STATUS OF HERBICIDES IN INDIA

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PAN INDIA

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The Savitri Waney Charitable Foundation is a philanthropic organisation working with some of the poorest and marginalised rural communities in India, with a desire to transform their lives. We work with local communities on aspects like the relief of poverty, education, and medical relief. Poverty reduction is at the core of what we do. Through this project, we wish to raise awareness among farmers, consumers and other stakeholders about the adverse effects of herbicides/weedicides which will not only benefit the farming community to ensure their health and safety but also will ensure a reduction in pollution of the environment

Developed and designed by

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Thanal Conservation Action facilitates Sustainable Solutions for the Environment. Its objective is to carry on the business of undertaking studies and projects, developing and running communication projects for institutions, companies, Government Organizations, and Individuals, contributing to a better understanding of environmental problems, conservation and protection of environment and wildlife

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Pesticide Action Network India (PAN India) is a non-profit, public interest, research and advocacy organisation formed in 2013. Its objective is to help communities and governments reduce dependence on toxic agrochemicals for pest control in agriculture, household as well as public health and to increase the use of sustainable alternatives. PAN India is working to empower farming communities to keep away from toxic pesticides and agrochemicals, and to take up non-chemical methods of farming practices based on agroecology.

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PREFACE

Herbicides are indicators of what is wrong with modern agriculture and how it relates to nature. The term weed is not a biological categorization. The taxonomy of plants does not include a category of weeds. Weed is an agronomic term. It was developed to give credence to a theory of productivity and yield. Weed terminology was developed to sanctify an agricultural practice which views competition between plants for natural resources as inefficient and uneconomic.

Herbicides are chemicals that are designed to kill plants that are castigated as weeds. However, Herbicides are the result of research to kill particular plants. Just like pests and pesticides, weeds and Herbicides should be related directly. Unfortunately, Herbicides are applied in general even if the research has been on a particular plant/ species. Herbicides are known as weed killers or pesticides that are used to kill vegetation or unwanted plants. Some of them are created to kill specific target plants while leaving the rest of the crop unharmed by its effect.

Registration of Herbicides indicates its approval for usage in a country. However, the communication of such approvals mentions crops such as paddy, wheat, corn and soybean. Herbicide, a chemical that has the proposed ability to kill a weed is ironically approved for crop usage. To be clear, a crop is tagged with the approval of a weedicide. Why this kind of approval has been adopted is not explained. In general, herbicide research is on weeds and how to kill them. Yet, approval of herbicides is always associated with a crop. There is no mention of the particular herbicide that is tolerant towards the approved crop. Since herbicides can kill or desiccate many other plants, and not just one particular weed, their usage is a matter of concern for unintended consequences.

Like other pesticides, drift from herbicides can be a major concern, as they can damage non-target crops, plants and vegetation. The off-target impact of herbicides has become a serious concern, documented and challenged across the world, but mostly in the United States. Herbicides were brought in to address an agronomic concern, i.e., the growth of weeds competing with crops. But these chemicals have become an agronomic concern by producing off-target impacts and desiccating non-target crops. The development of resistance to herbicides in weeds and the growth of super weeds (an extension of resistance) has led to a cycle of research – herbicides to kill, weeds to develop resistance, more research on chemicals to kill and so on. The buffer zone method, to avoid drift and secondary impacts of herbicide application, is not acceptable to both farmers and herbicide manufacturers. Farmers do not want to lose ‘some’ area and it does not match the gains in productivity promised by herbicide application. Thus, herbicides have now become a major agronomic concern, because of drift, secondary impacts, costs, resistance and tolerance factors, even while the environmental and ecological impacts are serious.

This report is yet another initiative of PAN India to increase awareness around pesticides and their harmful impacts. Highly Hazardous Herbicides (HHH), or weedicides (as the industry and regulators name them), are becoming a threat to food and nutrition. I would rename them as planticides, since they kill every plant, and are non-selective in such action. Weed management in agriculture, gardens, homes and open areas has always been done through non-chemical methods in India and elsewhere. New York city is rediscovering such methods, using goats to control plant growth in Manhattan’s Riverside Park. Way back in 2009, Google rented goats to eat their lawns. In India, ruminating animals were always integrated with agriculture for crop health and to avoid unwanted plants. The necessity of chemicals, which are killers, is being argued in terms of economics and not as an efficient method over non-chemical methods. To avoid manual labour costs and the hassle of hiring labour, herbicide usage is being called for. However, the ‘externalised’ costs due to herbicide usage far outweigh the monetary benefits of avoiding manual labour. We hope this report will generate more debate in this direction.

Dr. Narasimha Reddy Donthi
Public Policy Expert and Advisor to PAN India

CHAPTER 1

EXECUTIVE SUMMARY

PAN India pinpoints inadequacies in the Indian regulation of herbicides, including the pernicious method of allowing deemed to be registered herbicides, which enables some herbicides to bypass the minimal scrutiny at the time of registration. On the other hand, India is becoming a key player in the international herbicide trade, with increasing imports and exports. However, not much focus is on how Indian regulation is shaping up to meet this challenge. This report brings out the hollowness in herbicide regulation. Primarily, all is not well with information collection, data collation, monitoring and regulation of herbicide imports, exports and consumption. There is a huge incongruence between registered, approved uses of herbicides by PPQS and the herbicide recommendations by the States, Directorate of Weed Science Research, which is a cause of high concern. Most of these recommendations, apparently backed by scientists, are legally and scientifically incongruent. Backed by an unscientific community recommending highly hazardous herbicides wrongly, misguided, unaware farmers are led down the garden path by the pesticide companies.

Plants that limit the growth of crops are considered weeds, in modern agriculture, regardless of their biological significance. Herbicides are phytotoxic chemicals used to kill these plants. They are widely used in forestry, gardening, modern agriculture, landscaping, industries and aquatic food systems. Herbicides are classified into different groups under different criteria. They belong to various chemical classes and act through various mechanisms. Herbicides include growth regulator herbicides, seedling growth inhibitors, root growth regulators, photosynthetic inhibitors, pigment inhibitors, cell membrane disruptors, lipid synthesis inhibitors, amino acid synthesis inhibitors, carotenoid biosynthesis inhibitors and folic acid inhibitors.

The increasing demand for herbicides is being cited as a compelling cause for their large-scale production all around the globe. In India, years back, herbicide use was started in Punjab with the introduction of an inorganic compound called sodium arsenite. Later, the use of herbicides increased considerably with the import of 2,4-D (2,4-dichloro phenoxy acetic acid). Currently, 87 herbicides are registered and approved for use in India under the provisions of the Insecticide Act of 1968. Among them, 20 herbicides are considered highly hazardous according to the PAN international list of Highly Hazardous Pesticides (HHPs). It even includes the controversial and widely used herbicides: glyphosate and paraquat dichloride.

Indian pesticide regulatory authorities release only selective data, for unknown reasons. There is no pervasive transparency. Released data is selective and discontinuous. Data on the production, consumption, export and import, are not linear due to this kind of selective release. There are no proactive data release mechanisms operating both at national and State levels. In fact, most States do not release data at all, even though the Right to Information Act mandates proactive release. As per our analysis, within the available data, statistics for the production, import and export of herbicides in India reveal that every year the consumption of herbicides, especially 2,4 D, is increasing. Official data shows that it was higher during the years 2018-19 and 2019-20. In 2020-21, consumption has reduced from the preceding year. But again, rose in the following year. However, it is apparent that the consumption of herbicides in India varies and thus unpredictable, at least on record.

The consumption volume of herbicides has been generally less in India, when compared with other countries like the United States, Brazil, Argentina and China. The availability of large number of agricultural field labourers that help in the manual removal of weeds from the cropped area is possibly a strong reason, as well as other agronomic practices wherein unwanted plants are not seen as monsters. Comparable usage might be less, but inappropriate and excessive usage is pervasive in India. Farmers and agricultural workers are unaware of the persistent hazards and the consequences of using these plant-killing herbicides. Regulators play a limited role in registering them and do nothing more. Scientists endorse in principle usage but remain oblivious to the challenges in field application and acute and chronic impacts of such usage. There is as yet no assessment of the agronomic advantage from the usage of these herbicides, which is routinely parroted whenever there is a question on such recommendations. No studies have been done on the economic benefits and risks between herbicide usage and manual removal of weeds in India. There are no defined, researched economic thresholds for herbicide usage in India.

This study identified 13 herbicides in whose case, official recommendations contradict nationally approved usage. Among them, 2,4 D, butachlor, diuron, glyphosate, oxadiazon, oxyfluorfen and pendimethalin are listed among the Highly hazardous pesticides by PAN International. Horribly, these wrong and illegal recommendations are for food crops, even though the regulatory approval is for non-food crops. The science that became handy at the time of registration of these chemicals seems to have been lost when it came to field recommendation. It is illegal as well and a blatant violation of science and law. Scientists, regulators and herbicide companies get away because Indian law does not have a liability principle provisioned in pesticide regulation. Enforcement of conditions linked with registered approval at the farm level is nil. There is no hierarchical push to enforce as well. Agricultural scientists, especially plant pathologists, remain blissfully unaware of the mismatch between registration and field application of these highly hazardous herbicides.

Highly Hazardous Herbicides (HHH) are threatening life - humans, animals and the environment by contaminating the air, water and soil. These chemicals have various toxic effects (neurotoxicity (toxic to the nervous system) cytotoxicity (toxic to cells), reproductive toxicity, endocrine toxicity, carcinogenicity (can induce cancer), genotoxicity (toxic to genetic material DNA) and respiratory toxicity). They are a grave threat to the biosphere. They can drift away from the point of application easily to water resources through leaching or runoff water. They are a major threat to all ruminants and to other life forms through biomagnification, i.e., travelling along the food chain. Pesticide poisonings, intentional and accidental, involving herbicides are happening all over India, leading to deaths and debilitating chronic effects on the victims. Doctors in a public hospital in Burla, Odisha, went on a strike seeking a ban on paraquat, unable to see havoc caused by this herbicide on victims of poisoning. These Doctors were disturbed by the deaths of patients who ingested this most hazardous herbicide. Herbicide poisonings are being documented in different parts of India. Studies highlight the acute and chronic impacts of herbicides. Research on the residual effect of herbicides on human and animal health, through food, water and soil, is low and rare. Research on the same needs to be prioritised by public research institutions focussing on public health.

The looming threat of herbicide-resistant weeds is a serious concern too. These weeds, which have developed resistance to these chemicals can disrupt and distort biodiversity and lead to imbalances in local vegetation. The US has seen the proliferation of such herbicide-resistant weeds. The Presence of herbicide-resistant weeds is on par with the intensity of herbicide usage and persistent. Resistance to multiple herbicides, in a single weed, as found in Punjab, needs more research on impacts and consequences. Unfortunately, the Indian regulatory system has failed to develop a monitoring mechanism for weed resistance, and how extant is the problem. Alien, invasive species have become an added threat to beneficial plants and vegetation, as they colonise land space. There is as yet no data on how many acres of precious fertile land are occupied by these alien, invasive species in India.

Choosing safe alternate practices, taking appropriate protective measures and developing a thorough knowledge of herbicide toxicity can reduce hazards. The status of herbicides in India shows the need for stringent and rigid national regulations and legislation. Awareness among farmers and agricultural labour about herbicides has to increase too. Consumers need to be alerted about the residues of herbicides in their food and water. All India Coordinated Research Projects (AICRPs) & network projects on pesticide residues should start sampling herbicide residues in food, water and air. ICAR should undertake periodical research to ascertain herbicide residues in intensive herbicide usage areas. Depending on the results of this research, appropriate measures can be taken.

CHAPTER 2

INTRODUCTION

In modern agriculture, controlling weeds is regarded as a necessary step for assuring the maximum growth and output of crops. Weed control became a top priority with the increased use of chemical fertilizers on soils, excessive reliance on external inputs, and hybridization of crop seeds. In order to increase the production of monoculture crops, farmers began implementing a variety of weed control strategies. Weeds can be managed in a few ways. Cultural, mechanical, and chemical techniques are among them. Traditional farming techniques including crop rotation, cover crops, stale seed-bed technique, and intercropping are examples of cultural practices. Mechanical weeding is the practice of pulling weeds with tools and instruments. Chemical weed control involves the use of phytotoxic chemicals that are capable of damaging plants, basically called herbicides/weedicides/weed-killers (Vats, 2015).

Herbicides are the largest product type accounting for 47.6% of global pesticide sales followed by insecticides (29.4%), fungicides (17.5%) and others (5.5%). They are a group of pesticides that selectively kill or inhibit the emergence of undesired weed plants and are widely used in agriculture, landscaping, industries, and gardening. It was during the mid-nineteenth century when Copper sulphate was first used for the control of *Brassica kaber* (charlock) growing among wheat in France. Iron sulphate was also used as a weedicide in the US in 1929[1]. Later during the beginning of the 20th century, sodium arsenate gained attention and was widely used in the US for the control of annual, perennial, and aquatic submerged weeds. The first organic herbicide introduced was DNOC (Dinitro Ortho Cresol). Later the introduction of the synthetic herbicide, 2,4-D in 1946, which can act as a hormone as well, became a breakthrough in the world of agriculture. The use of herbicides in India started in 1937 in Punjab. Sodium arsenate was used for the control of the weed *Carthamus oxyacantha*. With the import of 2,4-D during the 1960s, herbicide use in India increased extensively. Over the years, the production of herbicides also increased (Choudhary et al, 2016). It is likely to increase from 20 per cent of total pesticides, according to the Handbook on Herbicides (2009), brought out by the Directorate of Weed Research, Jabalpur, India[2].

Herbicides pose many threats to both human health and the environment. They are known to cause mild to severe health problems in organisms and human beings. This includes neurotoxic disorders, respiratory, reproductive and other physiological problems. Some herbicides are endocrine disruptors that can interrupt the functioning of endocrine glands and hormones. For the same reasons, careful handling of herbicides is highly necessary. This book scrutinizes the chemical approach to weed management, its consequences and the sine quanon of organic farming for secure and sustainable agriculture. Perils of herbicide toxicity continue. However, a great delay in addressing these issues by the government bodies has made it an act of mindless vandalism. The current list of registered herbicides in India, their statistics (import, export, production, consumption), regulations and judicial control on the legislation of herbicides are analysed in this study. The impact of herbicide uses on the ecosystem, it's deleterious effects on humans and other living organisms and cases of acute poisoning are discussed in this work. This book also provides insight into non-chemical approaches that can be adopted for weed management.

Purpose & Scope of the study

The purpose of this study is to focus on the various herbicides that are being used in India and the prevalence of Highly Hazardous Herbicides (HHH) among them. HHH are on par with Highly Hazardous Pesticides (HHP), when it comes to toxicity, if not more. This study also discusses the classification, mode of action, toxicity, public health consequences

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[1] https://listings.lib.msu.edu/lawnc/1929aug_b.pdf

[2] https://dwr.icar.gov.in/Downloads/Books_and_Other_publications/Hand%20Book%20on%20Herbicide%20Recommondations%20-%202009.pdf

of herbicides and different alternative weed management strategies for the mitigation of the weed species. This study helps in the comprehension of approved herbicides in India and the hazards posed by these toxic chemicals on both humans and the environment and to educate the public about the same and to develop a sustainable approach towards weed management. The relevance of this study is that it addresses the definition and current status of weeds in India and the various problems that accompany their eradication by chemical means of weedicide application. This study also highlights the statistical data of registered herbicides and lacunae in their regulation in the Indian context. This book can be beneficial for the implementation of the law, in undertaking corrective measures, and serve as a supplementary guide for phasing out herbicides by policymakers (including State governments, central government and NGOs) for environmental protection.

Methods

Secondary data was obtained from various official sources including numerous papers, articles, publications and books. The herbicides registered in India under the Insecticide Act, of 1968, were collected from the official website of the Directorate of plant protection, quarantine and storage. Information regarding the banned herbicides, and classification based on WHO Criteria were collected from the PAN International consolidated list of banned herbicides (PAN International Consolidated List of Banned Herbicides | PAN International (pan-international.org) and The WHO Recommended Classification of Pesticides by Hazard and Guidelines to Classification 2019, respectively. The HHP among the registered herbicides was based on the PAN international HHP List of highly hazardous herbicides (PAN International List of highly hazardous Herbicides (HHPs) March 2021 (pan-international.org)) and JMPM (Joint FAO/WHO meeting on pesticides management) Criteria.

The statistical data on the consumption of nationally produced and imported herbicides in the Indian States were obtained from the database of the Directorate of Plant Protection, Quarantine and Storage, under the division, Monitoring & Documentation (Statistical Database | Directorate of Plant Protection, Quarantine & Storage | GOI (ppqs.gov.in). Herbicides recommended for different crops in six states were obtained from study materials obtained from online literature sources available in different state portals. They are Package of practices recommendations-Kerala (2016), Crop production guide agriculture-Tamil Nadu (2020), Package of practice for horticultural crops-Assam (2010), Farmer’s handbook on basic agriculture-Andhra Pradesh (2016), Package of practices for the crops of Kharif - Punjab, Package of practices for cultivation of vegetables-Punjab (2022), Manual of agricultural production technology, Kharif crops, 2008- Orissa. They were analysed and compared to nationally approved usage (major use of herbicides-Directorate of Plant Protection, Quarantine and Storage) and presented in this study. These guides were meticulously analysed and violations of the recommended usage of herbicides were noted. Herbicide data were also collected from Pesticide info (https://www.herbicideinfo.org) by Pesticide Action Network North America.

CHAPTER 3

WEEDS

Weeds are generally defined as undesired plants that grow predominantly in a specific geographical area (farm fields, gardens, parks and lawns, etc.) along with desired crops or plants and competing for water and sunlight with the desired plants. Natural plants are termed as weeds, merely because they are unwanted and compete with the growth of manually lodged plants. In modern agriculture, regardless of their biological significance, they are considered impediments, inhibiting higher harvest from crops or plantations. There are different definitions of a weed, including[3]:

- a plant out of place and not intentionally sown
- a plant growing where it is not wanted
- a plant whose virtues have not yet been discovered. (R.W. Emerson, 1912)
- plants that are competitive, persistent, pernicious, and interfere negatively with human activity (Montanya et al, 2013) and many others

3.1. Classification of weeds

Weeds can be classified into different types according to their life span. They include annuals, biennials and perennials. Weeds which grow and complete their life in a season or a year can be called Annuals. They propagate through seeds and germinate in the following year. Following the seasons, they can be called monsoon annuals (e.g., *Commelina benghalensis)* and winter annuals (e.g., *Chenopodium album)* etc. Biennial weeds emerge in a particular season, followed by flowering and seeding in the next year whereas perennial weeds emerge and live for more than two years. They usually undergo seed propagation or vegetative propagation (propagation through underground stems, roots, tubers, rhizomes etc.). Based on the ecology of weed species, they are classified as (i) wetland weeds, which emerge in waterlogged or partially dry conditions, (ii) garden weeds, which can withstand dry conditions, and (iii) dry land weeds which are hardy plants and also drought tolerant. Weeds emerge anywhere they can grow. Those weeds, which infest crop/ fruit cultivated areas, are called agricultural weeds. Modern agronomy lists weeds as one of the major concerns farmers have to face as their virulence results in lesser crop yield due to competition over water, minerals and sunlight affecting higher crop production.[4]

The environmental plasticity of weeds is one of their major characteristics. It enables them to respond differently to varying environments by exhibiting high tolerance towards a wide range of climatic and edaphic conditions, modifying the seed production and growth with the availability of moisture and temperature. They exhibit dormancy (temporarily inactive period) without losing their viability to survive the rigours of the environment and when the conditions become favourable, they germinate. Some weeds also produce seeds that resemble the size and shape of the crop seeds making it difficult to identify them. Loss in agricultural production is attributed to weeds in most countries where modern agriculture is pursued. Studies reveal that some weeds are also capable of causing health problems in human beings such as hay fever, asthma (by pollen), dermatitis, itching, inflammation etc.

