



World Agronomy: A Study of Pesticides Usage and Its Harmful Effects

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Abstract

Agriculture is the science as well as the art of cultivation of crops and also includes activities associated with it like animal husbandry. Agronomy is a part of agriculture which is restricted to the management of field only. The scope of agronomy includes every activity related to field management and better yield of crops. This study lays emphasis on the adverse effects of pesticide usage on crop, non-target plant, humans, soil and the overall environment. As per the data of Environews Forum, around 1 million people die of pesticide poisoning every year, several illnesses like redness in eyes, salivation, sweating, coughing, vomiting, frequent bowel movements, respiratory problems and most importantly the Parkinson's disease, are a threat to the people who are exposed to the pesticides.

Keywords: Agriculture, Agronomy and Pesticide.

1. Introduction

The science or inquiry of technology and methods used in agriculture for plantation, fuel, fiber, chemicals or land conservation is known as Agronomy. Agronomy also includes research on plant genetics, plant physiology, soil science and meteorology. In other words, it is the study of agricultural science that deals with crops and the soil where they grow [1]. The word agriculture is derived from the Latin word 'Ager' meaning field and 'cultura' meaning cultivation. It is concerned with the science and art of cultivating crops, harvesting them and also the rearing of livestock. Its scope is much wider consolidating farming with all the other allied activities like animal husbandry, raising livestock, sheep rearing, horticulture, sericulture, apiculture, pisciculture, etc. Whereas the concept of agronomy is narrower [2]. The word Agronomy is derived from the Greek word 'agros' meaning field and 'nomos' meaning management. It is basically the management of the field in the most efficient and productive manner. 'Therefore, agronomy becomes a part of Agriculture.'

2. Background of Agronomy

According to the Indian Society of Agronomy, 'Krishi Prashar' is an ancient Sanskrit text on agriculture where the author Prashar in the 4th century

AD laid emphasis on the management of agriculture. One of the types of evidence to prove his emphasis is the verse "Farms yield gold if properly managed but lead to poverty if neglected". The irony is that, in India during the last 70 years of the existence of free and independent society inclined towards prosperity, the agronomists and the policy makers of Indian agriculture have not much bothered about the efficient management of agriculture and field experiments. In the 20th century, Agronomy first developed with an American urge as a science to grow "bigger and better crops". The American Society of Agronomy founded in 1907 that lead to an overhaul of agronomy subject as a field science. According to Sir R G Stapledon "The major aim of agronomical research, which is essentially field research, is to study all the factors which are operative at once and together, and in their natural interplay, for "nature is a theatre for the interrelations of activities".

3. Scope of Agronomy

Agronomy denotes that more advancement in agriculture development of nations leads to greater contribution of agriculture in National Income. Agronomy is a dynamic discipline which changes with advancement in technology and more research



endeavors. It includes seeds and sowing, crop density and geometry, crop nutrition, manures and fertilizers, tillage and tilling, nutrient use efficiency, water resources, crop-water requirement, scheduling criteria, methods, water logging, water use efficiency and irrigation.

4. Background of Pesticides

The history of the usage of pesticides is as old as time. For convenience and simplicity, it can be divided into three stages. The first stage starts from 1870s, when pests were controlled by natural resistance techniques [3]. Some examples of natural resistance techniques are the use of mercury and arsenical substance by Chinese to control body lice, burning of straw, hedge clipping, crabs, fish and other animal products to produce smoke and spread it all over the orchard to prevent flies, mosquitoes etc. or controlling weed by hand weeding. The second phase began between 1870s and ran till 1945, where people started using 'inorganic synthetic materials' like copper, sulfur compounds, line arsenic against numerous fungal diseases [4]. The third phase started after 1945 when the synthetic pesticides and effects of DDT (Dichlorodiphenyltrichloroethane), Aldrin, dieldrin, endrin, chlordane, captan and parathion were discovered. These substances were highly toxic if used in larger quantities. The milestone was achieved by researchers and activists in 1972 when DDT was banned in the US because of its severe impact on non-targets. While in between, some new families of chemicals like triketone, isoxazole herbicides, strobilurin, triazolopyrimidine and azolone fungicides and spinosyn were introduced in the market. One specification of these chemicals was that they could be used in grams per hectare instead of kilogram per hectare [5-7]. According to National Library of Medicine, "Without the use of pesticides, there would be a 78% loss of fruit production, a 54% loss of vegetable production and a 32% of cereal production." Among all the above stated chemicals Chlorpyrifos is the most dangerous pesticide known to attack the nervous system. Around 5 million pounds (about 2267960 kg) of chlorpyrifos is applied every year. Chlorpyrifos is a conventionally used pesticide which belongs to a family of chemicals that were initially developed during World War 2 for use

