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A gestalt on the pesticide norm in agriculture: Pros and cons

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Abstract
Several technologies have been adopted to increase food grain production, pesticide application is one among them. Pesticide comprises a wide range of compounds embracing insecticides, herbicides, fungicides, rodenticides, nematicides and others. Various groups of insecticides are used against different kinds of insects. Usage of pesticides is an economical approach to get immediate protection from the nuisance of pest problems. Pesticide use has advantages in many situations and it has become a boon for many countries in avoiding pest nuisance. Pesticides offer various kinds of benefits including primary, secondary, national-level benefits, etc. On the other hand, pesticide application is accusing in recent years because of some negative effects on human health and the environment. Pesticides are known to cause some ill effects in humans such as cancer. Excess use of pesticides can also affect beneficial insects, productive insects and beneficial soil microorganisms. However, to overcome the hazards caused by pesticides, taking safety measures in pesticide usage is necessitous.

Keywords: Pesticides, impacts, benefits, resistance, human health, inevitability

Introduction
To meet the consumption need of growing world population, there is a need for increasing food grain production by adopting several modern technologies such as the use of high yielding varieties, use of pesticides, *etc*. More than half of the world's crops would be lost to insects, diseases and weeds without crop protection. This can help farmers to grow more food on less land by protecting crops from pests, diseases and weeds besides raising productivity per hectare. The word pesticide asylums a wide range of compounds embracing herbicides, insecticides, fungicides, rodenticides, molluscicides, nematicides, plant growth regulators and others [1]. The concept of pesticide usage started in 2500 BC when Sumerians used sulfur on their body to ward off lice. During the 19th century, organochlorines are the most used insecticide group followed by OP (Organophosphorus insecticides). Presently, various groups of insecticides are used against different kinds of insects. Usage of pesticides is an ultimate and economical approach to get immediate protection from the nuisance of pest problems to heighten crop productivity, thus safeguarding food security [2]. Chemical pesticides have been a fortunate thing to many nations in their efforts to exterminate insect-borne, endemic diseases, produce adequate food and protect forests, plantations and fibre (wood, cotton, clothing, etc.) [3]. However, integrated pest management (IPM) does not necessarily require the suppression of insecticides, but rather reduces their dependence, by eliminating unnecessary applications. Pesticide application is blaming in recent years because of their negative effects on human health and the environment [1]. The widespread usage of pesticides has the potential to pose unexpected risks, both directly and indirectly [4]. This paper throws the light on pesticide usage, their inevitability & benefits, risks associated with misuse of pesticides and ways to reduce/ overcome the risk posed by pesticides.

Pesticide usage across the world *vis-à-vis* India
Nearly, 2 million tonnes of pesticides are utilized annually worldwide, where China (> 20 Kg/ ha) is the major contributing country, followed by the USA and Argentina, which is increasing rapidly [5]. Herbicides are the major group of pesticides used extensively across the world followed by insecticides and fungicides [1]. The rate of pesticide uses is very high in the developed countries like North-Western Europe, Japan and the United States where they use three by four of the total pesticide employed worldwide [6]. The extent of pesticides applied in developing countries is lesser than the developed countries [7].

Insecticides, herbicides and fungicides are used in India, with insecticides forming the highest share. India is amongst the largest producers of pesticides in the world. According to a testimony by the database Research and Markets, the Indian pesticides market was worth Rs 197 billion in 2018. The market is further projected to reach a value of Rs 316 billion by 2024, growing at a Compound Annual Growth Rate of 8.1 per cent from 2019-to 2024. Total pesticide utilization is highest in the Maharashtra, followed by Uttar Pradesh, Punjab and Haryana. On the other hand, per hectare consumption of pesticides was the highest in Punjab (0.74 kg), tailed by Haryana (0.62 kg) and Maharashtra (0.57 kg) from 2016-to 17 [8].

The inevitability of pesticide uses in agriculture

Pesticide application is inevitable in some cases which are discussed hereunder. Firstly, concerning the landholding. The application of pesticides has wide scope in both small farm holding and large farm holdings. Under small farm holding, the farmer won't take a risk to face the loss caused by pests and hence he will ultimately go for insecticide application. Of course, large farm holding farmers are also not ready to take risks but adoption of pest control tactics such as physical and mechanical control across large areas might be difficult thus attracting the chemical control *i.e.* pesticide use. Secondly, crop value is also a major factor in magnetizing pesticide use. More the crop value higher the frequency of pesticide application. Thirdly, is the type of pest which damages the crop. If that is known to be a key pest of a particular crop, a voracious feeder and a strong vector then it needs to be controlled immediately or else farmers will face the crop loss. Lastly, if there is a failure in the control of pests by any of the tactics like biological, mechanical and physical control then chemical control is only the sole method which can bring down the pest population [1].