Weed emergence can be mitigated through various management techniques. Cultural, mechanical, biological, and chemical methods are among them. Cultural weed management techniques include intercropping, cover crops, crop rotation, using good quality seeds, and using stale seedbeds. Weeds are eliminated mechanically using a revolving hoe

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[3] **https://extension.psu.edu/introduction-to-weeds-what-are-weeds-and-why-do-we-care**
[4] **FSC 211: classification of weeds (iasri.res.in)**

(rotary or conical weeder), or weeding machine. The targeted employment of organisms like bacteria, fungi, viruses, insects, birds, fish, rodents, or plants for the selective eradication of weeds is done in biological weed management. Herbicides, however, which may be phytotoxic compounds, are used to manage weeds chemically. These can cause plant malformations by imitating natural plant growth hormones, which can limit cell division, photosynthesis, and amino acid synthesis. Application methods include spraying onto foliage, applying to soils and applying directly to aquatic systems[5]. Compared to other approaches, chemical weed control is more dangerous owing to the inherent toxicity of the chemicals used as weedicides.

3.2. Weeds in India

In India, nearly 337 weed species have been identified.[6]. Among terrestrial plants, many forest species have been identified as so-called weeds. They include both indigenous and introduced taxa. *Lantana camara* L., *Ulex europaeus* L., *Mikania micrantha* Kunth, *Euphorbia royleana* Boiss etc are a few to mention among forest weed species. Other than these sites, weeds can be commonly seen growing in roadsides, wastelands, public amenity areas and aquatic systems. Weeds when dominating the aquatic systems are a huge threat to other aquatic species as they compete for water, nutrients, oxygen and niche. The aquatic weeds of primary concern in India include the alligator weed {*Alternanthera philoxeroides*, (Mart.) Griseb.}, bullrush (*Typha angustata*, Bory & Chaub.), *Chara* spp., homwort (*Ceratophyllum demersum,* J.G. Klein ex Cham.), *Hydrilla verticillata* F. Muell., lotus (*Nelumbo nuciferct* Gaertn.), *Nitella* spp., *Potamogeton spp*, Salvinia (*Salvinia molesta* D.S. Mitchell), *Vallisneria spiralis* L., water hyacinth, and water spinach (*Ipomoea aquatica* Forssk.) (Rao and Chauhan, 2015). Weed emergence is usually linked to decreased crop yields in modern agriculture. They are considered major competitors for crop plants as they tend to self-sow and grow at a quicker rate throughout the early phases of crop development, competing for water, nutrients and space. Major weeds associated with different crops are provided in Annexure 2.

All India Coordinated Research Project on Weed Management (AICRP-WM) was launched in 1978 with the mandate to do research on weed management. This project grew to 23 centres by 2014, and has generated information relating to weeds in different cropped and non-cropped situations, management practices, herbicide residues and utilization aspects of weeds. Location-specific technologies for weed management were developed. Much before, in 1952, a Coordinated Weed Control Scheme on Wheat, Rice and Sugarcane was initiated in 11 States by the Indian Council for Agricultural Research (ICAR) to monitor the weed flora and explore the relative feasibility of economical weed control. In 1989, a National Research Centre for Weed Science (NRCWS) was established in Jabalpur, Madhya Pradesh. This was upgraded into the Directorate of Weed Science Research (DWSR) in 2009.

Weeds, sometimes, can be nasty as they as part of their defence, produce chemicals that are toxic to surrounding plants. A few become hosts and provide resources, shelter and reproductive sites for various pests including insects, mites, rodents, pathogens, nematodes and others. A study conducted by Prajapat et al in 2014 revealed that weeds serve as alternate hosts for certain plant viruses called begomo virus. This virus is capable of disrupting the photosynthesis of plants causing loss of yield. In Punjab and Haryana, carrot weeds (*Parthenium hysterophorus*) have been reported as a host for the *Ferrisia virgata o*r striped mealybug. They are also a host for *Nupserha* sp or cerambycid borer (Kumar et al, 2021). These are invasive and mostly alien, brought from elsewhere such as Parthenium[7] (popularly known as Congress grass).

However, the notion that all weeds are a menace to agriculture is a fallacy. Crops have many benefits from so-called weeds as some weeds can attract beneficial insects like wasps, flies and predatory beetles, which are natural enemies to pests. Many plants are consumable and can be used for medicinal purposes (herbs) and can also be used for distracting

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[5] **https://www.epa.gov/caddis-vol2/herbicides**
[6] **Hand Book on - Weed Identification.pdf (icar.gov.in)**
[7]**https://www.researchgate.net/publication/327592688_Parthenium_Weed_Biology_Ecology_and_Management**

insects (pests) from reaching target crops. Many plants when grown in combination with other crops, enhances their growth and survival. Such plants are called companion plants. Many so-called weeds are used for companion planting[8]. A very common example is Amaranthus. Most plants do better when planted with Amaranthus as this helps to improve the yield of crops and provides pest protection acting as a host for beneficiary predatory beetles. For the same reasons, it is used as a companion plant for crops like tomato, potato, sweet corn, eggplant, cucumber, runner beans, chilli pepper, peas and marigold[9]. In the same way, no plant is useless. They have their own biological significance. The table below summarizes the number of weeds and beneficial weeds growing among major crops in India. The beneficiary effects of certain weeds, commonly found in India are detailed in annexure 1.

Table 3.1. Table showing Major crops in India, associated weeds and beneficial weeds (in number)

Sl. No	Crop	Weeds	Beneficial weeds
1	Rice	25	8
2	sugarcane	29	12
3	maize	26	13
4	Soybean	44	10
5	cotton	35	11
6	wheat	28	9
7	Sorghum	8	4
8	Potato	14	9
9	Citrus	11	6
10	Grapes	20	15
11	Banana	6	2
12	Rubber	3	
13	Onion	17	7
14	Tea	33	9
15	Groundnut	20	7
16	Black gram	11	2
17	Green gram	3	3
18	Red gram	4	2
19	Sugarbeet	8	5
20	Tomato	10	4

(Source; major uses of herbicides- Directorate of Plant Protection, Quarantine and storage- compiled by PAN India)

3.2.1. Invasive weed species in India

The invasion of alien weed species has always been a concern in Indian agriculture and forestry. Many exotic weeds introduced as ornamental plants later flourished uncontrollably and became wild. Their morphological, physiological and demographical plasticity and the absence of natural enemies enabled them to flourish in their new world. Most of the invasive species in India are considered neotropical in origin, including *Lantana camara*, *Chromolaena odorata* (siam weed) and *Eichhornia crassipes* (water hyacinth). These 3 weeds are considered a few of the world's worst weeds. Lantana camara was introduced in Calcutta in 1809, which spread after getting adapted to the tropical, subtropical climatic conditions becoming a serious invasive plant in the country. Similarly, *C. odorata* (Gandhi gulabi/communist pacha) was introduced in Bengal as an ornamental plant which then spread to Kerala fortuitously through clothing of

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8 **Weeds as Companion Plants - Maine Organic Farmers and Gardeners (mofga.org)**
9 **What are the amaranth companion plants — ThumbGarden.com!**

the soldiers returning from Bengal. Other prominent invasive weeds include *Opuntia dillenii* Haw., *Mimosa pudica* Mill., *Lippia geminate* Kunth, *Jatropha gossypiifolia* L., *Parthenium hysterophorus* L, *Phalaris minor* Retz., *Eupatorium glandulosum* Michx., *Ulex europaeus* L., *Acacia mearnsii* De Willd, *Cytisus scoparius* (L.) Link, *Opuntia vulgaris* auct. non-P. Mill., *Prosopis chilensis* (Molina) Stuntz and *Euphorbia royleana* Boiss (Muniappan and Viraktamath, 1993). [10]. Directorate of Weed Science Research has not done research on the impacts of these invasive species on biodiversity, extinction of natural species and loss of ecological functions of these extinct species.

Invasive weeds, in most cases, is a biological impediment to not only agricultural crops but also to forest plants. They are generally termed Forest Invasive Species (FIS). According to the Asia-Pacific Forest Invasive Species Network (APFISN), the major FIS in India include *Ageratina adenophora* (Spreng.) (Crofton weed), *Ulex europaeus* L (Gorse), *Lantana camara* L, *Mikania micrantha* Kunth, *Cytisus scoparius* (L.) and *Euphorbia royleana* Boiss (Royle's Spurge). In a study conducted in Western ghats on the biological invasion of alien weed species in 1993, researchers reported the occurrence of weed species like *L. camara*, *C. odorata*, *Ageratina adenophora*, *Mikania micrantha*, *Mimosa invisa*, *Bidens pilosa* and *Prosopis julifora* (Muniappan and Viraktamath, 1993).

In India, Parthenium (*P. hysterophorus*) popularly called as Congress Grass, grows luxuriantly without any inhibition, colonising the given entire area in a matter of 3-4 years. The plants may grow as tall as 5-6 feet, with each plant producing over 5,000-10,000 seeds which are very small and light in weight. These seeds easily get disseminated by wind, water/ rain and movement of humans, animals and vehicles. It is believed it has arrived in India as a contaminant in wheat imports from the USA[11]. It was first recorded in 1955 in Pune and then the weed spread rapidly throughout the country within a span of 30-40 years, including the Andaman & Nicobar Islands. Besides roadsides, railway lines, playgrounds, parks, game sanctuaries and other vacant places, Parthenium thrives in neglected and poorly managed orchards, plantation crops and agricultural fields. Many methods, ranging from manual uprooting, chemical herbicides to biological control agents, have been proposed to limit the spread of this uncontrollable variety of grass. Biocontrol agents are the most preferred as they are inexpensive and cause few side effects. C*assia sericea*, a common leguminous plant, was introduced as a bioagent in parthenium-infested areas in India. *Cassia sericea* releases certain biochemicals by which it suppressed the germination and growth of parthenium, without affecting other plants and crops[12].

Alien, invasive weed species are a threat to local biodiversity as they can cause species extinctions, changes in hydrology and ecosystem function. They can also cause changes in the soil profile, nutrient content, decomposition and moisture availability of soil given the difference in their requirements, consumption and mode of resource acquisition from the species native to the area. As of now, nearly 60 invasive plant species have been identified in India (Bhatt et al, 2011). Some of the major invasive weeds in India are given in table 3.2.

Table. 3.2. Invasive plants in India.

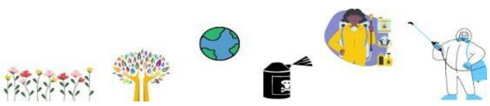
Sl. No	Invasive weed	Country of origin	Potential characteristics
1	*Ageratum conyzoides*	Tropical America	Fast-growing herb; high regenerative and reproductive potential (ay. 94,772/plant) lightweight seeds, dispersion through wind; strongly allelopathic
2	*Parthenium hysterophorus*	Tropical America	Fast-growing herb; high regenerative and reproductive potential (ay. 15,000/plant) lightweight seeds, dispersion through wind; strongly allelopathic
3	*Lantana camara*	Tropical America	Shrubby habit; high reproductive and regenerative potential; produces numerous seeds disseminated by birds, animals and even humans; strongly allelopathic

[10] https://dwr.icar.gov.in
[11] https://starofmysore.com/combating-congress-grass-scientific-name-parthenium-hysterophorus/
[12] https://www.downtoearth.org.in/news/biocontrolling-congress-grass-3054

4	*Chromolaena odorata*	Tropical America	Highly vigorous; high regenerative and reproductive potential; prolific seed producer (260,000/m2) with prolonged viability
5	*Mikania macrantha*	South America	Vigorous, rampant growth; produces 40,000 seeds/year
6	*Eichhornia crassipes*	Tropical America	Spreads fast due to quick vegetative (stolons) and sexual reproduction in water bodies
7	*Alternanthera philoxeroides*	South America	Aquatic herb, spreads through vegetative reproduction
8	*Salvinia molesta*	South America	Reproduces very fast
9	*Leucaena leucocephala*	South America	produces large number of seeds; ability to re-sprout
10	*Broussonetia papyrifera*	China, Japan	Prolific growth, multiplying rapidly vegetatively by suckering activity of root system
11	*Tagetes minuta*	South America	Spreads very fast by seeds and forms huge populations showing vigorous growth
12	*Prosopis juliflora*	Tropical America	Spread rapidly due to aggressive growth
13	*Sapium sebiferum*		Spreads very fast by suckers, re-sprouts very rapidly and produces large number of seeds over a year with effective dispersal
14	*Synedrella nodiflora*	Tropical America	Spreads through seed dispersal
15	*Anthemis cotula*	Europe, S. Africa	Spreads through seed dispersal
16	*Potamogeton crispus*	Eurasia, Africa, Australia, N. America	Tolerance to low light and low water temperature allows it to outcompete native plants
17	*Mimosa invisa*	Tropical America	Spreads very fast through seeds that remain dormant for up to 50 years
18	*Imperata cylindrica*	S E Asia	Aggressive and invasive nature is attributed to its rhizome, which produces numerous buds that sprout into new shoots

(Compiled by PAN India, Source: Bhatt, J.R., Singh, J.S., Singh, S.P., Tripathi, R.S. and Kohli, R.K., 2011. *Invasive Alien Plants an Ecological Appraisal for the Indian Subcontinent* (Vol. 1). Cabi.)

End note: Awareness, knowledge and research on weeds considered undesired plants is important. Local, biodiverse plants, castigated as weeds, in fact, may have a role in soil stabilization and improvisation, amenable for human consumption and co-development with crops. The biological significance of different weeds is inadequately understood. The dominance of monoculture and modernized agriculture has led to a reduction in native weed diversity and the disappearance of traditional farming systems. A negative perception towards weeds merely to enable profits for companies creates a conflict between modern agriculture and eco-friendly farming communities. Many so-called weeds have a major contributory role in supporting numerous ecosystem services. Dedicated institutions for weed research have to review their activities in relation to major native and invasive weeds found in India. This research has to be framed within the objectives of ensuring ecological conservation, biodiversity preservation and promotion of farmer's interests.



Chapter 4

HERBICIDES

Herbicides are chemicals that are used to kill weeds in a geographical area. In recognition of the way they are used in preventing the growth of alleged weeds, they are sometimes known as weed-killers or weedicides. They are frequently used in modern-day agriculture, landscaping, and domestic purposes. The potential for herbicides to have hazardous effects on non-target plants, the environment, and other organisms, including people, has made them a serious issue worldwide. In this chapter, we will discuss herbicides, their classification and their mechanism of action.

4.1. Classification of herbicides

Different herbicides belong to different chemical classes. They may function in a variety of ways, such as by obstructing cell division, reducing photosynthesis, or interfering with the production of amino acids by disrupting enzymatic activities. Herbicides can be categorized based on their chemical profile, mode and site of operation. Understanding how herbicides are categorized might help one better comprehend herbicide toxicity since it makes it possible to foresee how a herbicide might affect non-target creatures like plants, animals, or humans. Herbicides' disruptive and inhibitive impacts may have similar effects on other creatures, including humans, threatening their survival and well-being. For example, herbicides that prevent cell division may have the potential to alter both animal and human DNA, resulting in mutations and cancers. Knowing how herbicides are classified might therefore assist in weighing the disadvantages of using them in different environments. In this section, we will be discussing the classification of herbicides based on different criteria. They include,

1. Mode of application
2. Mechanism of transport
3. Soil degradation
4. Time of application
5. Chemical groups
6. Type of formulation
7. Specificity and
8. Mechanism of action

4.1.1. Based on the mode of application:

i) Soil-applied herbicides: Herbicides that are applied in the soil prior to planting or before the emergence of crops which are absorbed by roots and other underground parts of weeds are called soil-applied herbicides. E.g., Fluchloralin

ii) Foliage-applied herbicides: Herbicides that are applied in the foliage during the post-emergence period of crops, primarily acting on the plant foliage are called foliage-applied herbicides. e.g., Glyphosate, Paraquat

4.1.2. Based on the mechanism of transport

i) Contact herbicides: Those herbicides which should be applied specifically to plant parts to destroy the plant are called contact herbicides. E.g., Paraquat

ii) Systemic herbicides: They are also called translocated herbicides as they are applied on a part of the weed and are translocated to untreated parts of the plant through xylem/phloem tissues. E.g., Glyphosate. Those applied in the soil can also be included in this group.

4.1.3. Based on Soil degradation

i) Short-persistent herbicides: These include the herbicides whose residual effect (effects caused by the herbicides that remain in the soil after they are applied to plants) remains in the soil for up to a week. E.g., Paraquat, diquat, Amitrole.

ii) Medium persistent herbicides: For these herbicides, their residual effect remains in the soil for up to 2 to 6 weeks.

iii) Very long persistent herbicides: If the residual effect of the herbicides remains for a few months to years, they are called very long persistent herbicides. E.g. Prometon, Fenuron.

4.1.4. Based on the time of application

i) Pre-plant application

Pre-plant herbicides are applied to the soil before planting crops. They eliminate weeds prior to their emergence and resource competition with the crops. Depending on the weeds they target, pre-plant herbicides can either be selective or non-selective. E.g., fluchloralin, glyphosate.

ii) Pre-emergence herbicides

Preemergent herbicides are generally applied to prevent weed seedlings from germinating and growing. They function by preventing juvenile weeds from producing new root cells, which kill them before they can emerge from the ground. Depending on the type of crop and weed, preemergent herbicides are sprayed on the soil before the weeds or the crops have emerged. E.g., Atrazine, Pendimethalin, Butachlor.

iii) Post-emergence herbicides

Herbicides used against weeds after they have emerged from the ground are called post-emergence herbicides. Spraying plants with post-emergence herbicides causes them to be absorbed into the plant's system and impede its growth or metabolism. These herbicides are applied to the leaves and stems of the plants. Early post-emergence application is the application of herbicides that grow before the crop plants have emerged. E.g., Glyphosate, Paraquat, 2,4-D Na Salt.

