally.

Sun *et al.* (2018) reported that in the global pesticide market, bactericides represent 26%, insecticides 30%, and herbicides represent 30–40% of all the agricultural applied pesticide. During 2007, about 2363 million kg of pesticides was used in the world with herbicides constituting the highest share of 950.7 million kg followed by 404.6 million kg of insecticides followed by 262.17 million kg of fungicides (Gyawali, 2018). It has been estimated that globally nearly \$38 billion are spent on pesticides each year (Pan-Germany, 2012).

When applied responsibly, pesticides help to protect seeds and safeguard crops from unwanted plants, insects, bacteria, fungi and rodents. At the same time, pesticides can have negative environmental impacts through contamination of soil, water and non-target plants and animals that can decrease biodiversity and, in some cases,

reduce crop yield. Worldwide, total pesticides use in agriculture remained stable in 2020, at 2.7 million tonnes (Mt) of active ingredients. The worldwide application of pesticides per area of cropland was 1.8 kg/ha. Total pesticides trade reached approximately 7.2 Mt of formulated products in 2020, with a value of USD 41.1 billion (FAO, 2022).

Total pesticide use and specific active ingredients used has changed considerably over the past five decades. Use of pesticide on 21 crops analyzed in USA, rose rapidly from 196 million pounds of active ingredient (A. I.) in 1960 to 632 million pounds in 1981 (Fernandez-Cornejo et al, 2014). Insecticides accounted for 58 per cent of pounds applied in 1960, but only 6 per cent in 2008; whereas herbicides accounted for 18 per cent of the pounds applied in 1960 but 76 per cent by 2008.

Further, about 5-10% of corn, wheat, and cotton acres were treated with herbicides in 1952. By 1980, herbicide use had increased up to 90-99% of U.S. corn, cotton, and soybean acres planted. Moreover, the four most heavily used active ingredients in 2008 (glyphosate, atrazine, acetochlor, and metolachlor) were all herbicides. Pesticides such as fungicides, soil fumigants, desiccants, harvest aids, and plant growth regulators accounted for 5-11% of total pesticide use from 1960 to 1992, increased to 17 per cent of use in 2002. Total pesticide expenditures in U.S. agriculture reached close to \$12 billion in 2008, a 5-fold increase in real terms since 1960 (Fernandez-Cornejo *et al.*, 2014).

Fernandez (2022) reported that in 2020, the United States was the largest pesticide-consuming country worldwide, at about 407.8 thousand metric tons. Brazil trailed in second, with 377.2 thousand tons consumed (Table 2). During 2020, worldwide pesticide consumption became 2.66 million metric tons (mmt) and between 1990 to 2010, global consumption of agricultural pesticides increased by more than 50 per cent. Thereafter consumption has remained relatively

stable, dropping slightly from 2.68 million metric tons in 2011 to 2.66 in 2020.

Pesticides are currently a widely used tool for pest and disease management across developing countries. Concomitantly, human health and environment issues related to pesticide handling are often pronounced in these countries because farmers and agricultural workers very often do not have adequate personal protective equipment and may also be unable to read labels with safety instructions (OECD, 2012; EP, 2021).

Present Status of Pesticides Consumption in India:

In India, production of pesticides was started in 1952 for the production of BHC near Calcutta. Today, India is the fourth largest global producer of agro-chemicals after US, Japan and China. Currently, 279 pesticides are registered and more than 675 formulations are available for use in India. Along with agriculture and domestic sector, pesticides are also used in ornamental plants, forest trees, soil treatment, treatment of animals and pets, household pest management, storage places, wood or wood structure protection treatments, aquatic sites, non-crop wide areas and general indoor and outdoor treatments, building protection etc. (Rao *et al.*, 2018).

Globally more than half of the pesticides are utilized in Asia. India stands 12th in pesticide use globally and 3rd in Asia after China and Turkey. In India, of the total pesticide consumption, insecticides occupies the highest share. India share only 1% of the global pesticide use. According to FAO (2018), India has utilized around 58,160 tonnes of pesticide in 2018 with the application of 0.31 kg per hectare. Though India applies less amount of pesticides per hectare of cropland area, but uncontrolled and haphazard pesticide usage is responsible for the presence of high pesticide residues in both natural and physical environment (Nayak and Solanki, 2021).

Nayak and Solanki (2021) observed that use of pesticide in India has increased hundreds of times. During 2016-17, Maharashtra had the highest total pesticide consumption, followed by Uttar

Table 2: Leading countries with highest agricultural consumption of pesticides in 2020

Sr. No.	Name of the Country	Consumption of pesticides (In 1,000 metric tons)
1	United States	407.78
2	Brazil	377.18
3	China	262.7
4	Argentina	241.29
5	Russia	90.53
6	Canada	78.89
7	France	65.22
8	Australia	63.42
9	India	61.7
10	Italy	56.56

Pradesh, Punjab, and Haryana. Maharashtra and Uttar Pradesh account for 41% of India's pesticide consumption. More than 50% of the pesticides used in India are of insecticides of the Chlorpyrifos type. In India, from 2014-2018, average chemical pesticide consumption was about 55,000 tonnes/year.