Gains in pesticides use

Immediate outcomes of pesticide use can be termed as effective and which is different from the term benefit where the consequences of the effects have not manifested themselves yet. However, the benefits of pesticide use can be viewed in two categories i.e. primary and secondary benefits. Primary benefits are the direct gains expected from their use such as improved crop yield, life saved, improved self-life or produce *etc* by impairing pest activity/ life directly. On the other hand, secondary benefits are the ones which are less immediate, less intuitively obvious, or long term consequences. However, it is hard to establish cause and effect, but they can be powerful justifications for pesticide use. Secondary benefits can be achieved at three levels such as national benefits, community benefits and global benefits. Some of these can be mentioned as follows: food safety, food security, life expectancy *etc*. The main effects of pesticide use can be of three kinds *viz*., controlling pests and vectors of plant disease; controlling human and livestock disease vectors & nuisance organisms; and preventing or controlling organisms that harm other human activities and structures [9].

Agriculture is a major sector upon which the Indian economy is largely reliant. Food grain production is increasing many folds since 1948–49 mainly due to the use of advanced irrigation technologies, high-yield varieties of seeds and agricultural chemicals like pesticides [1]. Pesticides have been an essential part of the process by reducing losses from the weeds, diseases and insect pests that can markedly diminish the amount of harvestable produce. The spectacular increases in crop yields in the United States in the twentieth century are achieved mainly by the usage of pesticides. Considerable economic losses would be suffered without pesticide usage [10]. Exclusive of pesticides, more than half of our produce would be lost to pests and diseases. Farmers can produce crops on less land and increase crop productivity by 20-50 per cent with the application of pesticides. In addition, pesticides allow farmers to maximize the benefits of other valuable agricultural tools, such as high-quality seeds, fertilizers and water resources. Pesticides are therefore an indispensable tool for the sustainable production of high-quality food and fibres. All farmers use pesticides, counting organic farmers. The disparity is organic farmers can only use pesticides from natural sources. But both synthetic and natural pesticides have various levels of toxicity. The vectors of many fatal diseases are most effectively managed by applying pesticides. Use of pesticides is the only practical way to control the insects that spread deadly diseases to crops and humans [1].

Risks associated with pesticide usage

Indiscriminate application of the moderate and highly hazardous category of pesticides by the farmer son crop plants to a larger extent is a matter of concern [11]. Controversy subsists over the global dependence on pesticides, given their excessive use/misuse, long-distance transport and eventual environmental blemish in different climates [3]. Several pesticides and their metabolites have been identified in ground and surface waters [12, 13, 14], in soils [15, 16] and the atmosphere [17, 18]. Besides, pesticides are detained responsible for contributing to the loss of biodiversity and the deterioration of natural habitats [19, 20]. Pesticides have adverse impacts on water quality, plants and animals, and are associated with an abundance of negative human health effects, from short-term sickness to numerous cancers [21, 22, 23]. Previous studies into environmental fate, transportation and risks posed by pesticides are dominated by site-specific investigations. The book Silent spring (written by Rachel Carson) provides a series of examples and case studies about the damage to ecosystems and humans that synthetic pesticides can bring [21]. The risk posed by the pesticide use are discussed hereunder with the following subheadings:

Impact on the human health

The use of pesticides is not limited to agriculture. They are also expended to control domestic pests, disease insect vectors and home gardening. But they are very lethal in nature and pose acute risks to human health and the environment. The man working in the pesticide manufacturing organizations, in fields, assassinating household pests and greenhouse are mostly sufferers due of direct pesticide exposure. However, the risk of pesticide poisoning is very high at the time of production and formulation as compared to the application of pesticides in the field. Several types of health problems such as cancer, diabetes mellitus, neurological disorders, respiratory disorders, reproductive (sexual/genital) syndromes and oxidative stress are caused due to the direct exposure, handling of pesticides or pesticide residues present in the foodstuffs [24]. The general class of organochlorine pesticides are linked with health effects, such as endocrine disorders [25, 26], embryonic development [27], lipid metabolism [28], and haematological alterations [29]. Organophosphorus pesticides are connected with effects on the function of several enzymes and pathways such as