4.1.5. Based on chemical groups

The functional groups present in the active ingredient of herbicide formulations determine the activity, selectivity, persistence and mode of action of that particular herbicide. Any modification in the functional groups can lead to modification in the activity of a herbicide. Based on the chemical groups present, herbicides are grouped under different chemical classes (refer table 4.2) with each performing specific functions. For example, herbicides belonging to the aliphatic classes interfere with RNA synthesis and modify the structure of proteins. Inhibition of hill reaction[13] in photosynthetic electron transport is performed by the herbicides belonging to the classes' amides, uracil, pyridazines, nitriles, diphenyl ethers, triazines and ureas. Aromatic carbamates, triazoles and thiocarbamates interfere with photosynthesis and alterations in the meristematic activity and are involved in the disorganisation of microtubular assembly.

Thiocarbamates and other heterocyclic herbicides are also involved in the inhibition of lipid biosynthesis. Bipyridiliums induce lipid peroxidation via the production of ROS (reactive oxygen species). Herbicides containing carboxylic acids, benzoic acids, pyridine derivatives, propionic acid derivatives and phenobutyric acids are involved in the inhibition of

[13] It is defined as the light-dependent transfer of electrons to hill reagents against chemical potential gradient resulting in the splitting of water molecules and evolution of oxygen.

normal plant growth mimicking auxins IAA (Indole acetic acid) and inhibits oxidative phosphorylation. Cineole inhibit the action of the asparagine synthetase enzyme. Imidazolines, triazole pyrimidines, sulfonanilide, sulphonylureas and pyrimidinyl-thiobenzoates inhibit cell division by acting on an enzyme called acetolactate synthase (ALS) which is involved in valine and isoleucine biosynthesis. Disruption of cell division is the characteristic function of the herbicides which belong to the classes dinitroanilines, imidazolines etc. Organophosphorus compounds are well known for the inhibition of biosynthesis of the amino acid phenylalanine. Imidazolidinones inhibit respiration and biosynthesis in weeds and pyridinones are well known for blocking carotenoid synthesis in weeds.

4.1.6. Based on the type of formulations

Herbicide formulations simply mean the mixture of chemicals to improve the shelf-life, handling, application and efficacy of an herbicide. Formulating a herbicide involves the mixing of an active ingredient with herbicide function with some other ingredients like solvents, carriers and adjuvants. Solvents are used for dissolving the active ingredient whereas carriers are used for the easy delivery of the same[14]. Herbicides are sometimes mixed with adjuvants for increasing their efficacy and shelf life through wetting, deposit building, deflocculating, emulsifying and spreading (Green, 2000). Different types of adjuvants used in herbicide formulations include activators antifoam/defoam, buffering and chelating agents, detergents, dispersants, foam markers, neutralizer petroleum oil, surfactant, U V protectants, acidifying agent, antifreeze, binder, compatibility agents, deposition agents, emulsifiers, humectants and modified seed oils. Penetrators, synergists, vegetable oils, additives, attractants, couplers, colourants, rain fast agents, safeners, thickeners and wetting agents are also used as adjuvants (Choudhury et al, 2016)

Table 4.1. Herbicides - type of formulations

Sl. No	Type of formulation	Herbicides
1	Wettable Powder (WP)	2,4-D, Diuron,
2	Liquid Water Soluble (Concentrates) (WSC)	Paraquat
3	Water Soluble Powder	2,4-D
4	Granule	Butachlor, 2,4-D
5	Dusts	2,4-D.
6	Emulsifiable Concentrates (EC)	Propanil
7	Pellet	Arsenic Compounds.

Compiled by PAN India

4.1.7. Based on the specificity

Herbicides that are plant-specific and kill only certain plant species leaving others unharmed are called selective herbicides. e.g., Atrazine. Herbicides, which are non-specific and destroy plants, in general, are called non-selective herbicides. e.g., Paraquat.

4.1.8. Based on the Mechanism of action

Different herbicides act in different ways to accomplish their function. Once they are applied, the active ingredients interfere with the metabolic machinery of weeds by acting on specific target sites, disrupting specific biochemical pathways and causing irreversible damage to the weed. This affects the sustenance of the plants and results in their

[14] **Pesticide Formulations (orst.edu)**

elimination. The various modus operandi involves inhibition. Interruption, disruption or mitigation. [15] The major mechanisms of herbicides action are detailed in this section. The table 4.3 shows various modes of action for different classes of herbicides.

Table 4.2. Herbicides - chemical groups

Sl. No	Chemical class	Group	Herbicides
1	Amide	Amide	Saflufenacil, Fomesafen
		Anilide	Flufenacet, Metamifop, Propanil
		Chloroacetanilide	Butachlor, Metolachlor, Pretilachlor
		Sulfonanilide	Diclosulam, Florasulam
		Sulfonamide	Penoxsulam,
2	Aromatic acid	Benzoic acid	Bispyribac
		Pyrimidinyl thiobenzoate	Pyrithiobac, Bispyribac-sodium
		Picolinic acid	Aminopyralid, clopyralid, picloram
		Quinolinecarboxylic acid	Quinclorac, quinmerac
3	Benzoylcyclohexanedione		Tembotrione
4	Bipyridylium		Paraquat dichloride
5	Carbamate		Chlorpropham
6	Cyclohexene oxime		Clethodim,
7	Dicarboximide		Flumioxazin
8	Dinitroaniline		Fluchloralin, Pendimethalin, Trifluralin
9	Diphenyl ether	Diphenyl ether	Fomesafen
		Nitrophenyl ether	Oxyfluorfen
10	Dithiocarbamate		Dazomet
11	Imidazolinone		Imazamox, Imazethapyr
12	Organophosphorus		Glufosinate ammonium, Glyphosate, Anilofos
13	Oxadiazolone		Oxadiargyl, oxadiazon
14	Oxazole		Topramezone
15	Phenoxy	Chlorophenoxy acid	2,4 D, methyl chlorophenoxy acetic acid
		Aryloxyphenoxy propionic	Clodinafop, Cyhalofo p butyl, Fenoxaprop ethyl, Fluazifop, Haloxyfop P, Metamifop, Propaquizafop, Quizalofop-ethyl, Quizalofop-P-terfuryl
16	Phosphonoglycine		Glufosinate ammonium, glyphosate
17	Pyrazole	Pyrazole	Azimsulfuron, Pyrazosulfuron
		Benzoylpyrazole	Topramezone
18	Pyridine carboxylic acid	Flroxypyr-meptyl	Pyridine carboxylic acid
19	Thiocarbamate		Thiobencarb, Tri-allate
20	Triazine(chloro/methoxy/methylthio)	Triazine	Ametryn, Atrazine, indaziflam
21	Triazinone		Metribuzin, hexazinone, metamitron
22	Triazolone		Carfentrazone-ethyl, Sulfentrazone
23	Triazolopyrimidine		Diclosulam, Florasulam, Flumetsulam, Penoxsulam
24	**Urea**	Urea	Methabenzthiazuron, Isoproturon
		Phenylurea	Diuron
		Sulfonylurea	Ethoxysulfuron, Metsulfuronmethyl, Sulfosulfuron, Azimsulfuron, Pyrazosulfuron, triasulfuron
		Benzoylurea	Novaluron
26	Unclassified		Cinmethylin,Fluthiacet,Clomazone, Dazomet, Pyriftalid

(Compiled by PAN India; Source: Herbicides and Environment, Andreas Kortekamp)

[15] **Modes of Action of Different Classes of Herbicides | IntechOpen**

Table 4.3. Mode of Action of Herbicides

Sl. No	Mode of action	Site of action	Chemical family	Herbicides
1	Auxin growth regulators	Auxin mimics	Benzoates, Phenoxy-carboxylates Pyridyloxy-carboxylates, Quinoline-carboxylates, Pyridine-carboxylates	2,4-D, MCPA, Florpyrauxifen, Fluroxypyr, Picloram Halauxifen
		Auxin transport inhibitor	Aryl-carboxylates	Diflufenzopyr-sodium
2	Amino Acid Inhibitors	EPSP synthase inhibitor (5-enolpyruvyl-shikimate-3-phosphate)	Glycine	Glyphosate
		ALS inhibitors (Acetolactate synthase)	Imidazolinones Pyrimidinyl benzoates Sulfonanilides Triazolinones Sulfonylureas Triazolopyrimidine - Type 1 Triazolopyrimidine - Type 2	Imazamox, Imazethapyr, Bispyribac-sodium, Pyrithiobac-sodium, Azimsulfuron Bensulfuron-methyl Chlorimuron-ethyl, Ethoxysulfuron,Flucetosulfuron, Halosulfuron-methyl, Mesosulfuron-methyl, Metsulfuron-methyl, Orthosulfamuron, Sulfosulfuron Florasulam, Penoxsulam
3	Pigment inhibitors	Phytoene desaturase (PDS) Inhibitor	N-Phenyl heterocycles, Phenyl ethers Diphenyl heterocycles	Flurochloridone
		DOXP synthase inhibitor	Isoxazolidinone	Clomazone
		HPPD inhibitors	Triketones, Pyrazoles, Isoxazoles	Tembotrione, Topramezone
4	Lipid biosynthesis inhibitors	ACCase inhibitors (Acetyl Co A carboxylase)	Aryloxyphenoxy-propionates (FOPs) Cyclohexanediones (DIMs) Phenylpyrazoline	Clodinafop-propargyl, Cyhalofop-butyl Diclofop-methyl, Fenoxaprop-ethyl Fluazifop-butyl, Haloxyfop-methyl Metamifop, Quizalofop-ethyl, Clethodim, Pinoxaden
5	Cell membrane disruptors	Photosystem 1 electron diverter	Pyridiniums	Paraquat
		PPO inhibitors	Diphenyl ethers, N-Phenyl-imides N-Phenyl-oxadiazolones, Phenylpyrazoles, N-Phenyl-triazolinones	Fomesafen, Oxyfluorfen, Flumioxazin Oxadiargyl, Oxadiazon, Saflufenacil Carfentrazone-ethyl
6	Nitrogen metabolism inhibition	Glutamine synthetase inhibitor	Phosphinic acids	Glufosinate-ammonium
7	Photosynthesis inhibition	Inhibition of Photosynthesis at PSll - Serine 264 Binders	Phenlcarbamates, Pyridazinone Triazines, Triazinones, Uracils Triazolinone, Amides, Ureas	Ametryne, Atrazine, Metamitron Metribuzin, Propanil, Diuron Methabenzthiazuron
		Inhibition of Photosynthesis at PSll - Histidine 215 Binders	Benzothiadiazinone, Nitriles Phenyl-pyridazines	Bentazon
8	Cell division Inhibition	Microtubule inhibitors	Dinitroanilines, Pyridines Phosphoroamidates	Fluchloralin, Pendimethalin, Trifluralin
		VLCFA inhibitors	Benzofurans, Thiocarbamates α-Chloroacetamides, Isoxazolines Azolyl-carboxamides, α Thioacetamides, Oxiranes	Thiobencarb ,Triallate, Alachlor Butachlor, Pretilachlor, Metolachlor Anilofos

(Compiled by PAN India, Source: Weed Science Society of America as on 05 May 2021)

4.2. Mechanism of action of herbicides

Mechanism of Action is the process in which a substance produces its effect on a target through interaction[16]. In this context, it refers to the specific biochemical interactions between active ingredients in a herbicide and specific target molecular sites in plants. Herbicides eliminate or inhibit their growth by acting on these sites to interfere with plant metabolism and biochemical pathways inducing irreversible damage, tissue injuries and lethality. The weed science Society of America has developed a series of groupings to help users to navigate the countless herbicide options available. Herbicides act through various *modus operandi* like inhibition, interruption, disruption and mitigation. The interaction of plants and herbicides is associated with absorption, metabolism, physiological response and translocation (Duke, 1990). Based on these, plants interact with different herbicides differently. In general, herbicides undergo the following processes.

- Contact with weed
- Absorption by the weed
- Movement to the site of action
- Potency to induce toxicity
- Cause death to the plant

The following section discusses the different mechanisms through which herbicides kill or damage weed plants.

4.2.1. Growth regulator herbicides

Growth regulator herbicides disrupt the normal hormonal balance of plants and regulate the cell cycle, protein synthesis and respiration in weeds. For the same reason, they are also called 'hormone herbicides' or 'synthetic auxins' and are mostly applied to foliage. These are capable of mimicking the Indole acetic acid (IAA) activity, disrupting the nucleic acid metabolism and damaging the cell wall integrity of the plant by activating the ATPase proton pump. This ultimately leads to uninhibited vascular growth and cell bursts by increasing transcription and translation (protein synthesis activity) in weed plants leading to their death (Duke, 1990).

4.2.2. Cell division Inhibitors

Some herbicides inhibit weed growth at the seedling phase (The phase shortly after they germinate and before they emerge). Being soil-applied herbicides, their activity majorly occurs beneath the soil. For the same reason, their effects are seldom seen. Their over-application may even inhibit the growth of crop seedlings. Generally, these herbicides inhibit the action of plants by disrupting the cell division process. Herbicides like phosphoric amide and dinitroaniline are well known for directly inhibiting cell division. They bind to tubulin and prevent its polymerisation (Tubulins are proteins which are polymerized into microtubules). This thereby prevents cell division and cell wall formation since microtubules are major components of the cytoskeleton and have a significant function in DNA segregation, intracellular transport and cell division. They are important in the formation of mitotic spindles. Some herbicides also bind to other molecular sites like microtubule-associated proteins and microtubule-organizing centres. Some inhibit cell division by inhibiting the enzyme acetolactate synthase involved in isoleucine and valine biosynthesis. Cell division inhibitors can be divided into two groups (Duke, 1990).

- Root inhibitors and
- Shoot inhibitors

[16] **What is a Mechanism of Action? | Study.com**

Root Inhibitors: They are also called seedling root growth inhibitors. These interrupt cell division and root growth in seedling weeds. If roots are not well developed, plants will be unable to take up enough water and nutrients to sustain growth eventually causing death. They are most effective when applied to grass weeds. Large-seeded weeds and crops are capable of surviving normal dosages. They inhibit root extension and growth by blocking cell division. Microtubules being their primary site of action, they prevent the polymerisation of microtubules by forming a herbicide-tubulin complex leading to the loss of structure and function of microtubules causing cell death through defective cell wall formation, non-alignment of spindle fibres and mitotic non-disjunction (Duke, 1990).

Shoot inhibitors: They are also called seedling shoot growth inhibitors. The shoot growth inhibitors are absorbed by the seedling shoots of grasses and roots of broadleaf plants. Just like root inhibitors, they also disrupt cell growth. They are most effective at controlling broadleaf weeds and act by inhibiting the biosynthesis of fatty acids, lipids, proteins, gibberellins, isoprenoids and flavonoids. Other groups belonging to the same mode of action act on very long-chain fatty acid (VLCFA) locations in the cell membrane. Some conjugate with acetyl COA (acetyl coenzyme A) and sulfhydryl-containing molecules and inhibit long-chain fatty acids. Conjugation is through thiocarbamate sulfoxides. This occurs during the seedling shoot growth and interrupts weed emergence (Duke, 1990).

4.2.3. Photosynthesis Inhibitors

As the name indicates these herbicides inhibit photosynthesis. Specifically, Photosystem II (PSII). Photosynthesis is the process by which plants convert light energy from the sun into sugars (food). They are basically broadleaf herbicides. They majorly bind and inhibit the activity of the D-1, a quinone-binding protein, which is involved in photosynthetic electron transport. Herbicides belonging to the chemical classes' amides, triazines, triazinones and urea are potential herbicidal photosynthetic inhibitors. The native plastoquinone binds to D 1 and interacts with histidine-215 and serine-264 of the protein. Thus, they disrupt the electron transport system. Likewise, they also inhibit CO2 fixation, ATP generation, and NADPH2 production in plants. When the ETS (Electron Transport System) is interrupted, the plant will generate triplet-chlorophyll which in reaction with molecular oxygen, forms singlet oxygen. In the presence of these two, unsaturated fatty acids and lipids undergo dehydrogenation, causing lipid peroxidation. This in turn causes the lipids and proteins in the bilayer to be oxidized and produces ROS (Reactive Oxygen Species) which is harmful to the plant. Photosynthetic inhibitors can also cause disruption of anthocyanin, carotenoids and other protein synthetic pathways and also can lead to cell collapse, disintegration and plant death. Their overuse can lead to herbicide resistance (Duke, 1990).

4.2.4. Pigment Inhibitors

Pigment inhibitors destroy chlorophylls, the highly significant green pigments necessary for photosynthesis present in leaf tissue. When the chlorophyll degenerates, plants die. Plant leaves appear yellow or white in the absence of chlorophyll. Hence, they are also called "bleaching herbicides" or "photo bleachers". These herbicides are applied both on foliage and in the soil. When applied, these are reduced by the photosystem 1 (PS1) to a radical that in turn reduces molecular oxygen into superoxide radicals. This can lead to excessive accumulation of superoxide radicals followed by rapid lipid peroxidation. The bipyridyliums are the one group that has been commercialized with this mechanism of action. They include paraquat and diquat. There are herbicides that do not depend on photosynthetic systems for action. They include p-nitro diphenyl ethers (DPE), oxadiazoles, and N-phenyl amides. They inhibit the action of an enzyme called protoporphyrinogen oxidase. This causes the uncontrolled autooxidation of protoporphyrinogen to protoporphyrin IX, a potent photosensitizer. This gets accumulated in plants. In soil-applied conditions, they are absorbed by roots and are translocated to the shoot tissues, which inhibit the production of carotenoids (not destroy them). Carotenoids protect chlorophyll. So, without them, chlorophyll is degenerated (Duke, 1990).

4.2.5. Carotenoid biosynthesis inhibitors (Phytoene desaturase inhibitors)

Carotenoids are highly important to plant survival. They protect plants from photooxidation, and are involved in the transmembrane transport of molecular oxygen. Most herbicides acting as carotenoid synthesis inhibitors block the terpenoid synthesis pathway in which carotenoids are formed. They include substituted pyridazinones, fluoridones, di funone, 4-hydroxy pyridines and phenoxy benzamides. They act by inhibiting phytoene desaturase enzymes. Amitrole is another herbicide that can inhibit carotenoid synthesis (Duke, 1990).

4.2.6. Cell Membrane Disruptors and Organic Arsenicals

Some herbicides restrict the growth of weeds by causing rapid desiccation of the plant disrupting the cell membrane and are called 'cell membrane disruptor post-emergence herbicides. They are of two types, the bipyridyliums and the diphenyl ethers. The former has no soil activity and requires thorough plant coverage for effectiveness. The latter act slower than bipyridyliums. They control both grasses and broadleaf weeds. Organic arsenical herbicides (DSMA and MSMA) are also cell membrane disruptors. However, their true mode of action is still unknown. They are used to control wide-leaved grasses such as crabgrass, bermudagrass lawns, cocklebur and common ragweed. These herbicides have no residual, pre-emergence activity since they bind tightly to soil clay and organic matter. They are also called contact herbicides.