of nerve agents. Sarin Gas is the most used pesticide of this class. After World War 2 it was patented for both domestic and industrial use. A report by Environment Protection Agency (EPA) found that Chlorpyrifos was used in more than 40 parts of USA. After collection and investigation of data and evidence the chemical was banned in 2000 for residential purposes. Environment Law Organization Earthjustice petitioned the EPA for a total ban on chlorpyrifos in 2016 on behalf of farm workers and labor organizations. There was no route to escape for the workers even after wearing a full-bodied suit for prevention. The EPA agreed for a nationwide ban in 2016. But due to high political and corporate influence and pressure, it cannot be banned. In 2016, the NY state legislature approved a bill to enact a ban, which the then Governor Andrew Cuomo was expected to sign in December 2019 but at the end, he vetoed the bill by saying that the ban should go through 'chemists and health experts'. Consequently, till date chlorpyrifos is still the most widely used pesticide in the world.

5. Literature Review

Jean-Jacques Dethier and Alexandra Effenberger (2012) in their research article, "Agriculture and Development: A brief review of Literature" concluded that it is very important to increase food productivity and production in developing countries, especially in Sub-Saharan Africa and Asia due to rising food prices, increasing food insecurity and poverty [8]. It requires research in the field of seeds and agricultural extension, credit, rural infrastructure connection and policy making. Eric Lichtfouse, Mireille Navarrete, Philippe Debaeke, Véronique Souchère, Caroline Alberola, Josiane Ménassieu (2009) in their research article "Agronomy for Sustainable Agriculture: A Review" concluded that Agronomy, since many years, has been considered as a soft, side science but now due to upcoming global problems like starving people in poor nations, obesity in rich nations, pest adaptation and resistance, increasing fuel and transportation costs, flaws of the global market, increasing food prices, on-going climate changes, worldwide pesticide pollution, loss of soil fertility and organic carbon, soil erosion, decreasing biodiversity, desertification, etc



agronomy reached a status of crucial research and developing field. Out of the above stated problems, the problems related to food production, soil fertility and use and abuse of pesticides are directly connected and studied under agronomy [9]. Lucio G Costa (2006) in his research article, “Current issues in Organophosphate Toxicology” concluded that organophosphates are the most used classes of insecticides since 1940s. Organophosphates exert immense adverse effects on the non-target species including human, animals, aquatic life. Rattan Lal (2006) in his research article “Enhancing crop yields in the developing countries through restoration of the soil organic carbon pool in agricultural lands” concluded that the crop gains productivity when the Soil Organic Carbon pool is large, especially when it is combined with judicious input of fertilizers, irrigation and other required inputs [10]. The food-grain production in developing countries can be increased by 24-39% through improvement of soil quality and reversing degradation process of soil by various harmful substances. Usage of SOC pool leads to an increase in food security and moreover it leads to carbon sequestration which helps in offsetting fossil fuel emissions. Vincent F Gerry (2004) in his research article “Pesticides and Children”, concluded that there are more ways of exposure to children from pesticides than adults. They can be exposed to pesticides by playing in pesticide treated fields, unknowing aerial amalgamation (mostly in rural areas) [11]. Diet can be one of the predominant factors in the OP exposure of urban and suburban children but indoor household use of Ops such as chlorpyrifos can also be a reason for the short duration and high level of exposure hazard. Isra Mahmood, Sameen Ruqia Imadi, Kanwal Shazadi, Alvina Gul, Khalid Rehman Hakeem (2016) in their research article concluded that the excessive or indiscriminate use of pesticides leads to the destruction of biodiversity, many birds, animals and aquatic organisms are under serious threat of extinction [12]. They also discussed how the long-term usage of certain pesticides could be a probable cause of pollution. Shelia Hoar Zahm, Mary H Ward, Aaron Blair (1997) in their research article, “Pesticides and cancer” concluded that