cholinesterase enzymes [30], decline in insulin secretion, disruption of normal cellular metabolism of carbohydrates, proteins and fats [28], and also with genotoxic effects [31] and effects on mitochondrial function, causing cellular oxidative stress and problems to the nervous and endocrine systems [28]. Carbamates are associated with endocrine-disrupting activity [32], and possible reproductive disorders [33, 32], and consequences on cellular metabolic mechanisms and mitochondrial function [28]. Many studies have confirmed that synthetic pyrethroids can exhibit endocrine-disrupting activity [25, 34, 35], and affect reproductive parameters in experimental animals including reproductive behaviour [36, 37]. Neonicotinoids can also exhibit conceivable effects on the endocrine and reproductive systems of humans [35, 36, 37]. Recent studies demonstrated that neonicotinoids can increase the expression of the enzyme aromatase, which is betrothed in breast cancer [37].

Tragedies of pesticide use in India

The Bhopal gas tragedy was an accident that happened due to gas leakage in December 1984 at the Union Carbide India Limited (UCIL) pesticide plant in Bhopal, Madhya Pradesh, India. Over 500,000 people were exposed to methyl isocyanate (MIC) gas and 2,259 people were dead immediately [38]. Monocrotophos, the highly toxic pesticide that has been blamed for the deaths of 14 devotees in a temple in Karnataka. It was one of the pesticides also responsible for the deaths of farmers who had sprayed chemicals on their crops in the Yavatmal region of Maharashtra last year. A new tragedy of pesticide food poisoning occurred recently in India. According to available reports, 23 children died and more than 48 required medical treatment. This poisoning occurred mainly due to the consumption of a free lunch of rice, soybeans and lentils cooked with oil contaminated with monocrotophos, an organophosphate pesticide [39]. It is known that aerial spraying of endosulfan in the cashew estates of Kasaragod, Kerala, over a period of 20 years, caused severe health hazards and deaths. Many consider the endosulfan tragedy equivalent to the Bhopal gas tragedy. The Kerala State Department of Health and Family Welfare classified 6,728 persons with different types of diseases as “endosulfan generated,” and 779 deaths were recorded as due to endosulfan poisoning [40].

Impact on the biodiversity/ environment

Pesticides can contaminate soil, water, turf, and other vegetation. In addition to killing insects or weeds, pesticides can be toxic to a host of other organisms including birds, fish, beneficial insects, and non-target plants [41]. Diffusion of pesticide residues in the environment and mass killings of many organisms such as bees, amphibians, birds, fish and small mammals, were also reported. Pesticides enter the natural ecosystems by two different means depending upon their solubility: i) water-soluble pesticides get dissolve in water and enter groundwater, streams, rivers and lakes thus causing harm to untargeted species and ii) fat-soluble pesticides enter the bodies of animals and get absorbed in the fatty tissues of animals thus resulting in persistence of pesticide in food chains for extended periods (bio-amplification). Hence, the higher the trophic level, the more will be the concentration of pesticide in the top consumers [41]. Accumulation of pesticides in the food chains is of greatest worry since it directly affects the predators and raptors. The industrialization of the agricultural sector has increased the chemical burden on natural ecosystems.

Impact on the beneficial insects

IPM signifies a notable improvement over previous conventional approaches, therefore optimizing the efficiency of the entomophagy activity of natural enemies of pests is a decisive factor. However, the correct amalgamation of chemical and biological control is an indispensable part of sustainable pest management. In IPM agroecosystems a great proportion of non-target insects are mainly affected by sublethal dose/ concentration values [42]. Among the side effects of insecticides, it has been reported that beneficial arthropods are severely affected by sublethal effects [43, 44, 45], although their impact has often been overlooked or underestimated. The sublethal effects may be manifested as reductions in life span, development rates, population growth, fertility, fecundity, changes in sex ratio, deformities, feeding, searching and oviposition [46, 47, 48]. The sublethal doses/concentrations of insecticides cause many alterations in the behaviour of insects, interfering with their chemical communication system, thus reducing the chances of efficient localization of a pheromone source [45]. Quite the contrary, this set of behavioural modifications provides insects with an escape mechanism from the toxic effects of pesticides, which is why they have been called behavioural resistance since it provides the first barrier or mechanism of detoxification. The affected insects having this skill show hyperreflexia, with a trend to start the flight more easily [49, 50, 51]. Some plant-derived and synthetic pesticides have negative impacts on natural enemies and pollinators [52]. It is also reported that pesticide plants have active ingredients similar to synthetic pesticides and therefore, they can cause negative impacts on non-target natural enemies and pollinators [53].