PPO Inhibitors: These herbicides inhibit protoporphyrinogen oxidase (PPO/ PPG oxidase or Protox inhibitors) and thus disrupt the catalysis of chlorophyll and heme biosynthesis. That is protoporphyrinogen IX to protoporphyrin IX. This leads to the accumulation of PPIX, which in turn reacts to light and produces triplet-PPIX. This reacts with O2 and forms singlet oxygen and causes lipid peroxidation. The ultimate results are cell membrane disruption, oxidation of lipids and proteins, leaking of pigments, cell disintegration, wilting and plant death (Duke, 1990).

4.2.7. Lipid Synthesis Inhibitors

They are also called Acetyl Coenzyme A Carboxylase (ACCase) inhibitor. These herbicides disrupt lipid biosynthesis in weeds by inhibiting the ACCase enzyme, an enzyme which catalyses the primary step in fatty acid synthesis. They are more effective when they are applied to actively growing grass weeds. If grass weeds are stressed and slow growing, these herbicides will be less effective. Lipids are highly essential for the proper function and structure of plants. Plant cells contain lipid membranes, which help in the translocation of components in and out of the cell. When these herbicides inhibit the biosynthesis of lipids, it disrupts the formation of membranes in plants. They are mainly applied to foliage. They are hard to remove with water. An adjuvant like crop oil concentrate must be used to increase herbicide uptake into the leaf (Duke, 1990).

4.2.8. Pure electron transport inhibitors: They inhibit the hill reaction[17], photophosphorylation and can inhibit protoporphyrinogen oxidase (Duke, 1990).

4.2.9. Amino Acid synthesis inhibitors

They are also called AHAS (Aceto hydroxy acid synthase) inhibitors or branched-chain amino acid inhibitors. These Herbicides primarily inhibit the action of three major enzymes. They are

[17] **It is defined as the light-dependent transfer of electrons to hill reagents against chemical potential gradient resulting in the splitting of water molecules and evolution of oxygen.**

i) 5-enolpyruvyl-shikimate-3-phosphate synthase (EPSP synthase) which is an enzyme in the shikimate pathway that produces aromatic amino acids like tyrosine, phenylalanine and tryptophan

ii) Acetolactate synthase (ALS, also known as acetohydroxyacid synthase) which is involved in the branched-chain amino acid pathway which produces leucine, isoleucine and valine, and

iii) Glutamine synthetase (GS), an enzyme involved in the assimilation of inorganic nitrogen to produce an amino acid and converts L- glutamic acid to L- glutamine.

These three are highly important for the biosynthesis of amino acids. Glyphosate is a well-known competitive inhibitor of EPSP synthase. This results in the excessive accumulation of shikimate in plant tissues. This is aggravated by the deregulation of the shikimate pathway. ALS is majorly inhibited by three important herbicide groups; sulfonylureas, 1,2,4-triazole and imidazolines. Glufosinate is considered the actual inhibitor of GS (Glutamine synthetase). The inhibition of this enzyme leads to the accumulation of toxic levels of ammonia in plants causing rapid cellular collapse GS has a significant role in nitrogen metabolism which includes Nitrogen fixation, ammonia nutrition etc. It irreversibly inhibits the binding of glutamate to GS. These all lead to the disintegration of proteins, accumulation of ammonia, lowering of PH gradient across the cell membrane and disruption of PS1 and PSII which in turn leads to uncoupling of photophosphorylation. Some herbicides inhibit asparagine synthetase, an enzyme required for the generation of asparagine from aspartate. It is an important transport compound and has a significant role in the storage and transport of nitrogen.

Aromatic amino acid inhibitors: This is specific to glyphosate that are glycines. As the name suggests, they inhibit the synthesis of amino acids. They also inhibit the EPSP synthase enzyme and result in the depletion of aromatic amino acids (tryptophan, tyrosine, and phenylalanine) (Duke, 1990).

4.2.10. Folic acid biosynthesis inhibitors

They inhibit 7,8-dihydropteroate (DHP) synthase enzymes which are involved in folic acid synthesis by interrupting the conversion of 4-aminobenzoic acid and 7,8-dihydropteroate derivatives to 7,8-dihydropteroate. Folic acid is necessary for plants to transfer methyl groups involved in the synthesis of purines and pyrimidines (Duke, 1990).

4.3. Herbicide Resistance in weeds

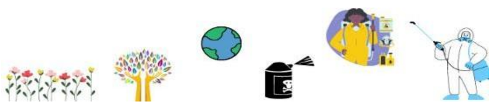
Herbicide resistance is the ability of plants including weeds to survive the effects of herbicides as a result of repeated application of a particular herbicide for the long term. Herbicide resistance when developed in weeds can result in the decreased response of weed species towards a particular herbicide. When a weed is resistant to more than one herbicide performing different mechanisms of action, it is termed multiple resistance. The development of resistance in *Lolium rigidum* is the first reported case of multiple resistance towards PS-II inhibitors, ALS inhibitors, ACCase inhibitors, mitotic inhibitors, glyphosate, etc. According to studies conducted on the same, multiple resistance in weeds can occur when a single herbicide is constantly used until that particular weed shows resistance followed by another herbicide resulting in the same. When a weed is resistant to more than one herbicide, all with a single mode of action, such resistance is termed cross-resistance. Such resistance in weeds can happen when there occur alterations in the target site of herbicides which makes them unable to induce their phytotoxic effects (Aslam et al, 2019). Sometimes the enhanced metabolism of plants detoxifies the toxic herbicides and inactivates them. Such resistance is reported in *E.colona* towards propanil as they have enhanced aryl-acylamidase activity.

A 4-year study was conducted to evaluate the impact of herbicide, an acetolactate synthase inhibitor, in annual broadleaf weed, field pennycress in wheat fields in Western Canada. The results of this study exemplified the development of ALS-inhibitor resistance in sensitive weed species through repeated application of herbicides (Beckie and Reboud, 2009). Studies say that the first cases of 2,4 D resistance in weed species were reported in climbing dayflower (*Commelina diffusa* Burm.f.) during the year 1957 (Busi et al, 2017).

In India, a case was reported in Punjab (1992-93), where a weed named *Phalaris minor* developed resistance towards the herbicide isoproturon (Malik and Singh, 1995). According to the reports, *Phalaris minor* has multiple herbicide resistance towards phenyl urea, sulfonylurea, aryloxy phenoxy propionates, phenyl pyrazolines, triazines and dinitroanilines herbicides with a different mode of action and is one of the major concerns in agriculture as it is considered one of the troublesome weeds of wheat in India (Chhokar and Sharma, 2008). The International survey of herbicide resistance recognizes 3 weed species with herbicide resistance in India. They are *Phalaris minor* (little seed canary grass), *Rumex dentatus* (Toothed dock) and *Cyperus difformis* (small flower umbrella sedge).

The resistance in weeds as a result of using herbicides has led to the development and modification of herbicide-tolerant (HT) crops. With HT crops being widely adopted, the application of herbicides increased. Increased usage of herbicides, particularly broad-spectrum ones like glyphosate, which can have detrimental effects on the environment and human health, is one of the main effects of HTCs. Research by Benbrook (2012) found that the use of HTCs in the U.S. increased herbicide use by 239 million kilograms between 1996 and 2011. This can result in the growth of "superweeds," or herbicide-resistant weeds, which need greater dosages or more toxic herbicides to manage. Additionally, the excessive use of herbicides can endanger human health as well as biodiversity by contaminating the land, water, and air. Therefore, HTCs shouldn't be considered a panacea for weed control. Rather, non-chemical weed management (IWM) strategies that incorporates various techniques such as crop rotation, cover crops, mechanical weeding, and biological control should be promoted. This can improve crop yield and quality, lessen the need for herbicides, protect the environment, and promote animal well-being.

End note: This chapter addresses the chemical approach of weed management and introduces hazardous herbicides particularly utilized for killing plant species. The various criteria for the classification of herbicides, how these herbicides induce phytotoxicity acting on specific target sites of the plants and herbicide resistance are elaborated in the chapter.



Chapter 5

Herbicides Regulation in India

5.1. Herbicides in Indian regulation

The Ministry of Agriculture under the Government of India regulates the export, import, sale and use of pesticides including herbicides in the country within the scope of the Insecticides act of 1968. According to the updated list of registered pesticides in 2022, 87 herbicides are registered in India as per the Insecticide act of 1968 (Table 5.1). The crops and the weeds approved for each herbicide are provided by the Directorate of Plant Protection, Quarantine and Storage.[18] Even though herbicides are one of the major concerns for native biodiversity, the Insecticide Act of 1968, does not integrate such a concern about them. It is merely registering a herbicide as approved for a particular crop-weed combination.

The herbicides are being registered and mass-produced in several countries despite the fact that they are toxic chemicals. According to USEPA (US Environmental Protection Agency), the effects of herbicides are strongly influenced by their toxic mode of action and their method of application.[19] Their unbridled use all over the world threatens the native biodiversity. Herbicides are applied either directly to the soil or on the foliage of the weeds. Usually, they are used on naked soil, even before the sowing of the crop has started. If sprayed on the soil, herbicides can bind with the nutrients in the soil and make it difficult for plants to take up these nutrients. Research[20] says that herbicides pose two major problems. i) environmental pollution ii) destruction of the soil-plant nutrient system. Consequently, crop yields can be affected by herbicide application. Direct applications can lead to the poisoning of non-target species (plants & animals) or indirect effects by the death and decomposition of plants. Farmers who are unaware of this have lost their standing crops, or have seen their yields affected due to the application of weedicides (Hussain et al, 2021)

The quantity and quality of a herbicide are the principal factors to be considered from manufacture to its application in the fields – a complete cycle. The USEPA declares transparency and accuracy in the risk assessments of pesticides and pesticide decisions. This is done by periodically re-evaluating pesticides through a registration review which includes the identification and mitigation of the risks that can be caused by pesticides by implementing necessary steps. Indian regulators also need to do periodic reviews of registered agrochemicals, especially Highly Hazardous Herbicides.

In India, the regulatory approval for herbicides is focused on crops rather than weeds. An herbicide should be approved for use according to its activity on specific weeds. It is still unclear how the CIB&RC (Central Insecticide Board and Registration Committee) approves a particular weedicide for a particular crop rather than weeds. Because of this kind of approval, one of the major challenges observed is that herbicides are being used on crops even in the absence of the respective weeds. Farmers believe that it is approved for application on the crop, not on the weeds associated with the crop. But then so-called weeds grow as per soil conditions, unlinked with the crop.

In 2019, the Kerala State government banned the sale and distribution of Glyphosate and all associated products citing its potentially threatening effects on both human health and the environment. Even though glyphosate is approved for tea and non-cropped areas, it was and is still being used in paddy fields and for crops like pineapple and banana and even in households for clearing grass. The action was based on a report put forward by Kerala Agricultural University (KAU) and a recommendation by the Agriculture Director. It was also part of the movement to transform Kerala into an 'Organic State'. This led the government to invoke Section 27(1) of the Insecticides Act, of 1968. Initially, the ban

[18] **Major_use_of_pesticide_herbicide_as_on_30.11.2021.pdf**
[19] **https://www.epa.gov/caddis-vol2/herbicides**
[20] **https://www.researchgate.net/publication/353181561**

was for 60 days from February 2. The continued ban on glyphosate with trade names 'Roundup' and 'Glycil' greatly relies on a report by KAU (Kerala Agricultural University) on its biosafety aspects. As per statistics of herbicides in the State, in 2017-18, glyphosate accounted for 129.436 tonnes alone of the total herbicides (318.476 tonnes). Glyphosate is one of the herbicides that top the sales chart of States in India. Not only glyphosate, the application of other harmful weedicides also surged by 71.25% compared to 2015-16 in the State. On 6th July 2020, The Ministry of Agriculture & Farmers' Welfare (MOA&FW) of the Government of India issued a draft notification restricting the use of Glyphosate through PCOs (Pest Control Operators).

Similarly, in 2018, Punjab Government issued a ban on all products of Glyphosate (Round-up, Excel, Glycil, Glider, Glydon, Sweep, Glyphogen etc.), citing its carcinogenic effect. PGIMER (Postgraduate Institute of Medical Education and Research), Chandigarh, stated that Glyphosate is a Group 2A Cancer causing material and can also cause other health problems and damage humans. But still, it is available for purchase online.

Telangana issued a temporary ban on glyphosate usage for a period of 5 months (June-October), for 3 years, from 2019-2021. The Andhra Pradesh government issued a similar order in 2018. Punjab government issued an order, dated 23rd October, 2018, wherein directions were issued to all pesticide manufacturers/marketers and dealers in the State not to sell glyphosate, to licensing authorities to take necessary steps for removal entries for glyphosate and return the stock to the companies. This order by Punjab mentions that in a meeting under the Chairmanship of the Union Secretary of Agriculture, on 14th June, 2018, the following resolutions were passed: 1. Instead of a nationwide ban on glyphosate, cotton-growing States can impose a temporary ban on glyphosate 2. States can remove the entries for glyphosate from the licenses issued by them. The Maharashtra government also issued such a limited order in 2019 against glyphosate to prevent the spread of illegal Herbicide-tolerant BT cotton seeds[21]. On 21st October, 2022, the Ministry of Agriculture and Farmers Welfare issued a restriction on the use of Glyphosate Order to restrict its use in the country considering its ill-effects, based on a draft notification issued on 6th July, 2020. However, following a challenge in the Delhi High Court, by the pesticide lobby, the government capitulated and put this order in abeyance.

5.2. Herbicide Regulations in other countries

Restrictions under law, on herbicide use, can be seen in many countries. One among them is the UK Poison Act of 1972. It states that liquid formulations of paraquat should only be used by professional farmers and gardeners.

In 2016, the U.S. Environmental Protection Agency approved Monsanto's dicamba-based herbicides under a conditional two-year registration with a constraint for drift. By 2017, dicamba usage increased after the introduction of new genetically modified soybean and cotton seeds that could be sprayed by dicamba. Another conditional registration was again given in 2018. However, in response to a lawsuit filed by conservation groups, in June 2020, the U.S. Ninth Circuit Court ruling invalidated the federal registration of Dicamba, used since the 1960s.

Ironically, and rather irrationally, one of the factors that contributed to the surge of herbicides was the herbicide resistance of weeds. Over-application of herbicides also caused damage to non-resistant crops in millions of acres of agricultural land and natural areas in the United States of America. Farmers protested and filed suits claiming damages for the loss as a result of herbicide use. More than 4,200 complaints were filed in 2018 that alleged damage to almost 4.7 million acres of soybean and cotton plants.

In 2015, Sri Lanka issued a ban on the import of glyphosate under the Import and Export (Control) Act citing its potential to cause chronic kidney disease. But later, this was allowed for tea and rubber cultivation for a period of 3 years. By 2019, glyphosate was permitted to be imported in restricted quantities for floriculture, sugarcane and coconut palms. In 2021, a ban was imposed on this along with other agrochemicals. Later, the ban on Glyphosate was lifted on August 5,

[21] https://www.thenewsminute.com/article/illegal-ht-bt-cotton-seed-trade-no-regulation-farmers-continue-be-scapegoats-133105

2022, allowing its imports into the country with an import control license requirement[22] and the blanket ban was removed.

In 2022, glyphosate is on the verge of the ban by the States of Guernsey's Health and Safety Executive following the accumulation of evidence regarding its toxic impacts on the environment, from October 31st. After the interdict, the retailers are completely prohibited from marketing or using glyphosate and glyphosate-linked products.

5.3. Legislation in India

All plant protection chemicals including herbicides/weedicides, insecticides, fungicides, and plant growth regulators are governed and regulated in India by the Insecticide Act, 1968 and the Insecticides Rules 1971. This Act and Rules are meant to regulate the registration, manufacture, sale, distribution, import and transport of pesticides, which applies to herbicides as well. They do not have separate or distinct provisions for regulating herbicides.

There are herbicides considered as 'deemed to be registered' which are being used in India without proper registration scrutiny. They were the ones that were being used before the establishment of the Insecticide Act in 1968. According to the report by Pesticide Action Network (PAN) India, 9 herbicides have entered into the list of deemed to be registered pesticides. They include 2,4 D, atrazine, butachlor, diuron, methyl bromide, MCPA, paraquat dichloride, propanil and triallate (Dileep et al, 2022). Five of them (2,4 D, butachlor, diuron, paraquat dichloride and triallate) has listed among Highly Hazardous Pesticides (HHP; refer to section 6.1 in chapter 6) by PAN International.

The dereliction of the Government in regulating herbicides is the ground for illegitimate and negligent use by the citizens. These chemicals are being distributed all over India. There is nothing in the regulation that can assure safety for a user. No training, not even a proper informative guide by responsible authorities. People, especially farmers are unaware of the toxic hazards of these chemicals and are becoming the victims of herbicide toxification. Even the bystanders and residents can sometimes become unintentional sitting targets. Among the herbicides registered in India, many are HHP and are banned in other countries because of their toxic effects. It is distressing that despite their pernicious effects; these herbicides are being registered and approved for use.

5.3.1. Product liability

The rising incidences of both intentional and unintentional pesticide poisonings in India are currently becoming one of the shockingly perturbing issues in the country. Several cases have been reported from different states like Maharashtra, Himachal Pradesh, Telangana, and Tamil Nādu due to the erroneous, ignorant and unabated use of pesticides. The causes of these pesticide poisonings are diverse. Occupational and intentional poisoning with herbicides has been reported in many Indian states such as Odisha, Karnataka, etc. Questions are being raised on these poisoning, including who is responsible for this affliction – producers, retailers or the customers.

Ideally, manufacturing companies and suppliers can be held responsible for the implications of pesticide poisoning. Herbicide manufacturing companies and suppliers are profiteering on farmer's ignorance about the plethora of products in the markets. Riding on such ignorance, these HHHs are being pushed through persuasive marketing strategies. Farmers are their prime targets. They are bewitched by the incentives of manufacturers and are lured to buy these products without much information on their hazardous nature. Many farmers and applicators are leading miserable lives due to chronic health effects from long-term exposure.

In California, a resident named Dewayne Johnson filed a lawsuit against the agrochemical company named Monsanto Co. He alleged that the herbicide product (roundup) manufactured by this cooperation was responsible for the occurrence of non-Hodgkin lymphoma in him. He accused the company of their negligent actions and of the production of a

[22] **https://www.dailymirror.lk/business/Government-lifts-import-ban-on-glyphosate/215-242574**

hazardous product. The company was made liable for the victim's illness and had to provide a compensation of $289 M.[23] There are cases in India where farmers were made liable for poisoning cases. These are the manifestations of judicial laxity. Product liability is the legal responsibility inflicted on manufacturers/suppliers/traders for producing or selling a defective product. In India, the Consumer Protection Act, of 2019, provides this provision. This act recognizes product liability and claims under Chapter VI, from Sections 82 to 87 and helps the victims of herbicide imperilments to act, utilize their rights and claim justice as citizens of India and bring herbicide cases before consumer courts. "Product Liability" is becoming one of the contentious discussions in India. But the act and provisions are meagrely explored in the country. The manufacturers of pesticide/herbicide products are no doubt liable for the sufferings of the victims due to their toxic products. This provision can be utilized by the customers to raise their voices against the market stratagems of companies to shove their toxic products into society, and needs to be publicized for wider awareness.