organophosphate insecticides have a close link to leukemia, non-Hodgkins's lymphoma and lung cancer. The most exposed ones to these substances are the farmers who have shown more risk of these diseases [13]. People living in proximity with the cranberry bogs, whose cultivation is more prone to the usage of herbicides, insecticides and fungicides, have been linked to brain cancer. Timothy C Marts (1993) in his research article “Organophosphate Poisoning” concluded that OP poisoning is not common in the UK as compared with the USA because of the strict regulations of pesticides and veterinary drugs usage. In the developing countries like Sri Lanka severe cases of OP poisoning are prevalent. The reason behind the high prevalence of organophosphates in developing countries is not uniform and simple to understand but it may depend upon the scale of use, condition of working practices and the ease in availability of poison, all play a significant role. R Kamanyire and Lakshman ralliede (2004) in their research article “Organophosphates Toxicity and Occupational exposure” concluded that organophosphate compounds are usually esters, amides and thiol derivatives of phosphoric acid. These derivatives constitute a large family of 50,000 chemical agents that have unique implications on man but most of the “Ill health following exposure” was done by the cholinesterase. Although it is becoming visible that cholinesterase is one of the most toxic organophosphates, the inhibition of other enzymes is also important to study.

6. Research Methodology

6.1.Objectives of the Research

- To study the use of pesticides since 1990 till date.
- To study the impact of pesticides on the environment, soil, humans, water, non-target plants and other organisms.
- To study the type of vegetation and usage of pesticides by Top 15 countries using pesticide.

6.2.Data Analysis

According to the World Health Organization, there are at least 1000 pesticides used all over the world to ensure food safety from harmful pests. Many old and

cheap pesticides such as dichlorodiphenyltrichloroethane (DDT) can remain there in the soil for several years. In 2001, it was banned in some countries who signed the Stockholm Convention Treaty. But in the present time, pesticides are used everywhere in the agricultural process. For instance, the worldwide agriculture consumption of pesticides in 2023 was 4.3 million metric tons which is estimated to grow and reach 4.5 million metric tons in 2027.

6.3. Agriculture Production and Pesticide Usage Through the Years Around the World

The figure given below (fig. 1) shows the persistent rise in the usage of pesticides from 1990 to 2021. Despite several warnings and circulars issued, code of conduct formulated, there is not a tinge of decline in the overall trend in usage of pesticides in various farm fields.