Impact on the productive insects

In general, sublethal doses cause toxic effects that do not kill the organisms but still affect their normal functioning and health. For example, exposure of bees to sublethal doses of neurotoxic insecticides may cause stress [54], paralysis or abnormal behaviours without killing the bees [55]. Systemic insecticides, such as neonicotinoids (*e.g.* imidacloprid) and fipronil, are more toxic and persistent than conventional insecticides such as OC, OP and Carbamates. As they are applied consistently as seed dressings, their residues may remain in the soil for years and are taken up by the crop and weeds, ending up in the nectar and pollen of all plants in the treated landscape [56]. Wild bees (*Osmia bicornis*) exposed to sublethal levels of thiamethoxam and clothianidin had their reproductive success reduced by 50% [57], while honey bee queens experienced unusually high rates (60%) of supersedure [58]. Silkworms are affected by pesticides in many different ways. Pesticides may cause acute toxicity or sublethal effects leading to the impairment of silk production and quality. Pesticides cause retardation of growth and development of larva, spinning ability of lava, the fecundity of moths *etc* [59]. The use of pesticides in or around mulberry fields with carelessness causes contaminated mulberries. By feeding silkworms with such mulberry leaves, various damage such as poisoning to death of silkworms, deteriorated cocoon quality, reduced cocoon yield, and abnormal oviposition in silkworm egg production often occurs [60]. Studies also signify the residual impact of some majorly used pesticides such as Proclaim on the fourth instar larvae of silkworm [61]. It is also reported that lambda-cyhalothrin, alphameric and bifenthrin

were found safe for lac insect at lower concentrations, but can pose a detrimental effect on survival of lac insect with the increase in dosages, henceforth may not be suitable for application at the initial stage of crop development in lac production system [62].

Threats to Aquatic fauna

Aquatic ecosystems are experiencing considerable damage due to the drifting of pesticides into the lakes, ponds and rivers. Pesticides pass into the water bodies by different processes such as runoff, drift and leaching via the soil or they may be applied directly into surface water to control some aquatic pests such as mosquitoes. Aquatic animals exposed to pesticides in three ways namely, breathing (Uptake via gills during breathing), dermally (Direct absorption via skin) and orally (Entry via drinking contaminated water) [63]. Pesticides can affect aquatic forms by decreasing dissolved oxygen in the water and can trigger physiological and behavioural changes in fish populations [41]. With the gorge of pesticides, a waning in populations of different fish species is witnessed [64]. A laboratory study conducted with insecticides and herbicides also witnessed the reduction in the species richness and biomass of predatory insects [65].

Drawbacks with excessive pesticide use: Resistance and resurgence

Frequent use of the same group of pesticides to control a pest can cause unfavorable changes in the pest population leading to the problem of resistance and resurgence. When a pesticide used for the first time, a small proportion of the pest population may survive exposure to the material due to their distinct genetic makeup. These individuals pass along the genes for resistance to the next generation. Subsequent usage of the pesticide increases the proportion of resistant individuals in the population. In the course of this process of selection, the population gradually develops resistance to the pesticide. Worldwide, more than 500 species of insects, mites, and spiders have developed selected level of pesticide resistance [66]. If a pest develops resistance, then the pesticide lacks efficacy thus efficacy and resistance are inversely related [67]. It is also important to keep in mind that pest populations can also develop resistance to non-chemical methods of control. For instance, the northern corn rootworm (*Diabrotica barberi*) evolved resistance to a corn-soybean crop rotation by spending its life when the field is planted with soybeans in a diapause [68]. Resurgence is the situation where insecticide application initially reduces an infestation, but soon afterwards the pest rebounds (resurges) to higher levels than before treatment [69]. The reason for this is the removal of predators together with pests. They either die from the pesticide or move away because their food source has disappeared [70]. Disruption of natural controls is not always the cause of resurgence or replacement events. A dose-response phenomenon called hormoligosis can occur in pest populations exposed to sublethal doses of pesticides. This can cause an increase in fecundity or oviposition behaviour [71].