5.4. Herbicides registered for use in India

In India, 87 out of 318 pesticides are herbicides according to the updated list of registered pesticides as of 1-10- 2022 as per the Insecticide act of 1968. These herbicides are registered for commercial use, production, import and export as obtained from the list of insecticides registered under Insecticides/ Pesticides registered under Section 9(3).

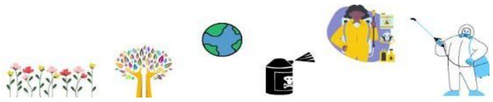
Table 5.1. Herbicides registered in India

Registered herbicides in India (As on 01.10.2022)					
1	2,4-Dichlorophenoxy acetic acid	30	Flucetosulfuron	59	Orthosulfamuron
2	2,4-D sodium	31	Fluchloralin	60	Oxadiargyl
3	2,4-D Amine salt	32	Flufenacet	61	Oxadiazon
4	2,4 D ethyl ester	33	Flumioxazin	62	Oxyfluorfen
5	Ametrine	34	Flupyrimin	63	Paraquat dichloride
6	Anilofos	35	Flurochloridon	64	Pendimethalin
7	Atrazine	36	Fluroxypyr meptyl (FI-WRT)	65	Penoxsulam
8	Azimsulfuron	37	Fluthiacet methyl (TIM)	66	Pinoxaden
9	Bensulfuron- methyl	38	Fomesafen	67	Pretilachlor
10	Bentazon	39	Glufosinate ammonium	68	Propanil
11	Bispyribac- sodium	40	Glyphosate	69	Propaquizafop
12	Butachlor	41	Halauxifen-methyl	70	Pyrazosulfuron- ethyl
13	Carfentrazone- ethyl	42	Halosulfuron- methyl	71	Pyriftalid
14	Chlorimuron- ethyl	43	Haloxyfop P Methyl	72	Pyrithiobac- sodium
15	Chlorpropham	44	Hexazinone	73	Pyroxasulfon
16	Cinmethylin	45	Imazamox	74	Quizalofop- ethyl
17	Clethodim (FI-WRT)	46	Imazethapyr	75	quizalofop-P-tefuryl
18	Clodinafop-propargyl	47	Indaziflam	76	Saflufenacil
19	Clomazone	48	Isoproturon	77	Sodium acifluorfen
20	Cyhalofop- butyl	49	Mesosulfuron Methyl	78	Sulfentrazone(TIM)
21	Dazomet	50	Mesotrione	79	Sulfosulfuron
22	Diclofop- methyl	51	Metamifop TI	80	Tembotrione
23	Diclosulam	52	Metamitron (TIM)	81	Thiobencarb
24	Diuron	53	Methabenzthiazuron	82	Topramezone
25	Ethoxy sulfuron	54	Methyl bromide	83	Triafamone
26	Fenoxaprop- P-Ethyl	55	Methyl chlorophenoxy acetic acid	84	Triallate
27	Florasulam	56	Metolachlor	85	Triasulfuron
28	Florpyrauxifen	57	Metribuzin	86	Trifloxysulfuron sodium
29	Fluazifop-P-butyl	58	Metsulfuron- methyl	87	Trifluralin

(Source: Directorate of plant protection, quarantine and storage)

[23] Monsanto ordered to pay $289m as jury rules weed killer caused man's cancer | Monsanto | The Guardian

End note: Regulation of herbicides in India and other countries needs debate and discussion. The regulation of herbicides in India is inadequate. The existing act has no provisions for the safe management of these chemicals, giving rise to illegal and unauthorized use in India. Many hazardous planticides are assertively being dumped into the Indian markets in the absence of a robust regulatory mechanism. The ignorance of farmers about the hazards from the usage of these chemicals is being exploited, and on which these companies are thriving on. Here, PAN India pinpoints inadequacies in the Indian regulation of herbicides, including the pernicious method of allowing deemed to be registered herbicides enabling some herbicides to bypass the minimal scrutinization at the time of registration. Information on herbicides registered in India as per the Insecticide act of 1968 is also given here. Other countries are also grappling with herbicide regulation. However, everywhere citizen groups have been raising issues from herbicide usage and trying to activate dynamic regulation. It has been a see-saw battle, of course.



CHAPTER 6

STATISTICS OF HERBICIDES IN INDIA

Herbicide actually began to be used in Punjab, India in 1937, for the control of *Carthamus oxyacantha* (also called wild safflower or jewelled distaff thistle) by using an inorganic compound, sodium arsenite. It was during the 1950s, the first synthetic herbicide 2,4 D invaded the Indian agricultural system. Herbicides became the most widely used class of pesticides due to rising global demand and consumption, which later led to their massive annual output around the globe. The consumption of herbicides is comparatively less in India with leading countries being the United States, Brazil, Argentina and China.24 In this chapter, the status of herbicide production, import, export and consumption in India is discussed.

As mentioned earlier, the regulation of herbicides in India is inadequate. The majority of the country's officially registered herbicide products demonstrate this deficiency. Among the 87 herbicides registered in India, many are Highly Hazardous Pesticides as per the PAN International list of HHPs and are banned in other countries due to their perilous effects on both humans and the environment. Among them, Paraquat and atrazine are the herbicides banned in most countries. Paraquat is one of the highly consumed herbicides, which is responsible for several poisoning cases in and outside of India. Atrazine is also one of the most commonly used herbicides in the world banned in the European Union. It is a skin and eye irritant with risks of posing reproductive effects and interfering with hormonal activity in humans and animals (USEPA, 2013). The table below shows the nationally registered herbicides, which are banned in other countries according to PAN International, consolidated list of banned pesticides, 6th edition, May 2022.

Table 6.1. Registered Herbicides in India and banned in other countries

Sl. No	Herbicides in India	No of Banned Countries	Sl. No	Herbicides in India	No of Banned Countries	Sl. No	Herbicides in India	No of Banned Countries
1	2 ,4-D	**5**	11	Fluazifop-P-butyl	1	21	Oxadiazon	29
2	Anilofos	**30**	12	Glufosinate ammonium	29	22	Oxadiargyl	31
3	Ametryn	**30**	13	Glyphosate	**4**	23	Oxyfluorfen	1
4	Atrazine	44	14	Hexazinone	**40**	24	Paraquat dichloride	58
5	Butachlor	32	15	Isoproturon	**30**	25	Pendimethalin	1
6	Chlorpropham	**30**	16	Methabenzthiazuron	**30**	26	Propanil	**31**
7	Dazomet	1	17	Metsulfuron- methyl	1	27	Sulfosulfuron	1
8	Diclofop- methyl	**3**	18	Metolachlor	31	28	Thiobencarb (Benthiocarb)	29
9	Diuron	**31**	19	Novaluron	**30**	29	Triasulfuron	**31**
10	Ethoxy sulfuron	29	20	Orthosulfamuron	29	30	Trifluralin	**31**

(Compiled by PAN India, Source: PAN international consolidated list of banned herbicides, 6th edition, May 2022)

[24] Global herbicide consumption by country | Statista

6.1. Production of key herbicides in India

Table 6.2. Production data of key herbicides during the year 2016- 22
(Unit: QTY in Metric Ton)

Sl. No	Herbicides	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22
1	2,4-D	23358	25830	24236	22555	27050	39996
2	Atrazine	1895	2249	1477	1730	1611	1689
3	Diuron	3679	3262	3618	3397	3423	2325
4	Glyphosate	6352	6294	6684	5911	6129	5722
5	Isoproturon	132	-	-	-	-	-
6	Metribuzin	1120	882	1919	2648	3191	1999
7	Pendimethalin	-	3780	2822	2753	3639	4764
8	Pretilachlor	2581	3597	3626	3066	3587	3218
	Total	39117	45849	44382	42060	48630	59713

(Source: Production of key herbicides in India (2016-21), Directorate of Plant Protection, Quarantine and Storage, India)

The production data of only 8 herbicides out of 87 registered is available officially, as in Table 6.1, for the period 2016-22. Among the 8, for Isoproturon only one-year data is available. The production data for other 79 registered herbicides are not provided. There is no officially provided explanation about why the regulatory authorities think only these 8 are key herbicides. From this data, it is apparent, 2,4 D is highly produced in India, followed by glyphosate, pendimethalin and pretilachlor. Also, each year, the production of this herbicide shows a fluctuating trend with the highest production marked in 2021-22. A similar trend is observed for pendimethalin too. As for glyphosate, the production rate is fluctuating with the lowest production in 2021-22. In the absence of export data of these HHHs, except on 2,4 D, it can be assumed these volumes are consumed nationally. The overall production of key herbicides had increased in 2022 (59,713 MT) from the previous year (48,630 MT), which in turn surpassed the preceding years. While data integrity is a question, given the secrecy surrounding regulation, the growth of herbicides is accelerating in India. Higher production of HHHs (2,4 D, glyphosate, pendimethalin, diuron and metribuzin) is disturbing. Globally, herbicides have the highest share of consumption, among all agrochemicals, which was not the case in India. Trends in the production of key herbicides in India are depicted in graph 6.1. The overall production of herbicides from 2016-22 is given in fig 6.2.

Fig 6.1. Production data of key herbicides during the year 2016- 2022

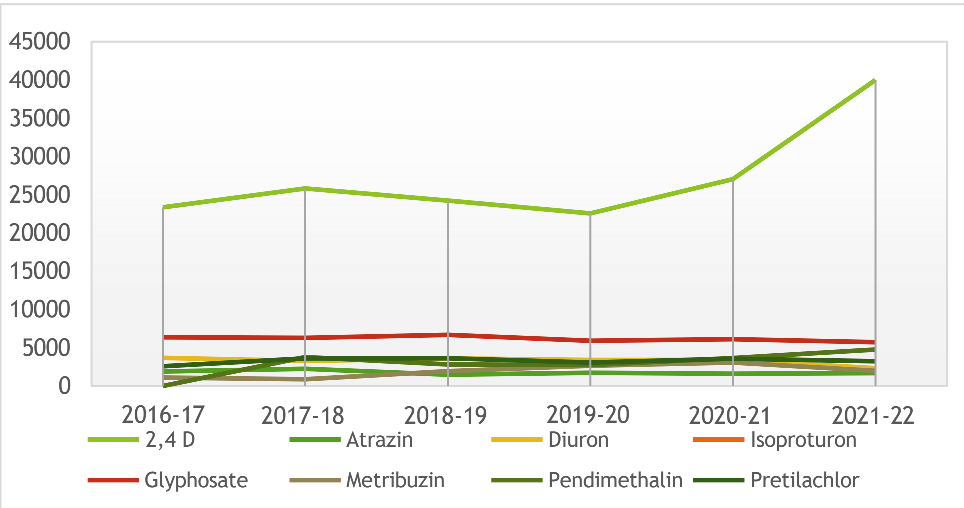
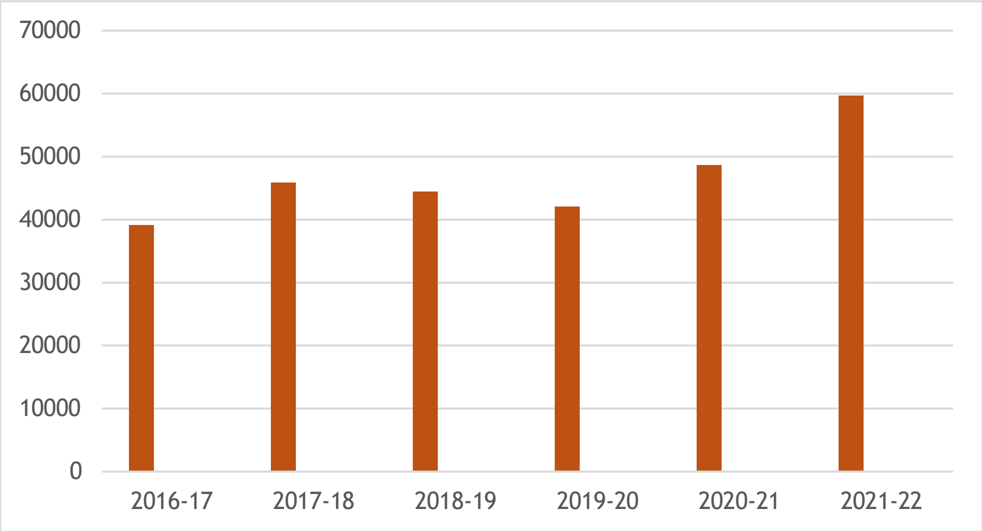


Fig 6.2. Overall Production of Key herbicides during the period 2016- 2022



6.2. Import of key herbicides in India

Herbicide imports are rising in India. The reason for the higher imports in 2020-21 needs to be researched. China is the largest herbicide supplier to India. The statistical data of 3 imported key herbicides for the period 2016-2022 are given in table 6.3. The import data for herbicides except these 3 are provided under 'other herbicides'. This data does not provide adequate information on which specific herbicides are accountable for these values for the herbicides listed under "other herbicides." HHPs may or may not be a part of it.

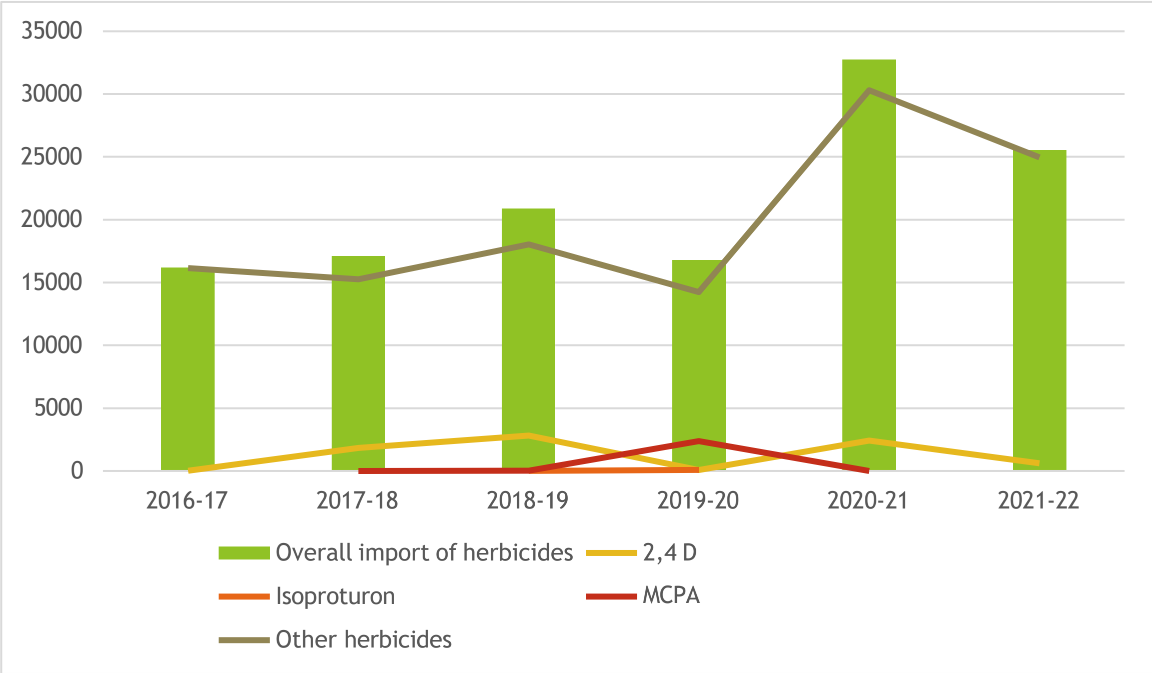
Table 6.3. Import of key herbicides in India
(Unit: QTY in Metric Ton)

Sl. No	Herbicides	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22
1	2,4-D	16	1824	2819	85	2412	600.72
2	Isoproturon	-		3	84	-	-
3	MCPA	-	10	13	2,378	0.04	0
4	Others Herbicides	16,149	15,248	18,044	14,238	30,307	24,958.93
	Total	16,165	17,082	20,879	16,785	32,719.04	25,559.66

(Source: Import key herbicides in India (2016-21), Directorate of Plant Protection, Quarantine and Storage, India)

Among these three herbicides, 2, 4-D is a highly hazardous herbicide given its toxic effects on human beings. In 2016, 16 Metric Tonnes of 2, 4-D were imported into India. In each subsequent year, an increasing trend in its imports can be seen, with the highest import quantities in 2018-19 and 2020-21. This indicates an increasing demand for 2,4-D even though it is an HHP. For the rest of the herbicides, isoproturon and MCPA, the highest import can be seen during the year 2019-20. The data for the former is inadequate. For the latter, a decreasing trend of import is observed from 2020-22. But the import of "other herbicides", exclusive of 2,4 D, isoproturon and MCPA, reached a higher level of 32,719 metric tons in 2020-21, but decreased in the succeeding year. Overall, the import rate of these 4 kinds of herbicides is increasing each year, with the highest rate reported in 2020-21, but decreased in 2021-22. The increasing and decreasing trends in the import of herbicides and overall import in India during 2016-22 are depicted in the graph below.

Fig 6.3. Import of key herbicides (2016- 2022)



6.3. Export of key herbicides in India

The statistical data of 3 key herbicides exported, for the period 2016-2022, are given in the table 6.4. The export data for herbicides except these 3 are provided under 'other herbicides'. This data does not provide adequate information on which specific herbicides are accountable for these values for the herbicides listed under "other herbicides." HHPs may or may not be a part of it.