India is the largest pesticide producer in Asia and the 12th largest pesticide user globally. In India, the consumption of pesticides is 0.5 Kg/hectare, which is far lower as compared to developed countries (Boudh and Singh, 2019). Rani and Dhaniala (2014) stated that, in India, insecticides are the most used pesticide, followed by herbicides and fungicides, mainly due to increased insect outbreaks by warm humid climatic conditions. The main use of pesticides in India is for cotton crops (45%), followed by paddy and wheat. During 1999-2000, in India, consumption of pesticides in agriculture was highest in Haryana (5,030 MT), followed by Uttar Pradesh (7,400 MT), Punjab (7,100 MT) and Andhra Pradesh (7,000 MT) (Kumar *et al.*, 2013).

According to Rao *et al.* (2018), three important components that helped India to achieve food

production are high yielding varieties, fertilizers and pesticides. Pesticides are important components of the plant protection tools across the world and during 2016-17, about 57,000 Metric Tonnes active ingredient of pesticides consumed in the country.

In India, Andhra Pradesh, Maharashtra and Punjab are top three states contributing to 45% of pesticide consumption and Andhra Pradesh is the leading consumer with 24% share. The top seven states together account for more than 70% of crop protection chemicals usage in India. State-wise consumption of pesticides in India in the increasing order was represented as: Andhra Pradesh (24%) > Maharashtra (13%) > Punjab (11%) > Madhya Pradesh, Chattishgarh (8%) > Karnataka, Gujarat (7%) > Tamil Nadu, Haryana, West Bengal (5%).

In Asia, India is the biggest maker of pesticides and stood twelfth as world client of pesticides. In India, states like Andhra Pradesh, Uttar Pradesh and Punjab are the top buyers of pesticides (Abhilash and Singh, 2009). Tomer *et al.* (2015) documented that utilization of pesticides was presented in India amid the mid-sixties as a piece

Table 3: Applications of pesticides in various sectors

Sector	Use of pesticides
Agriculture	For control of weeds, pests, rodents etc.
Domestic	Household and garden spray. Control of animals and birds.
Material building	Incorporation of paints, glues, plastic protection sheeting, foundation of buildings etc.
Personal	For application of clothing and skin care.
Public health	For control of malaria, dengue fever, cholera

of green revolution and malaria anticipation programs. Nayak and Solanki (2021) stated that bio-pesticides are the best substitute for chemical pesticides for sustainable agriculture and also to reduce the soil and water pollution. At present, microbial bio-pesticide consumption is only 8% in India. Various formulations of biopesticides should be practised for sustainable agricultural development and to protect the environment from adverse effect of chemical pesticides.

Aktar *et al.* (2009) described that there has been a steady growth in the production of technical grade pesticides in India. Also, the pattern of pesticide usage in India is different from that for the world in general. In India, 76% of the pesticide used is insecticide, as against 44% globally. The use of herbicides and fungicides is correspondingly less heavy. The main use of pesticides in India is for cotton crops (45%), followed by paddy and wheat.

The Role of Pesticides/Benefits from pesticide usage (Gyawali, 2018) (Table 3):

❖ *Primary benefits from pesticide usage (Aktar et al., 2009; Tudi et al., 2021):*

- Public health: Used in daily life to kill pests (mosquitoes, ticks, rats, and mice) in houses, offices, malls, and streets.
- Decrease in the burden of diseases caused by the vectors.

- Control of insects that spread deadly diseases (malaria).
- Agriculture: Control of weeds and insects. Enhance production and yield.
- To cope with demographic growth by increased food productivity.
- Reduction in harvest losses caused by weeds, diseases, and insect pests.
- Reduction of diseases and increase in crop yields worldwide.
- Alleviating hunger and to provide abundant supply of high-quality food.
- ❖ *Secondary benefits from pesticide usage (Cooper and Dobson, 2007):*
 - Farm and agribusiness revenues. Reduced vet, medical and maintenance costs.
 - Nutrition and health improvement. Fit and healthy population without stress.
 - Food safety. Quality of life improvement. Increase in life expectancy.
 - Wider range of viable crops. Loss of Soil erosion/moisture.
 - Greenhouse gas emission. International spread of diseases. Global warming.

- Increased export revenues, workforce productivity, biodiversity, and cropping due to agronomic consultation.

Use and application considerations for pesticides (USDA, 1998; Nicolopoulou-Stamati et al., 2016):

- Apply pesticides at the lowest effective level.
- Avoid unnecessary pesticide treatments.
- Use Integrated Pest Management.
- Follow all label instructions.
- Apply proper rates and times as label indicates.
- Calibrate application equipment.
- Apply formulations that minimize drift.
- Use safety equipment when handling.
- Store and dispose of pesticide containers properly.
- Use biological controls when appropriate.
- Alter farming or cropping systems to control pests.
- Use disease and insect resistant crop varieties.
- Sustainable and ecological approach by agriculture reforms and food production with sustainable practice.
- Implementation of a new agricultural concept for food production.

Conclusion

Pesticides play major role in shaping the availability and accessibility of food production in developing countries. This study suggests that, instead of continued reliance on chemical pesticides, urgent steps to be taken for the awareness and use of bio-pesticides in agriculture and at public places to help to reduce the health and environmental risks of pesticides. At initial level, bio-pesticides should be used in combination with the chemical pesticides but afterwards, bio-pesticides must be used as single or mixture of different bio-pesticides. Also, the

guidelines of use and application considerations for pesticides should be implemented to safeguard environmental components and human health.

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