Residues in the soil and water

Pesticides have been widely distributed and their traces can be detected in all areas of the environment (air, water and soil) [72]. A large number of transformation products (TPs) from a varied range of pesticides have been documented [73]. The persistency and movement of these pesticides and their TPs are the key features of pesticides deciding the fate of pesticides in soil. These features are determined by some parameters like water solubility, soil-sorption constant, water partition coefficient and half-life in soil. The pesticides and their TPs are retained by soils to different degrees, depending on the interfaces between soil and pesticide properties [74]. The most persuasive soil characteristic is the organic matter content. The larger the organic matter content, the greater the adsorption of pesticides and TPs [1]. Residues in the soil may subsequently pollute groundwater aquifers through leaching, thereby affecting the quality of the agricultural crops and products. This in turn may affect the health of the consumers in the region. The pesticide residues are also found in the body of earthworms which gives a hint of frugal soil contamination [75]. There are several studies which highlight the presence of pesticides and their residues in both surface and groundwater. Around 90 per cent of water and fish samples which were drawn from all streams contained one, or more often, several pesticides [76]. Pesticides were also found in samples from major rivers [77]. Groundwater pollution caused by pesticides is also a worldwide problem. Rendering to the USGS, a minimum of 143 different pesticides and 21 transformation products have been observed in groundwater, embracing pesticides from every major chemical class [78]. A study which was conducted in India revealed the presence of Organo Chlorine pesticides in 58% of drinking water samples which were taken from various hand pumps and wells around Bhopal [78].

Impact on the beneficial soil microorganisms

In general, chemical compounds could undergo several transformations and be transferred among environmental compartments, reaching other ecosystems outside the area of application and exercising toxic effects on non-target species [79]. Excessive use of chemical fertilizers and pesticides has effects on beneficial soil organisms. Indiscriminate use of chemicals could work for a few years, but after a while, there aren't adequate beneficial soil organisms to clamp onto the nutrients. Excess application of pesticides can reduces the growth and activity of free-living nitrogen-fixing bacteria in soil. Further, mycorrhizal fungi nurture with the roots of many plants and aid in nutrient uptake can also be damaged by pesticides in the soil [80].

Strategies to overcome the pesticide risks

The jeopardy of suffering health problems from a pesticide depends on the toxicity of the pesticide and the amount of exposure. Limiting the amount of pesticide used, selecting lower toxicity products and using protective equipment to minimize the exposure can help to minimize the hazards connected with pesticide use. Following are some strategies which can reduce the hazards of pesticides [81, 82]: a) Integrated Pest Management approach emphasizes prevention, exclusion and sanitation, and make use of pesticides only as a last resort when other options have failed. b) Label directions should be followed exactly while mixing and applying pesticides. One should review the product signal word and active ingredients, and then select the product lowest in toxicity. c) Use of protective equipment, like gloves or goggles, is indispensable to reduce exposure. d) Store and dispose of pesticides properly. e) Following label directions and not to apply pesticides before heavy rain or in places where they might wash into water bodies to prevent pesticides from getting into groundwater or surface water. f) Following the guidelines for preventing potential impacts on non-target species, including

wildlife, fish, bees, and endangered plants and animals. g) Applying outdoor use pesticides when there is no more than a light breeze and the temperature is cool, such as early morning or evening, to reduce the travel of pesticides to nearby areas. h) Following IRM (Integrated Resistance Management) strategies to overcome the problem of resistance and resurgence. i) Use of alternative products such as microbial and botanical pesticides which are known to have less hazards to human health and the environment [83].

Conclusion

Intensive food production in agriculture may not bestow the usage of current agrochemicals in the next few years. However, numerous measures could be introduced to better mitigate their collateral effects in the meantime. Because of the vast benefits which man amasses from pesticides, these pesticides provide the best opportunity to those who juggle the risk-benefit equations. Like other technological developments, that improve the quality of our lives, pesticides can pose risks if they are not used judiciously. In this, they are not unique. Cars kill over 40,000 people each year in the US alone. Their emissions contribute to greenhouse gases and they are inefficient users of energy compared with alternatives, such as buses or trains [9]. Pesticide residues are identified in soil and air, and surface and groundwater across the countries. Further, urban pesticide use can promote the problem. Pesticide contamination creates significant risks to the environment and non-target organisms vacillating from beneficial soil microorganisms to insects, plants, fish, and birds. Though, to maximize the benefits of pesticides should be used at a minimum human and environmental cost. Pesticides must be strictly regulated and used astutely by properly trained and appropriately equipped personnel, ideally in tight integration with other complementary technologies. The development of new pesticides with novel modes of action and improved safety profiles could minimize acquaintance with pesticides and the undesirable effects of exposure on human health.

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