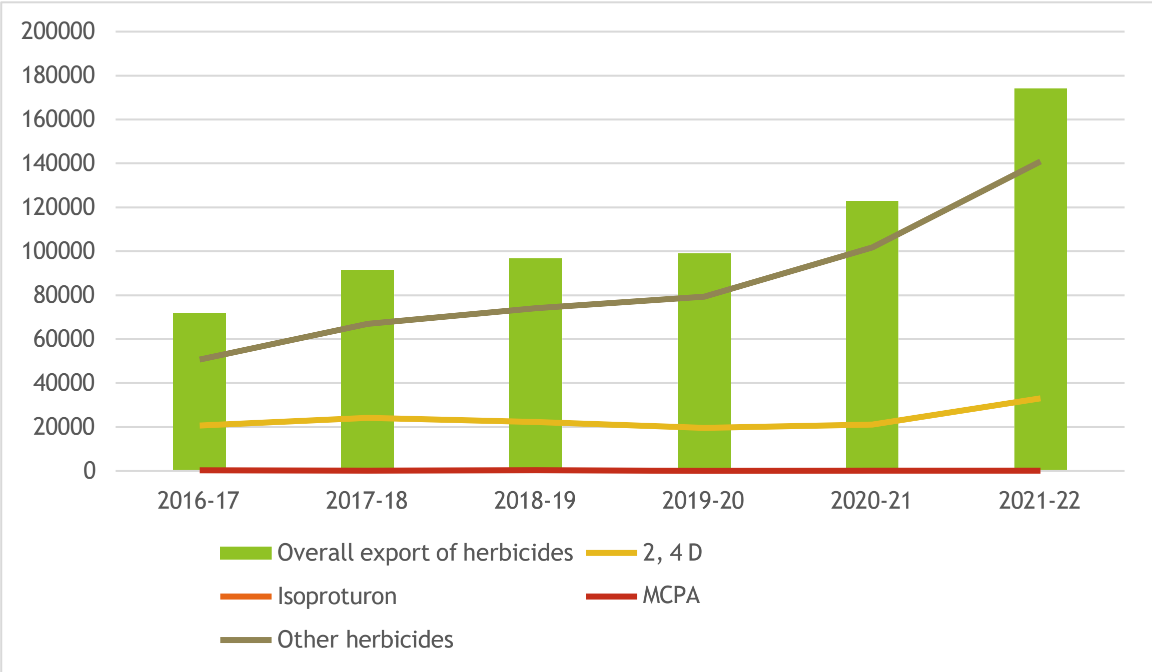
Table 6.4. Export of key herbicides in India
(Unit: QTY in Metric Ton)

Sl. No	Herbicides	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22
1	2:4 D	20,677	24,212	22,242	19,620	21,097	33,070
2	Isoproturon	356					
3	MCPA (Methyl chlorophenoxy acetic acid)	344	215	345	66	167	163
4	Others Herbicides	50,720	67,002	74,058	79,365	1,01,726	1,40,909
	Total	72,097	91,429	96,645	99,051	1,22,990	1,74,142

(Source: Export of key herbicides in India (2016-21), Directorate of Plant Protection, Quarantine and Storage, India)

Export of 2,4 D and other herbicides except for isoproturon and MCPA (Methy chloro phenoxy acetic acid) has increased a lot when compared to the preceding years. An increase in the export rate of a product clearly represents its increased production. The statistical data for the production of herbicides showed us that 2,4D is highest produced herbicide in the country in the last year. The export rate is also high for 2,4 D. It can be inferred that the reason for the high production of this HHP is not only because of its high demand in India but also in other countries as well. 2,4 D is the highest exported herbicide in 2021-22. A similar trend is also observed for 'other herbicides. Overall, the export rate of herbicides kept on increasing each year, with the highest rate reported in 2021-22. India is becoming an exporter of herbicides is apparent from this data.

Fig 6.4. Export of key herbicides during the year 2016- 22



6.4. Consumption of nationally produced herbicides in India

The statistical data for the consumption of nationally produced herbicides in India during the years 2017-22, provided by the Directorate of Plant Protection, Quarantine and Storage (PPQS) is given in table 6.5 (Those listed as HHPs are coloured). The data are inadequate as the consumption of a few herbicides is not disclosed for certain years. Only 31 herbicides whose data is available for 2017-22 are mentioned in the table.

During the year 2017-18, the consumption of 31 herbicides was 3139 MT. By 2021-22, the consumption level of these 31 herbicides increased by 76 percent to 4079.48 MT. The highest consumption between 2019 and 2022 is reported for 2,4-D (amine, ethyl and sodium salts) which supports our inference that 2,4 D is a highly produced herbicide in India. High production combined with the import of 2,4 D (amine, ethyl and sodium salts) might have led to higher consumption. This is also a matter of concern given its harmful potential to both living things and the environment. Overall, the consumption of given 31 nationally produced herbicides has increased when compared to the preceding year 2020-21. For the past 6 years, consumption is growing and has not faltered.

From the statistics, it is evident that the consumption of HHHs in India has increased in the past year. In the case of diuron and oxyfluorfen, a decreasing trend in consumption can be seen during 2021-22. But for other HHPs increased consumption can be observed. Among the indigenous highly hazardous herbicides (HHHs), 2,4 D holds the topmost position followed by glyphosate and butachlor in 2021-22. This can be a result of the high production of 2,4 D and glyphosate as a result of its high demand. It supports the finding that 2,4 D and glyphosate have first and second positions among the production of herbicides in India. 2,4 D consumption in India is alarming because it is considered a group 2B carcinogen by IARC. Glyphosate consumption was 654 MT in 2017-18. But in 2020-21 its consumption had decreased to 505.19 MT (29.45 percent decrease) but again rose the next year to 571.06 MT (13 percent increase). Even the slightest increase in the consumption of this herbicide is alarming because Glyphosate is labelled as a 'probable human carcinogen' (IARC, 2015) and is responsible for several poisoning cases in India (Dileep and Reddy, 2020). Figure 6.8 shows the statistical representation of nationally produced HHHs in India whose data is fully provided by PPQS. A similar trend can be seen for paraquat dichloride, another hazardous controversial herbicide with the highest consumption observed in 2021-22 (127.82 MT, a 58% increase from the preceding year). This herbicide itself is responsible for several poisoning cases reported in India. Hence, its consumption increase is tensing. The consumption of pendimethalin follows a fluctuating trend over the past years with its highest consumption marked in 2021-22 similar to paraquat.

Table 6.5. Consumption of Nationally produced herbicides in India (2016-21)
(Unit: Qty in Metric Ton) - coloured row indicates HHP

Sl no	Herbicides	2017-18	2018-19	2019-20	2020-21	2021-22
1	2,4-D Amine Salt	2	5.33	1066.81	926.8	1031.45
2	2,4-D Ethyl Ester	13	12.81	5.65	12.86	10.20
3	2,4-D Sodium Salt	898	26.88	22.9	8.2	0.01
4	Ametryn	28	64	25	25	25.00
5	Anilophos	14	159.53	138.2	28	29.00
6	Atrazine	302	387	346.26	287.82	331.88
7	Butachlor	343	565.24	354.1	209.17	220.01
8	Bispyribac sodium	147	25.08	25.76	35.12	33.01
9	Carfentrazone Ethyl	4	13.15	15.7	15.67	16.99
10	Clodinafop-Propargyl	67	134.03	147.4	53.16	149.68
11	Chlorimuron Ethyl	2	9	13	12	12.00
12	Diuron	123	56.53	12.46	11.54	10.37
13	Ethoxysulfuron	1	1	1	1	1.00
14	Fluchloralin	6	9.4	3.35	15	14
15	Fenoxaprop-P-ethyl	3.00	7.00	15.00	13.00	12.01

Sl. No	Herbicides	2017-18	2018-19	2019-20	2020-21	2021-22
16	Glyphosate	654	679.81	571.49	505.19	571.06
17	Halosulfuron methyl	3	13	16	16	16
18	Imazamox	1	1	1	1	1
19	Imazethapyr	60	45	48	74	84.06
20	Isoproturon	12	174.1	291.9	14	184.00
21	Metribuzin	67	106.73	110.7	68.2	105.43
22	Methyl bromide	8	18.00	16.20	28.00	88.48
23	Oxadiargyl	2	6.66	4.5	4	5.14
24	Oxyfluorfen	5	16.37	17.66	34.16	29.25
25	Paraquat Dichloride	53	107.3	113.18	74.49	127.82
26	Pendimethalin	152	137.69	198.94	149	201.92
27	Pretilachlor	132	276.68	621.37	666.83	657.83
28	Propanil	3	3.7	2.5	4	2.00
29	Pyrazosulfuron ethyl	3	1.62	2.14	7.18	4.30
30	Quizalofop ethyl	8	15.00	31.00	33.00	31.00
31	Sulfosulfuron	23	58.20	76.40	56.84	73.58
TOTAL		3139	3136.84	4315.57	3390.23	4079.48

(Source: Directorate of Plant protection, Quarantine and Storage)

Fig 6.5 a. Consumption of nationally produced herbicides and HHHs in India (2017-22)

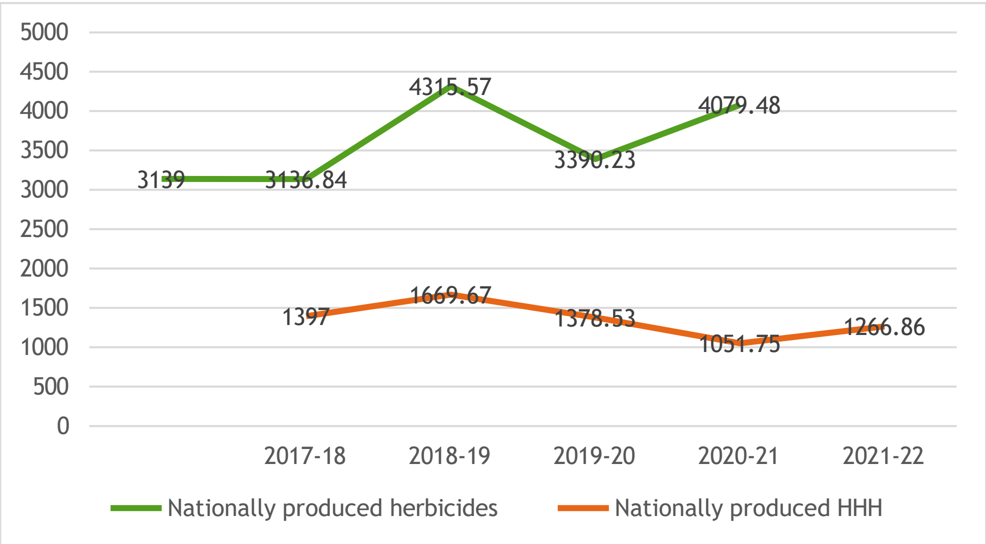
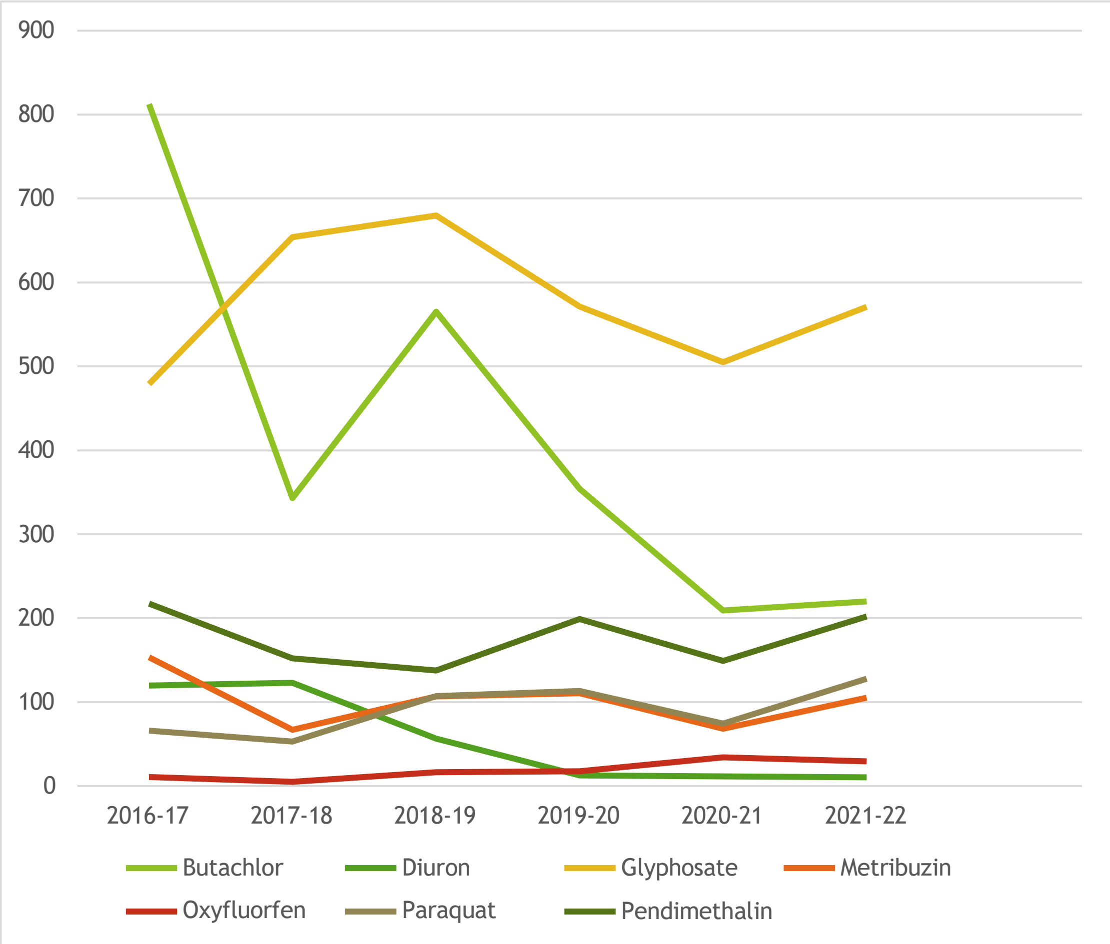


Fig 6.5 b. Consumption of nationally produced herbicides and HHHs in India (2017-22)



6.5. Consumption of imported herbicides in India

Given how many herbicides that are Highly Hazardous are being unrestrictedly brought into India, it is a mind-numbing issue. The HHPs that are being imported into India include 2,4 D, Butachlor, Glufosinate Ammonium, Glyphosate, Metribuzin, Oxyfluorfen, Paraquat dichloride and Pendimethalin. Among these imported herbicides, paraquat, glufosinate ammonium and butachlor have been banned in many countries and still are being imported to India.

The statistical data for the consumption of 21 imported herbicides in India between 2017 and 21 is given in table 6.6. However, this is not complete and there are data gaps for 21 herbicides. Only for 3 herbicides data for all 4 years is available. Inconsistency in data is not explained by the government. It would be interesting to know how the consumption of imported herbicides is tracked or collected. For example, 2,4 D import data between 2017-22 shows 7740.72 MT. But the consumption data for 2017-18 shows 28 MT and that of proceeding years is not provided. But the import of 2,4 D for 2017-18 shows 1824 MT. It can be seen that consumption is far lower than the imports in this year. It is not clear where and how did the 1,796 MT surplus 2,4 D go. Was it exported or consumed next year or thrown away as an obsolete herbicide? This indicates that all is not well with information collection, data collation, monitoring and regulation of herbicide imports, exports and consumption.

Table 6.6. Consumption of imported key herbicides in India
(Unit: QTY in Metric Ton)

Sl. No	Herbicide	2017-18	2018-19	2019-20	2020-21
1	2,4-D	28.00	-	-	-
2	Anilophos	3.00	-	-	-
3	Atrazine	30.00	-	-	-
4	Butachlor	37.00			
5	Clomazone	-	0.90	-	-
6	Ethoxysulfuron	-	-	0.20	-
7	Fluchloralin	4.00	-	-	-
8	Glufosinate-Ammonium	-	-	0.20	-
9	Glyphosate	104.00	-	-	-
10	Imazethapyr	1.00	0.50	0.40	
11	Mesosulfuron Methyl	-	0.60	-	-
12	Metsulfuron methyl	0.50		0.50	
13	Metolachlor	2.00	-	-	-
14	Metribuzin	11.00	10.40	19.00	19.00
15	Oxadiargyl	3.00	2.00	4.00	4.00
16	Oxyfluorfen	3.00	2.20	6.00	6.00
17	Paraquat Dichloride	20.00	-	-	-
18	Pendimethalin	7.35	1.50	1.40	-
19	Pretilachlor	33.00	8.64	2.00	-
20	Propanil	-	4.50	-	-
21	Sulfosulfuron	6.47	6.93	8.05	
	Subtotal	293.32	38.17	41.75	29

(Source: Directorate of Plant Protection, Quarantine and Storage, India)

The data for the year 2021-22 is not yet available. The coloured rows indicate the HHPs. When it comes to the case of imported herbicides, the consumption is very low compared to the nationally produced herbicides. Even in the case of HHPs. The use of imported herbicides cannot be assessed given these data gaps. Of the 3 herbicides, for which complete data is available, consumption is on the rise from 17 MT in 2017-18 to 29 MT in 2020-21. In 2017-18 the consumption volume of 21 imported herbicides was 293.32. In 2020-21, available consumption data of only 3 herbicides shows 29 MT. As in the case of imported HHHs, the consumption volume is not updated for the year 2020-21, except metribuzin and oxyfluorfen. The status of imported HHHs is unclear. In fact, the import reduction was quite drastic in 2018-19, for whatever reason. For example, Glyphosate data for the years 2018-19 to 2021-22 is not shown. This kind of fragmentary data provided by official sources makes it difficult to derive an anticipation.

6.6. Comparative analysis of State level recommendations of herbicides and nationally approved usage

In this study, the recommended usage of herbicides in different states in India was analysed. States selected for this study are Kerala, Tamil Nadu, Andhra Pradesh, Orissa, Punjab and Assam. Herbicide recommendations for different crops were collected from the package of practices recommendation provided for each state. Violation of the recommended usage of 13 herbicides to non-recommended crops was noted in the study. The herbicides and their recommended crops in selected states of India along with their recommended usage are tabulated below. The national crop recommendation for each herbicide is also given in the tables. Herbicides which are used in non-recommended crops are marked in blue. Not all the sources are taken from official government sites. However, care is taken while interpreting the data.

6.6.1. Kerala

Table 6.7. Herbicide recommendations in Kerala

Sl. No	Herbicides	Recommended Crops	Nationally approved crops	Crops not in compliance with Nationally approved crops
1	2,4 D (HHP)	Rice	Rice, Maize, wheat, sorghum, potato, sugarcane, citrus, grapes	-
2	Azimsulfuron	Rice	Rice	-
3	Bispyribac sodium	Rice	Rice	-
4	Butachlor (HHP)	Rice	Rice	-
5	Carfentrazon	Rice	Rice, wheat	-
6	Cyahalofop butyl	Rice	Rice	-
7	Diuron (HHP)	Pineapple	Cotton, banana, rubber, maize, citrus, sugarcane, grapes	Pineapple
8	Ethoxysulfuron	Rice	Rice	-
9	Fenoxaprop- p-methyl	Rice	Rice, Soybean, Wheat, black gram, cotton, onion, groundnut	-
10	Glyphosate (HHP)	Cashew, Rubber, Pineapple	Tea & non-crop area	Cashew, Rubber, Pineapple
11	Metribuzin (HHP)	Sugarcane	Soybean, wheat, sugarcane, potato tomato	-
12	Oxyfluorfen (HHP)	Rice, Sugarcane	Rice, tea, Onion, Potato, Groundnut, Mentha	Sugarcane
13	Pendimethalin (HHP)	Rice	Wheat, rice, cotton, Soybean, Pigeon pea, chilli, Onion, groundnut Mustard, cumin	-
14	Penoxsulam	Rice	Rice	-
15	Pretilachlor	Rice, cowpea	Rice	cowpea
16	Pyrazosulfuron ethyl	Rice	Rice	-

(Source: Package of practices; Recommendations: Crops 2016, 15th edition)

The herbicides recommended for use in Kerala are given in the above table along with the nationally approved crops for these herbicides. Among them, diuron, glyphosate, oxyfluorfen and pretilachlor are used for crops other than the approved crops. These herbicides are used on 5 crops, other than the recommended ones, including pineapple, cashew, rubber, sugarcane and cow pea. Three of these herbicides, except pretilachlor, are marked as HHP by PAN International.