SOURCE: United Nations Food and Agriculture Organization

Figure 1: Global pesticides use by category

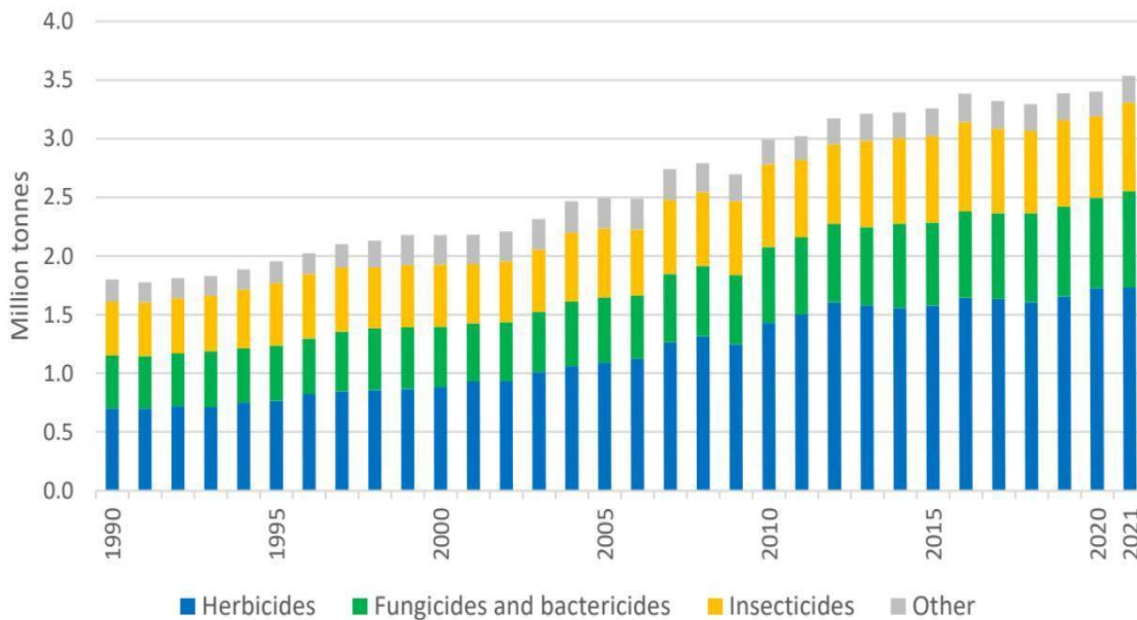


Figure 1 Global Pesticides Use by Category

Within a timespan of 33 years (1990-2023) the use of pesticide has increased from 1.5 million metric tons in 1990 to 4.3 million metric tons in 2023 (approximately 105% increase in 33 years). This means that higher amount of pesticide is required for killing the same pests but with stronger immunity. In simple words, it means that earlier the amount of pesticide used on a given piece of land is insufficient now for the given piece of land to kill the same pesticides. There are numerous reasons behind it like the increased tolerance of the pests over the pesticide used and indifferent use of pesticide for better yield.

The estimates of United Nations Population Division states that there will be 9.7 billion people on this earth by 2050, around 30% more humans than in 2017. This drastically increasing population is a warning bell to increase crop productivity and yield. Food security is a matter of utmost concern. As shown in the figure given below (fig. 2), the global production of primary crops like cereals, vegetables, sugar crops, oil crops, etc. has increased since 2000. According to the figure, there is an increase in the production of cereals by 55%, sugar crops by 46.66%, vegetables by 98%, oil crops by 140% and fruits by 50%.

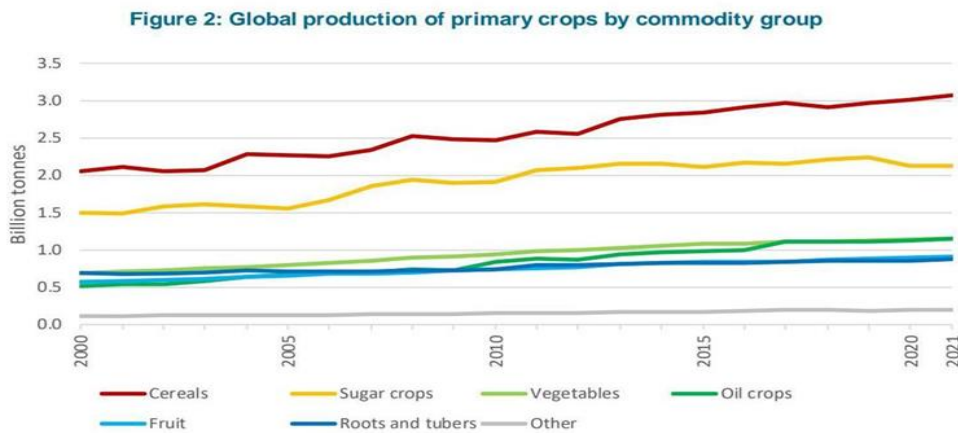


Figure 2 Global Production of Primary Crops by Commodity Group
SOURCE: United Nations Food and Agriculture Organization

As per the figure given below (fig. 3), the production of cereals like maize, wheat, rice, barley and sorghum has also increased. Some crops have seen an exponential rise in the production due to various reasons, among them the most important reason is the advancement of technology in several countries and change in cropping pattern, but the increased use of pesticide cannot be denied as a determining factor. These cereals are mostly consumed as a staple food in many countries like India, USA, China etc. On an average these crops have seen an aggregate rise of

50% since 2000. The matter of concern is the pace of increase in population and increase in agriculture production. The crop yield must keep pace with the drastic rise in world population. The matter of concern is also the source of productivity, it must not come from the use of excessive chemicals like pesticides and fertilizers. If we look carefully in the above diagrams, we can find a relation between the excessive use of pesticide since 1990 and the rise in agriculture production.