Despite their harm potential, they are being erroneously recommended by agricultural extension scientists to be used in rice fields, pineapple farms, cashew plantations, rubber plantations, sugarcane and cowpea farms. Among them, diuron is banned in many countries and is widely applied in rice fields even though it is not recommended for rice. This indicates the negligent attitude of extension systems towards legal compliance and unauthorised use of herbicides on crops in Kerala. Other HHPs recommended include 2,4 D, butachlor, metribuzin and pendimethalin.

6.6.2. Tamil Nadu

In the package of practice for crops (2016), Tamil Nadu, recommended the use of sixteen herbicides is noted. Among these, an erroneous recommendation is observed for 11 herbicides. They are colour marked in Table 6.8. HHPs like 2,4 D, butachlor, glyphosate, oxadiazon, oxyfluorfen and pendimethalin are also listed among them. The national recommendation of crops for each herbicide is also mentioned in the table. Horribly, Ragi (a millet) is also not spared. Pulses such as red gram, black gram, green gram, cowpea are also in the list of unauthorised usage of herbicides. Coconut is also marked in this list. Harm to food consumers, because of this usage, is multiplied. The Agricultural extension system in Tamil Nadu also is not following legal compliances with regard to herbicides is obvious.

Table 6.8. Herbicide recommendation in Tamil Nadu

S. No.	Herbicides	Recommended Crops	Nationally approved crops	Crops not in compliance with Nationally approved crops
1	2,4-D (HHP)	Sorghum, ragi	Rice, Maize, wheat, sorghum, potato, sugarcane, citrus, grapes	Ragi
2	Anilophos	Rice	Rice	-
3	Atrazine	Sorghum, Cumbu, Maize, Coconut, Sugarcane	Maize, sugarcane	Sorghum, Cumbu, Coconut
4	Bispyripac sodium	Rice	Rice	-
5	Butachlor (HHP)	Rice	Rice	-
6	Fluchloralin	Jute, Castor	cotton, soybean	Jute, Castor
7	Glyphosate (HHP)	Coconut, Sugarcane	Tea & non-crop area	Coconut, Sugarcane
8	Imazethapyr	Redgram, Soybean, Groundnut	Soybean, Groundnut, black gram, green gram, red gram	-
9	Isoproturon	Ragi, Wheat	Wheat	Ragi
10	Metolachlor	Redgram	Soybean	Red gram
11	Oxadiazon (HHP)	Groundnut, Rice	Rice	Ground nut
12	Oxyflurofen (HHP)	Ragi, Groundnut, Sugarcane	Rice, tea, Onion, Potato, Groundnut, Mentha	Sugarcane
13	Pendimethalin (HHP)	Rice, Sorghum, Maize, Red gram, Black gram, green gram, Cowpea, Soybean, Castor, Cotton, Sugarbeet, Sunflower.	Wheat, rice, cotton, Soybean, Pigeon pea, chilli, Onion, Mustard, groundnut, cumin	Sorghum, Maize, Red gram, Black gram, green gram, Cowpea, castor, sugarbeet, sunflower
14	Pretilachlor	Sugar beet, Rice	Rice	Sugarbeet
15	Pyrazosulfuron ethyl	Rice,	Rice	-
16	Quizalofop ethyl	Red gram	Soybean, Cotton, Groundnut, Black gram, Onion	Red gram

(Source- PACKAGE OF PRACTICES: RECOMMENDATIONS: CROPS 2016, 15th edition)

6.6.3. Assam

The herbicide recommendation for the crops in Assam is mentioned in the table below 6.9. They are also compared to nationally approved crops. In the Package of Practices for Horticultural Crops, Fisheries and Home Science, jointly prepared by Assam agricultural university, Jorhat and the Department of Agriculture, Assam, the use of 5 herbicides is specified. Among them, diuron, fluchloralin, glyphosate and metolachlor are recommended for pineapple, pea, onion, khasi and tomato respectively, in violation of the nationally approved use. HHPs mentioned in the POP (Package of Practice) include diuron, glyphosate and oxyfluorfen.

Table 6.9. Herbicide recommendation in Assam

Sl. No	Herbicides	Recommended Crops (Violated are marked as blue)	Nationally approved crops	Crops not in compliance with Nationally approved crops
1	Diuron (HHP)	Pineapple, Banana	Cotton, banana, rubber, maize, citrus, sugarcane, grapes	Pineapple
2	Fluchloralin	Pea, Onion	Cotton, soybean	Pea, Onion
3	Glyphosate (HHP)	Khasi	Tea & non-crop area	Khasi
4	Metolachlor	Tomato	Soybean	Tomato
5	Oxyfluorfen (HHP)	Tea	Rice, tea, Onion, Potato, Groundnut, Mentha	-

(Source: Package of Practices for Horticultural Crops, Fisheries and Home Science, Assam)

6.6.4. Andhra Pradesh

In Andhra Pradesh, recommendations for 2, 4 D, Diuron, Glyphosate, and metolachlor show contradictions with nationally approved usage of registered herbicides. These are wrongly suggested for millets, Nagpur mandarin, citrus, cotton and groundnut respectively. HHPs recommended for usage include 2,4 D, diuron, pendimethalin and glyphosate.

Table 6.10. Herbicide recommendation in Andhra Pradesh

Sl. No	Herbicides	Recommended Crops (Violated are marked as blue)	Nationally approved crops	Crops not in compliance with Nationally approved crops
1	2,4-D (HHP)	Millet	Maize, wheat, sorghum, potato, sugarcane, citrus, grapes	Millet
2	Anilophos	Rice	Rice	-
3	Diuron (HHP)	Banana. Nagpur mandarin	Cotton, banana, rubber, maize, citrus, sugarcane, grapes	Nagpur mandarin
4	Glyphosate (HHP)	Citrus	Tea & non-crop area	Citrus
5	Isoproturon	Wheat	Wheat	-
6	Metolachlor	Cotton, ground nut	Soybean	Cotton, ground nut
7	Pendimethalin (HHP)	Rice, Cotton, Groundnut	Wheat, rice, cotton, Soybean, Pigeon pea, chilli, Onion, Mustard, groundnut, cumin	-

(Source: Farmer's handbook of basic agriculture; Andhra Pradesh)

6.6.5. Orissa

In the Manual on agricultural production technology, Kharif 2008, published by the Directorate of Agriculture and food production, Orissa, the herbicides recommendation for the state is specified. They are mentioned in table (6.11). the erroneous recommendation is observed for 9 herbicides among which HHPs are also included. HHPs specified for use include 2,4 D, butachlor, fluazifop-p-butyl, glyphosate, oxadiazon, oxyfluorfen, paraquat and pendimethalin. Paraquat is considered a highly acutely toxic herbicide.

Table 6.11. Herbicide recommendation in Orissa

S. No.	Herbicides	Recommended Crops (Violated are marked as blue)	Nationally approved crops	Crops not in compliance with Nationally approved crops
1.	2,4-D sodium salt (HHP)	Ragi	Maize, wheat, sorghum, potato, sugarcane, citrus, grapes	Ragi
2.	Atrazine	Maize, jowar	Maize, sugarcane	Jowar
3.	Butachlor (HHP)	Rice, maize, jowar	Rice	maize, jowar
4.	Fluazifop-p-butyl (HHP)	Ground nut	Soybean, cotton, groundnut	-
5.	Fluchloralin	Ground nut, Jute, cotton, bhindi	cotton, soybean	Groundnut, jute, bhindi
6.	Glyphosate (HHP)	Cotton	Tea & non-crop area	Cotton
7.	Isoproturon	Ragi	Wheat	Ragi
8.	Metolachlor	Groundnut	Soybean	Groundnut
9.	Oxadiazone (HHP)	Pulses	Rice	Pulses
10.	Oxyfluorfen (HHP)	Rice, cotton	Rice, tea, Onion, Potato, Groundnut, Mentha	Cotton
11.	Paraquat (HHP)	Cotton	Tea, Potato, cotton, rubber, coffee, rice, wheat, Maize, Grapes, Apple	-
12.	Pendimethalin (HHP)	Rice, pulses, ground nut, cotton	Wheat, rice, cotton, Soybean, Pigeon pea, chilli, Onion, Mustard, groundnut, cumin	Pulses
13.	Pretilachlor	Rice	Rice	-
14.	Quizalofop ethyl	Ground nut	Soybean, Cotton, Groundnut, Black gram, Onion	-

(Source: Manual on agricultural production technology-Kharif 2008; Orissa)

6.6.6. Punjab

The methods for cultivating and treating various crops in Punjab are detailed in the Package of Practice (POP) - Kharif 2022 published by Punjab agricultural university. It provides the latest recommendations for herbicides along with improved farming techniques for increasing the productivity of various major crops in Punjab. The herbicides suggested for different crops are mentioned in the table below. Unlike the other states discussed earlier, the herbicide recommendation of this state complies with the nationally approved usage. But the HHPs are recommended for state wise use. They include 2,4 D, butachlor, glufosinate ammonium, metribuzin, oxyfluorfen, paraquat and pendimethalin.

Table 6.12. Herbicide dose recommendation in Punjab

Sl. No	Herbicides	Recommended Crops (Violated are marked as blue)	Nationally approved crops	Crops not in compliance with Nationally approved crops
1	2, 4-D sodium salt (HHP)	Sugar cane	Maize, wheat, sorghum, potato, sugarcane, citrus, grapes	-
2	Atrazine	Sugar cane, maize	Maize, sugarcane	-
3	Bispyribac sodium	Rice	Rice	-
4	Butachlor (HHP)	Rice	Rice	-
5	Fenoxaprop-p-ethyl	Rice	Rice, Soybean, Wheat, black gram, cotton, onion, groundnut	-
6	Glufosinate ammonium (HHP)	Cotton	Tea, Cotton	-
7	Imazethapyr	Soybean	Soybean, Groundnut, black gram, green gram, red gram	-
8	Metribuzin (HHP)	Tomato	Soybean, wheat, sugarcane, potato, tomato	-
9	Oxyfluorfen (HHP)	Rabi onion	Rice, tea, Onion, Potato, Groundnut, Mentha	-
10	Paraquat (HHP)	Cotton	Tea, Potato, cotton, rubber, coffee, rice, wheat, Maize, Grapes, Apple	-
11	Pendimethalin (HHP)	Cotton, Soybean, Rice	Wheat, rice, cotton, Soybean, Pigeon pea, chilli, Onion, Mustard, cumin, groundnut	-

(Source: Package of practices for the crops of Punjab - kharif 2022; volume 39)

6.6.7. Major findings

From the analysis of the state-wise recommendation of herbicides for different crops in Kerala, Tamil Nadu, Assam, Andhra Pradesh, Orissa and Punjab, 13 herbicides have been identified in the study wherein recommendations contradict nationally approved usage. The herbicides that are erroneously recommended in the majority of these states include glyphosate and metolachlor. Among the 11, 2,4 D, butachlor, diuron, glyphosate, oxadiazone, oxyfluorfen and pendimethalin are listed among the Highly hazardous pesticides by PAN International. The wrongful, wide use of 2,4 D and glyphosate among different states in India can be one of the contributing factors to its high production in India. Most of these contradictions of herbicide recommendation for crops from that of nationally approved usage were noted in Tamil Nadu followed by Orissa. Horribly, these wrong and illegal recommendations are for food crops, even though the approval is for non-food crops. The Science that is projected at the time of registration of these chemicals seems to have lost its way at the time of the recommendation. It is illegal as well. It is a blatant violation of science and law based on science.

Table 6.13. Herbicides and States in which their use contradicts nationally approved usage

Sl. No	Herbicides	National recommended crops	Violated states
1	2, 4 D	Maize, wheat, sorghum, potato, sugarcane, citrus, grapes	Tamil Nadu, Andhra Pradesh, Orissa
2	Atrazine	Maize, sugarcane	Tamil Nadu, Orissa
3	Butachlor	Rice	Orissa
4	Diuron	Cotton, banana, rubber, maize, citrus, sugarcane, grapes	Kerala, Assam, Andhra Pradesh
5	Fluchloralin	Cotton, soybean	Tamil Nadu, Assam, Orissa
6	Glyphosate	Tea & non-crop area	Kerala, Tamil Nadu, Assam, Andhra Pradesh, Orissa
7	Isoproturon	Wheat	Tamil Nadu, Orissa
8	Metolachlor	Soybean	Tamil Nadu, Assam, Andhra Pradesh, Orissa
9	Oxadiazon	Rice	Tamil Nadu, Orissa
10	Oxyfluorfen	Rice, tea, Onion, Potato, Groundnut, Mentha	Kerala, Tamil Nādu, Orissa
11	Pendimethalin	Wheat, rice, cotton, Soybean, Pigeon pea, chilli, Onion, Mustard, cumin, groundnut	Tamil Nādu
12	Pretilachlor	Rice	Kerala, Tamil Nadu
13	Quizalofop methyl	Soybean, Cotton, Groundnut, Black gram, Onion	Tamil Nadu

Compiled by PAN India

6.7. Comparative analysis of herbicide recommendation by the Directorate of Weed Science Research and nationally approved usage

In this study, herbicides recommendations of 35 herbicides provided by the Directorate of Weed Science Research (DWR), Jabalpur and their contradictions to nationally approved usage were analysed (annexure 3). From the analysis, 15 were identified as being recommended against the nationally approved usage which is summarized and highlighted in the table below along with the number of violated crops. 12 HHHs are recommended by DWR of which 8 contradict nationally approved usage. The explicit table comprehending the recommended crops provided by both PPQS and DWR is given in Annexure 3.

Table 6.14. Herbicides recommendation by DWSR and their contradiction to nationally approved usage

Sl. No	Herbicides	Crop recommendation by DWR (in numbers)	Nationally approved crops (in numbers)	Crops not in compliance with Nationally approved crops (in numbers)
1	2,4 D (HHP)	6	9	1
2	Anilophos	1	1	-
3	Atrazine	4	2	2
4	Azimsulfuron	1	1	-
5	Bispyribac sodium	1	1	-
6	Butachlor (HHP)	7	1	6
7	Carfentrazone	1	2	-
8	Chlorimuron	2	2	-

9	Clodinafop	1	1	-
10	Cyhalofop-butyl	1	1	-
11	Diuron (HHP)	2	7	-
12	Ethoxysulfuron	1	1	-
13	Fenoxaprop	4	7	1
14	Fluchloralin	32	2	30
15	Glufosinate ammonium (HHP)	1	2	-
16	Glyphosate (HHP)	3	2	3
17	Imazethapyr	2	5	-
18	isoproturon	7	1	6
19	metolachlor	4	1	4
20	Metribuzin (HHP)	12	5	7
21	Metsulfuron methyl	1	3	-
22	Oxadiargyl	3	3	2
23	Oxadiazon (HHP)	19	1	18
24	Oxyfluorfen (HHP)	12	6	9
25	Paraquat (HHP)	2	10	1
26	Pendimethalin (HHP)	37	11	27
27	Pinoxaden	1	1	-
28	Pretilachlor	1	1	-
29	Pyrazosulfuron	1	1	-
30	Pryithiobac sodium	1	1	-
31	Quizalofop-ethyl	21	5	17
32	Quizalofop-p-terfuryl (HHP)	1	1	-
33	Sulfosulfuron	1	1	-
34	Thiobencarb	1	-	-
35	Trifluralin (HHP)	4	-	-

(Source: Handbook on Herbicide Recommendations, Directorate of Weed Science Research, Jabalpur)

A research institution on weeds has been recommending 42 percent of herbicides wrongly and illegally. Among them, herbicides like fluchloralin, oxadiazon, pendimethalin and quizalofop-ethyl are falsely recommended for more than 15 crops. This gives a certain amount of discrepancy as nearly half of the herbicide's recommendations are contradictory. Not only that, among 87 herbicides registered in India, this research institution on weeds has recommendations for 35 herbicides only. It is apparent that this institution has no role in herbicide registration and approval. If so, if not this specialised institution, who is qualified to approve applications of herbicides for registration at the national level? Herbicides like thiobencarb and trifluralin find no nationally approved usage. This dissimilitude between the herbicide recommendations by the States, DWSR and PPQS is a cause of high concern. With a misguided scientific community recommending highly hazardous herbicides wrongly, unaware farmers are led down the garden path by the pesticide companies. It can vary depending on which resource they can access.

The presence of non-approved herbicides is detected in several food commodities. Inappropriate recommendations by herbicide manufacturers, retailers and agriculture officers are a major concern as they are the major sources of information for farmers. The 2015 report 'Conditions of Paraquat use in India' and the 2022 report titled 'State of chlorpyrifos, fipronil, atrazine and paraquat dichloride in India' provides several non-approved uses of mentioned herbicides in India (Dileep and Reddy, 2015; Dileep and Reddy, 2022). The non-compliance with approved use and recommended use in POPs and various other crop production guides may lead to misapprehensions in the use of herbicides by farmers. Such publications should be more prudent and aware of the HHPs and their health effects on humans. Recommending toxic herbicides for weed management in food crops can cause residual impacts leading to chronic health issues in farmers and consumers. Proper use of Personal protective equipment (PPE) and strictly followed precautions should be also mentioned. Weed management strategies other than chemical methods should be recommended more in POPs and crop production guides.

6.8. Herbicide manufacturers in India

Chemical manufacturing companies are in fierce competition with each other to produce pesticide products in India. Many of their products are potentially toxic to human beings and are included in the PAN International list of Highly hazardous pesticides. But still, they are being manufactured exorbitantly, limitlessly stored, and carelessly applied to the fields. Customers who buy these products are bewitched by the blandishments of manufacturers and are lured to buy these products without much information on their hazardous nature. They are not even aware that these herbicides are banned in other countries as they can cause severe public health consequences. Not only that, the crops recommended by the manufacturing companies often contradict nationally approved usage of herbicides for crops. Especially those who are considered HHPs.

An updated list of some of the major herbicide manufacturers in India and their products along with the target crop to apply is given in Annexure 6. Various herbicide products and the crops recommended by certain manufacturing companies working in India are also provided in the Annexure 6. Almost all the companies mentioned in the table manufacture toxic controversial herbicides like glyphosate and paraquat dichloride. Some of them even erroneously recommend them to crops, which are not nationally approved for that particular crop. Nearly 93 indigenous companies are manufacturing herbicides in India. Most of these companies are based in capital cities like New Delhi and Mumbai. From the table, the HHP produced by the highest number of manufacturing companies goes to the highly controversial herbicide, glyphosate. Nearly 35 indigenous companies working in different parts of the country are producing glyphosate. This is followed by HHPs like pendimethalin and 2,4 D formulations. From this analysis, we can comprehend that, even after certain herbicide products are labelled highly toxic and threatening to public health, these are produced on a large scale in India, regardless of their toxicity. Also, these are being extensively consumed by farming communities in India. The table below shows the number of indigenous herbicide manufacturers in India provided by the Directorate of Plant Protection, Quarantine and Storage. From the table, it can derive that 11 HHPs are actively manufacturing in our country. They include even the controversial herbicides that are banned or restricted in other countries in the world.