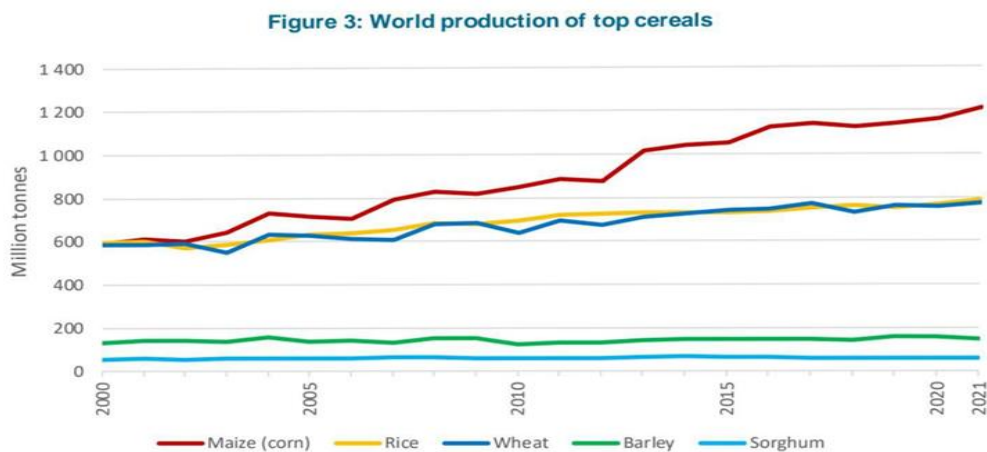


Figure 3 World Production of Top Cereals
SOURCE: United nations Food and Agriculture Organization

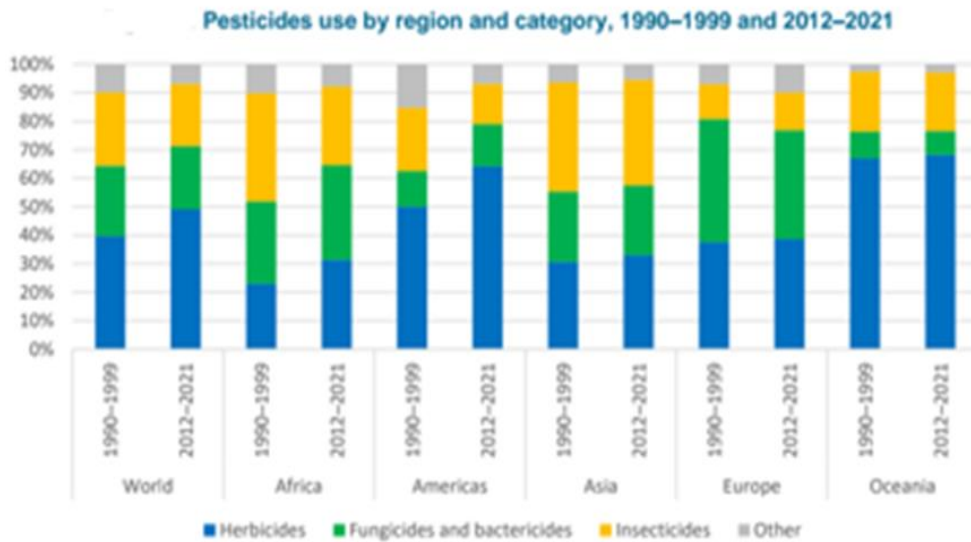
7. Impact of Pesticides

Pesticides can contaminate soil, water, humans, non-target plants and other organisms like birds, fish,

necessary insects etc. Pesticides include insecticides, herbicides, rodenticides, bactericides, fungicides and larvicides. According to the figure 4 given below, the

most used pesticide is herbicides, and its usage has increased in most of the regions of the world. As per the National library of Medicine, “if the debits of pesticides include enhanced economic potential in

terms of increased production of food and fiber, and amelioration of vector-borne diseases, then their debits have resulted in serious health implications to man and his environment.”



SOURCE: United Nations Food And Agriculture Organisaon

Figure 4 Pesticides Use by Region and Category, 1990-1999 and 2012-2021

7.1. Impact of Pesticides on Humans

According to Environews Forum, almost 1 million people die due to the exposure of pesticides every year. Pesticides, mostly insecticides, are prepared in such a way that they act upon the nervous system of the insects, but they may pose a similar threat to humans if not removed properly before consumption. They act upon the neurons by causing a sodium-potassium imbalance in the body and prevent normal nerve impulse transmission. A research study published in Nature Communications states that among a number of most commonly used pesticides, ten of them were directly linked to toxicity and death of dopaminergic neurons – which is one of the most prominent causes of Parkinson’s disease. Apart from that the farmers and field workers are entirely exposed to the chemical even when they are wearing a full body cover. They do not have any escape route to it. They experience redness in eyes, salivation, sweating, coughing, vomiting, frequent bowel movements, respiratory problems and other infections on a regular basis.

7.2. Impact of Pesticides On Soil and Non-Target Plants

Pesticides cause the degradation of soil if they do not break-down early and remain in the soil for longer period. This residual of pesticide in the soil may be taken up by plant roots and moved to other plant tissues including the fruit as well. Pesticide that is applied to sandy or course-grained soil is more likely to leach through the soil and contaminate groundwater. Pesticides are sprinkled on the crop where it is required but sometimes it reaches the crops that are non-target i.e., they were not in need of any chemical sprinkle. It affects their chemical as well as physical properties.

7.3. Impact of Pesticides On Environment

Environment consists of our surroundings, whatever is there in the surrounding makes up the environment. Pesticides contaminate soil, water, grass and other vegetation. Insecticides are generally the most toxic class of pesticides, but that does not imply that others are less harmful.



7.4. Impact of Pesticides on Water

The chemicals present in pesticides contaminate water and make it unusable for any purpose. Water is a universal solvent therefore chemicals get mixed with water easily. Movement into bodies of water occurs when runoff, after rainfall, moves through the areas that have been earlier sprayed with pesticide. It can be done by either displacement of pesticides from absorption sites near water or through treated soil that has moved into the water because of soil erosion.

7.5. Nation wise Analysis of Pesticide usage (Top 15)

As shown in the table below, the heaviest users of pesticides are China, United States, Brazil, Argentina, Canada, etc. Their usage of pesticide in agriculture production is a serious threat to not only the consumers but also the farmers, environment,

aquatic organisms and non- target plants. It was found in a study that the farmers or field workers exposed to pesticide usage are more likely to develop respiratory problems, nervous problems and most importantly the Parkinson's Disease. Most of the developed countries like China, United States, Canada, etc. use more pesticides in comparison to the developing countries like India where there is a combination of traditional and modern agriculture techniques used on the field. The heavy mechanization and modernization of agriculture could be a probable cause of increased usage of chemicals in farming. Refer Table 1.

Table 1 SOURCE: World Meter

#	Country	Pesticide Use (tons)	Kg of Pesticide per Hectare of Cropland
1	China	1,763,000	13.1
2	United States	407,779	2.5
3	Brazil	377,176	6.0
4	Argentina	196,009	4.9
5	Canada	90,839	2.4
6	Ukraine	78,201	2.3
7	France	70,589	3.6
8	Malaysia	67,288	8.1
9	Australia	63,416	2.0
10	Spain	60,896	3.6
11	Italy	56,641	6.1
12	Turkey	54,098	2.3
13	India	52,750	0.3
14	Japan	52,249	11.8
15	Germany	48,193	4.0



1. **China:** China was the world's most populous country with a wide area of land. But that land is of no use in terms of agriculture as only 10% of the total land cover is cultivatable. Therefore, the need for better yield within the limits of land is very crucial for the country. The cultivation in China incorporates rice, wheat, potatoes, tomatoes, sorghum, peanuts, tea, millet, barley, cotton, oilseed, corn and soybean. In 2019, the volume import of pesticides in China surpassed 89000 tons with an import value of 897 million US dollars.
2. **United States:** US heavily depends on mechanization for agriculture. The scope of mechanization can be determined by the fact that only 1 labor is required for per square kilometer of farmland. One of the most important crops of the country, alfalfa, requires humongous amounts of pesticide for production, other than that corn, soybeans, wheat, tobacco and barley are also cultivated. The pesticide consumption in 2019 was 408000 tons.
3. **Brazil:** Brazil is the third country among the list of countries using pesticides. The main agricultural crops of Brazil are coffee, soybean, crop-based ethanol, corn and sugarcane. Out of which. The pesticide usage in Brazil in 2020 was 680000 tons with a value up to 28 billion euros.
4. **Argentina:** The agriculture in Argentina is extremely capital intensive. The use of money, machines and chemicals is more evident than the use of labor. The main crops grown in the region are soybean, maize, sugarcane, wheat, sunflower seed, sorghum, potato, grape, apple, lemon and barley. The Argentine state of Misiones banned the use of Glyphosates (a type of pesticide) through a law passed by local Chamber of Deputies but there is no such provision for any other organophosphate usage.
5. **Canada:** Rapeseed, alfalfa, barley, canola, flax, rye, and oats are popularly grown crops in Canada whereas wheat is the staple food. A predominant use of pesticides is seen in the region. However, there is a regulatory body i.e. Health Canada's Pest Management Agency which looks over the pesticides sold, used, or imported.
6. **Ukraine:** Ukraine's more than 55% land is arable and it provides employment to 14% of the population. Agriculture products constitute the most important part of the exports accounting for 41% of the country's total exports.
7. **France:** A total of 74 million acres of land, more than three-fifths of this land is used for plowing and tillage. The widely grown crops of the nation are sugar beet, rice, persimmon, carrot, wheat, tangerine, potatoes and cabbage. Herbicides and moss killers used in cemeteries have been banned in the country since 2014 which included ban on pesticide use in public places like parks, public gardens and roadsides.
8. **Malaysia:** Malaysia is the country which relies heavily on the farming sector and its cash crops, palm oil and rubber. These crops are then exported all over the world. In the year 2020, around 36000 metric tons of pesticides were used in Malaysia in agricultural activities. Most used pesticides in the region are organophosphates, pyrethroids, glyphosphate and 2,4-D-dimethylammonium.
9. **Australia:** In Australia a mix of irrigation and dry land farming is seen. Cereals, oilseeds, sugarcane, legumes and grains constitute the farming sector of the country. Although, the use of pesticide is lesser in Australia in comparison to other nations, but it has increased three-fold since 1990, according to the data provided by the Food and Agriculture Organization of the United Nations.
10. **Spain:** Spain is a producer of fruits like apples, apricots, bananas, pears, peaches and plums. Spain is also the largest producer of wine therefore cultivation of grapes is of considerable importance. Among all the countries in EU, Spain is the leader in sales of pesticides.
11. **Italy:** Italy is the leading producers of olive oil as well as fruits like apples, olives, grapes, oranges, lemons, pears apricots etc. in the world. According to the annual report of Italian environment association Legambiente, only 0.6% of fruits and vegetables marketed in Italy had traces of some illegal pesticides.
12. **Turkey:** Main crops of the land are wheat, sugar beets, cotton, tomatoes, apricot, hazelnuts and



oregano. An annual average of pesticide consumption in Turkey is 33000 tons.

13. **India:** In India, a mix of traditional and modern farming is seen. About 60% of the total land is cultivatable, which is the reason behind lesser use of chemicals in farm practices. According to the FAO, in 2022, the use of pesticide in India was 61000 tons, which is comparatively very low.
14. **Japan:** The main agriculture crops of Japan are corn, rice, barley, peanuts, soybeans, oats, etc. Japan saw a peak in pesticide consumption in 2015 at over 54000 tons but gradually the use of pesticides is reduced to 49000 tons in 2021.
15. **Germany:** Germany's top agriculture exports include rapeseed, barley, wheat and potatoes. In 2021, Germany was among the largest importers and exporters of consumer oriented agricultural products. According to a research study published in the journal of Environmental Science and Technology, the toxicity of pesticides used in the country has increased for fish, terrestrial plants and soil organisms since the past 25 years.

8. Suggestions

- a. **Promotion of bio-pesticides usage:** According to US Environment Protection Agency, bio pesticides include "naturally occurring substances that control pests (biochemical pesticides), and pesticidal substances produced by plants containing added genetic material (plant-incorporated protectants) or PIPs." Plant Incorporated Protectants or PIPs are a kind of pesticidal substance produced by plants and the genetic material that is necessary for the plant to produce that substance. For example, a specific pesticidal protein is inserted into the plant's genetic material, after that the plant itself manufactures the pesticidal protein that will control the pest when it feeds on the plant. The best part about PIPs is that they are approved for many crops, including corn, cotton, potato, soybean, papaya and plum.
- b. **Organic Farming:** Organic Farming is the farming done on organic principles. According to the definition given by the United States Department of Agriculture,

Organic Farming is the "system which avoids and largely excludes the use of artificial inputs." In organic farming, there is a build-up of organic matter which is beneficial for the soil. It works on improving the efficiency of conventional agriculture while lowering the negative and harmful impacts of various chemicals used. The entire system of agriculture in the world could be shifted to organic farming but the constraint is that organic farming requires more land and for that purpose deforestation must be done, which itself has severe impacts. The kind of organic farming done nowadays is more relevant for the elite classes of society because of the lavish pricing of organic products. Organic Farming will serve its purpose if it reaches all the strata of society without any discrimination. Then only it will help in achieving sustainability in agriculture.

- c. **Crop Rotation:** The system of continuous cropping becomes more infested with weeds, as the weeds get adapted to the system. Therefore, the crop must be rotated at appropriate periodic intervals. A build-up of diseases can be prevented by rotation of crops. Plants also absorb nutrients from soil, repetition in planting of the same family of crop may cause depletion of soil. Crop rotation disrupts the life cycle of the pests and diseases that grow on them.
- d. **Integrated Pest Management:** It is an environmentally effective and sensitive approach to manage pests; it is a combination of common-sense practice. It is not a single pest management technique but rather a series of pest management evaluations, decisions and controls. There are four steps process involved to it:
 - Set Action Thresholds
 - Monitor and Identify Pests
 - Prevention
 - Control
- e. **Companion planting:** Companion planting, as the name suggests, means planting variety of crops in proximity to each other for various



reasons like utilizing the space properly, increase crop productivity and most importantly to provide habitat for beneficial weeds and prevent the harmful ones. Some good companions to planted are cabbage with celery, lettuce, spinach and onions, carrots with beans, onions, lettuce, peas, peppers and tomatoes, corn with cucumber, peas, pumpkins, squash and sunflowers, and onions with cabbage, carrots, chard, lettuce, peppers, tomatoes, etc.

Conclusion

Pesticides have been a part of the agriculture system but their indiscriminate use in some of the major developed countries of the world has become an issue of concern. Using more and more chemicals to improve the yield artificially is a substandard for the consumers. In this study, we have analyzed that the agricultural production of top cereals has increased since 1990s by 50% but at the same time the use of pesticides has increased more than two-fold by 105%. It is found in the study that the crops like corn, soybean, wheat, potatoes, tomatoes and other commodity crops require more pesticides than others, therefore the countries that grow them on large scale consume most of the pesticides. Farmers cannot afford to not use pesticides and reduce the yield in times when there is huge demand for food by continuously increasing population. Pesticide usage, if not fully ceased, can be controlled if the above techniques are adopted in the regular farm practices.

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