Table 6.15. Herbicide manufacturers in India

Sl. No	Name of Herbicides	Local manufacturers (in numbers)	
1	2,4-D Ethyl Ester Technical 97% min.	7	**HHP**
2	2,4-D Sodium Salt Technical 94.5% min. 80% min Dichlorophenoxy acetic acid	7	-
3	Ametryn 80% WG (FI-WRT), *95% min.	1	-
4	Anilophos Technical 93% min.	3	-
5	Atrazine Technical 80%, 95% min*, 97% min. (418)	9	-
6	Bispyribac - sodium Technical 95% min, 96% min*	11	-
7	Butachlor Technical 95% min.	6	**HHP**
8	Butachlor Technical 85% min	3	**HHP**
9	Clodinafop -propargyl Technical 93% min (Piroxofop - Propinyl)	24	-
10	Chlorpropham technical 98% w/w min	1	**HHP**
11	Chlorimuron ethyl Technical 95% min.	5	-
12	Dazomet tech 94% min	1	-
13	Dichlorophenoxy Acetic Acid Sodium salt (2,4-D) 80.3% acid	5	-

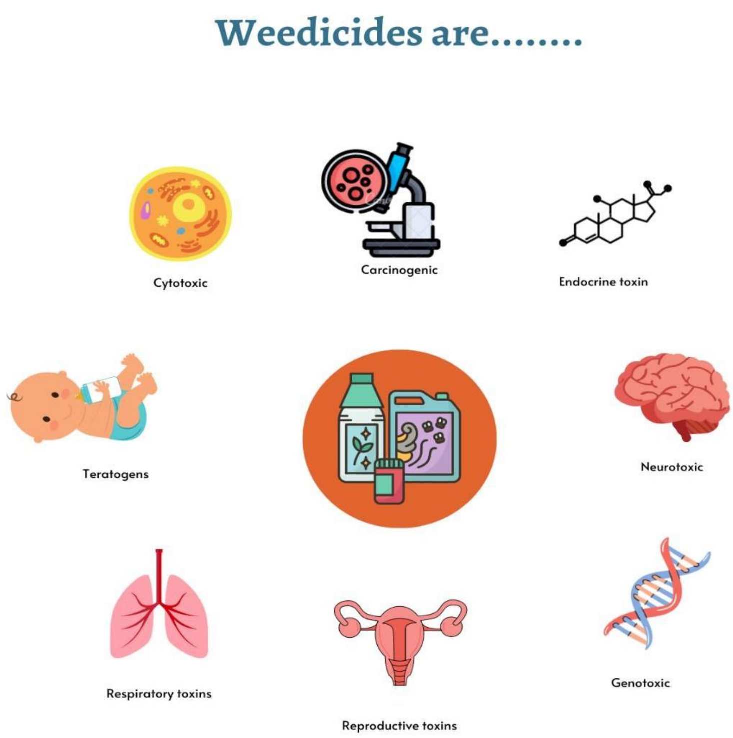
14	Glufosinate Ammonium Technical 50% min. (LC)	1	**HHP**
15	Glyphosate Tech. 95% min.* Glyphosate IPA Salt Technical 62%min.	35	**HHP**
16	Halosulfuron Methyl 75% WG (FI -WRT), *97%min.	1	-
17	Hexazinone 13.2% + Diuron 46.8% WP	1	-
18	Imazethapyr Technical 90% min, 93% min.*, 98% min **, 97.00% w/w min., 95% w/w min.,	16	-
19	Isoproturon Technical 95% min	10	-
20	1. Metsulfuron methyl Technical 93% min. 96% min. 2. Metsulfuron Methyl20% WG* 3. Metsulfuron methyl 10% w/w + Carfentrazone Ethyl 40%w/wDF**	14	
21	Methyl bromide Technical 99%m min. & 98% min.	3	
22	Metamitron Technical 98.00% w/w min.(w/w)	1	
23	Metribuzin Technical 88% min., 95% w/w Min	12	**HHP**
24	Oxadiargyl Technical 96% min.,	1	-
25	Oxyfluorfen Technical 97% min.	1	**HHP**
26	Paraquat dichloride Technical 40% min.,**42% min**. (418RC)	2	**HHP**
27	Pendimethalin Technical 90% min.	18	**HHP**
28	Penoxsulam Technical 97.0% min	1	-
29	Pinoxaden tech 95.0% Min	1	-
3 0	Pretilachlor Technical 94% min., **96% min (414), 97% min.**	23	-
31	Propanil Technical 88% min., 97% w/w min	1	-
32	Pyrazosulfuron ethyl Technical 97.00% w/w min., **98% min**	4	-
33	Pyrithiobac Sodium 95% min	1	-
34	Quizalofop ethyl Technical, 98% w/w	3	-
35	Sulfentrazone Technical 91% Min., 95.00% w/w min. *	1	-
36	Sulfosulfuron Technical 98% min., 98.5% min.	20	-
37	Tembotrione Technical 94% min	1	
38	Topramezone Technical 95.8% w/w min.	1	
39	Trifluralin Technical 85% min. 95% min	2	**H H P**

End note: This chapter deals with the production, import, export and consumption of registered herbicides in India. As we analyse the data provided for the same, discrepancies can be found. Sufficient data is not provided for registered herbicides to reach a plausible inference. The link between production, consumption and transport in and out of the country is bewildering. As in the case of production data, of very few herbicides are provided, but others find their existence and manufacture in the country. There are many indigenous companies which manufacture the herbicides not provided in the data. As in the case of import and export, no sufficient data is available. A similar scenario can be visible in statistical data for consumption of the nationally-produced and imported herbicides. A very similar lacuna is seen with herbicide recommendations by the agricultural extension system. Faulty recommendations lead to erroneous use and exploitation among farmer communities. Symmetries in information are necessary for the establishment of a rigid regulatory system. Asymmetries in them can lead to misapprehensions and misemployment. The farmer community must be aware of ambiguities in the laws and regulations regarding herbicides. From the analysis, it can be clearly stated that, the “status of herbicides in India is poignant”. The very purpose of this chapter is to reveal the loopholes in the statistical data and recommendations provided for herbicides by official sources, how indigenous manufacturing companies are dumping Highly Hazardous herbicides into markets and to call out the attention of official authorities and also farmers to the same.

CHAPTER 7

HERBICIDES AND TOXICITY

Herbicides are unquestionably toxicants when one takes into account the facts and characteristics that make up a toxicant. The toxicity of a substance can be referred as the inherent potential harm it can bring to living things and the environment. Herbicides, being synthetic chemicals have the potential to inflict multifaceted negative effects on both plants and animals. The various commercial herbicides that are readily accessible in the markets have varying degrees of toxicity. They are significantly impacted by factors like the dose, exposure route and duration, physiological detoxification, persistence, and sensitivity. It is a complete misconception that using herbicides in low doses is safe. In organisms, herbicides can have acute or chronic impacts that appear shortly following exposure to its high dosage and repeated exposure to a low dose respectively. In animals, including humans, these are capable of causing major health issues with multiple clinical manifestations. A wide range of health issues are thought to be exacerbated by hundreds of different hazardous herbicides. The skin, eyes, respiratory system, central nervous system, endocrine system, and even our reproductive system can all be negatively impacted by these chemicals, which can enter our bodies through a variety of different pathways. There are even herbicides that are potent carcinogens!



Toxicological evaluations are therefore crucial to evaluate their toxicity and the possibility of poisoning that can be measured by various indicators. Acute toxicity assessment is generally done by determining the LC 50 value (the concentration of the test substance resulting in 50% mortality of test organisms over a period of 96 hours)[25]. Chronic toxicity assessment is done by exposing the subject for long-term to low concentrations of herbicides and assessing the chronic effects at all stages of life of the experimental subject (embryonic, larval, juvenile and adult).

[25] **What is Lethal Concentration 50 (LC50)? - Definition from Safeopedia**

The toxicity of herbicide can also be estimated by its ‘persistence’, the duration in which herbicides remain active or stay in a treated area before degrading into by-products. It depends upon its chemical nature, its innate stability and certain environmental factors. Mostly, herbicides when incorporated into the soil, are reduced by volatilization and photo-decomposition or can be degraded by microorganisms present in the soil. But some are strongly absorbed into the colloidal fraction of soil and are carried by leachate or irrigation to contaminate surface/ groundwater (Choudhury et al, 2018).

Herbicides with higher persistence have the potential to pose greater risks since they remain in their active stage in treated areas for a long period. This depends on many factors like water solubility, vapour pressure, and susceptibility to biotic or abiotic degradation of a particular herbicide. Solubility is directly related to the leaching potential. When a herbicide dissolves in water easily, it can move down through the soil profile and can move away from weed germination zones. This in turn is influenced by the herbicide-soil binding properties, soil physical characteristics, herbicide concentration, rainfall frequency, rainfall intensity and time of application. Vapour pressure links to the volatility of a herbicide. Volatile herbicides are capable of dissipating rapidly with an increase in temperature and moisture. Highly volatile herbicides belong to the families of thiocarbamates, dinitroanilines, butylates and clomazones (Curran and William, 2016). The toxicological characteristics and the duration and frequency of exposure together determine impacts herbicide residues can impose.

The Higher the persistence, the higher will be the chance for contamination (ground water, surface water, etc). Table 7.1 shows the persistence of herbicides under Indian conditions. Within their persistence period, the risks of contaminating the nearby water sources and food are high. If contaminated, it can cause undesirable impacts on domestic animals, domestic people, and wildlife that are dependent on these resources. It can affect the microbial population also. Some of them can disturb the biochemical balance of the soil, thus reducing its fertility and productivity. In general, the short term and long-term effects of a herbicide depend on factors like the chemical class of the herbicide, its route of exposure and the amount of exposure (Choudhury et al, 2018). Herbicide fate in the soil depends on the hydrogen ionic properties of the compound in the soil. In soil with normal PH, acidic herbicides are negatively charged and are movable in the soil. Rather some herbicides are neutral in these soils, so they bind to the soil colloids in several forms due to electronic dislocations.

Table 7.1. Persistence of herbicides under Indian conditions

< 1 month	1- 3 months	3 - 6 months	> 6 months
2,4-D, Glyphosate, MCPA	Ametryn, Anilofos, Bispyribac-sodium, Butachlor, Carfentrazone-ethyl, Fluazifop-butyl, Halosulfuron, Metribuzin, Metsulfuron-methyl, Metolachlor, Oxyfluorfen, Thiobencarb	Clomazone, Chlorimuron-ethyl, Fluchloralin, Imazethapyr, Isoproturon, Oxadiazon, Pendimethalin,	Atrazine, Diuron, Trifluralin, Paraquat

(Source: Choudhury, Partha P., et al. "Herbicide use in Indian agriculture." (2016))

7.1. Herbicides and ecotoxicity

Many herbicides have ecotoxicological effects on aquatic and terrestrial life in addition to altering ecosystem processes. They degrade the quality of our bountiful faunal resources and reduce the diversity of our diverse microbial life. They can drift into water resources through leaching or runoff water and contaminate the environment can disrupt the functioning and equilibrium of aquatic ecosystems thereby putting the biotic components at risk by affecting their survival. Several herbicides with different specificities are available in the markets. Studies on contamination of marine environments highlight that, herbicides are transported into these environments from agricultural sites by runoff waters and compromise the photochemical efficiencies of intracellular symbiotic algae within the corals leading to coral bleaching[26]. Especially herbicides can result in the reduction of photochemical efficiency of the photosystem II of algae and the dissociation of symbiotic association (Jones, 2005). Prolonged use of herbicides can also induce changes in weed physiology. They can lead to the development of herbicide resistance in weeds. When used beyond their recommended doses, they can cause poor crop emergence, root damage and white heads in crops (Choudhury et al, 2018). Chapter 9 continues to address the effects of herbicides on our biodiversity.

7.2. Acute toxicity of herbicides

To estimate the toxicity hazard of a pesticide, the WHO (World Health Organisation) uses the acute toxicity hazard categories according to the GHS[27] (The Globally Harmonized System of Classification and Labelling of Chemicals) as a starting point. Acute toxicity is estimated by analysing their experimentally derived oral LD-50 value. Herbicides are deemed extremely hazardous (1a), highly hazardous (1b), moderately hazardous (class II) and slightly hazardous (Class III) based on their capability to induce oral and dermal toxicity by the active ingredients considering their LD50[28] value. According to the WHO hazard classification (2009), an herbicide with oral concentration toxicity value <5 (and dermal toxicity value <50 is considered extremely hazardous (class 1 a) and oral concentration toxicity ranging from 5-50) and dermal toxicity ranging from 50-200 are classified as highly hazardous (class 1b). Herbicides with toxicity ranges (both oral and dermal) over 2000 and 5000 are regarded as slightly hazardous and unlikely dangerous, respectively, while those with toxicity ranges between 50 and 2000 (oral) and 200 and 2000 (dermal) are recognized as moderately hazardous. The table below are given the WHO recommended classification of herbicides by hazards, 2019 for the registered herbicides in India.

Table. 7.2. Acute Toxicity of different herbicides

Sl. No	Toxicity based on WHO Classification		Number of herbicides
1	**Class 1a**	Extremely hazardous	None
2	**Class 1b**	Extremely hazardous	None
3	**Class II**	Moderately hazardous	23
4	**Class III**	Slightly hazardous	17
5	**Class U**	Unlikely to present acute hazard in normal use	18
6	**Class O**	Obsolete for use as herbicide	1
7	**FM**	Fumigant	1
8	**Not classified**		27

(Source: The WHO Recommended Classification of Herbicides by Hazard and Guidelines to Classification 2019)

[26] **Coral bleaching is the whitening/ loss of colour of corals due to the expulsion, loss or destruction of symbiotic algae which give corals their characteristic colour**

[27] **See About the GHS | UNECE**

[28] **Median lethal dose or LD 50 is the dose of a substance that kills half of the test subjects or organisms.**

Interestingly, 26 out of 87 herbicides registered in India are not classified under any category. Among the classified ones, most belong to Class II (moderately hazardous). Oxyfluorfen is classified under class U which is unlikely to present an acute hazard, but is a deemed HHP. No extremely hazardous herbicides are registered in India. But those belonging to Class II, III and U include the herbicides which have entered into the PAN International list of HHPs (Table. 7.3). Among the 26 herbicides which are not classified under any category, triallate, an HHP is also included. The comprehensive table showing the herbicides registered in India and their respective WHO recommended classification of herbicides by hazards, 2019 tabulated in annexure 4.

7.3. Highly Hazardous Herbicides

"HHPs are Pesticides that are acknowledged to present particularly high levels of acute or chronic hazards to health or the environment according to internationally accepted classification systems such as WHO or Global Harmonized System (GHS) or their listing in relevant binding international agreements or conventions. In addition, herbicides that appear to cause severe or irreversible harm to health or the environment under conditions of use in a country may be considered to be and treated as highly hazardous"

- FAO/WHO)[29]

In India, among the 87 herbicides registered under the Insecticide Rule of 1968, 20 herbicides are considered HHP based on the PAN international HHP list are given in table 7.3. According to JMPM criteria, fluazifop-methyl and glufosinate ammonium are considered HHP (PAN Consolidated List of Banned pesticides, 6th edition, May 2022).

Table 7.3. Herbicides-HHP- PAN International HHP list

Sl. No	Herbicides (HHP)		
1	Butachlor	11	Methabenzthiazuron
2	Diclofop-methyl	12	Metribuzin
3	Chlorpropham	13	Oxadiazon
4	Diuron	14	Oxyfluorfen
5	Flumioxazin	15	Paraquat dichloride
6	Fluthiacet methyl	16	Pendimethalin
7	Fluazifop p butyl	17	Quizalofop P-tefuryl
8	Glufosinate Ammonium	18	Triallate
9	Glyphosate	19	Trifluralin
10	Haloxyfop-methyl	20	2 ,4-Dichlorophenoxy acetic acid

(Source: PAN International list of Highly hazardous herbicides)

[29] **World Health Organization and Food and Agriculture Organization of the United Nations, 2016. *The International Code of Conduct on Pesticide Management: Guidelines on Highly Hazardous Pesticides*. Food and Agriculture Organization of the United Nations.**

Among these HHPs, Glyphosate holds the first position among highly consumed herbicides in the world[30]. During earlier times it was considered eco-friendly. But later its overuse led to severe adverse effects and is a considered group 2A carcinogen by IARC. Studies reveal that its hazardous effects are not only bound to unicellular but also multicellular organisms. In a study conducted by Relyea in 2005 on the impact of Glyphosate and 2,4 D in the biodiversity of aquatic communities, she could observe that glyphosate caused a decrease of 22% of the species richness. In humans' herbicides can induce neurological, reproductive, dermatological, endocrine, respiratory and carcinogenic effects (Relyea, 2005).

Paraquat is also placed among the highly consuming herbicides globally. There are several cases in which farmers/ workers handling paraquat have been subjected to accidental or occupational exposure. Dermal or inhalational exposure by Paraquat, on severe occasions, can lead to acute poisoning with a fatal outcome. It is considered extremely biologically active and toxic to plants and animals by the US Environmental Protection Agency. The longer we are exposed to it, the greater the danger will be. Paraquat has been known to accelerate the development of Parkinson's disease endocrine disruption. When exposed during pregnancy conditions, paraquat causes acute poisoning to both the mother and foetus. In a study conducted by Ribas et al in 1998 for the assessment of cytotoxic, genotoxic and mutagenic potentials at different concentrations of paraquat, the results revealed that paraquat is capable of inducing cytotoxicity for lymphocytes by promoting the reduction in nuclear division rate (Ribas et al, 1998). Another study conducted by Speit on the genotoxic potential of paraquat in Chinese hamster V79 cells could give evidence of chromosomal aberrations induced by the same (Speit et al, 1998).

When we compare the WHO recommended classification of herbicides by hazard (2019) with the list of PAN International HHP list, we can find that several herbicides that the latter classifies as HHPs don't belong to the appropriate categories listed in the former. Even though 2,4 D and glyphosate are considered group 2B and 2A carcinogens by IARC respectively, they are still classified as moderately and slightly hazardous respectively by the WHO. 2,4 D is a neurotoxicant, reproductive toxicant, endocrine disruptor and irritant. Paraquat is classified as moderately hazardous. Metribuzin poisoning can lead to centrilobular hepatic necrosis and histopathological changes in the thyroid, adrenal and liver in rats (Bleeke et al, 1985; Christenson and Wahle, 1993) and is a thyroid toxicant. It is an occupational hepatotoxin (secondary) and has been reported to have genotoxic and carcinogenic effects in mammals. It was capable of causing potential immunotoxic reactions in the body of studied mammals (Zhu et al, 2022). But it is considered slightly hazardous (Class III). Similar cases can be observed for other HHPs. The human health effects of HHPs are mentioned in annexure 5.

7.4. Toxic effects of herbicides

As mentioned earlier, numerous dangerous herbicides are thought to aggravate a wide range of health problems. These chemicals, which can enter our systems through a multitude of different paths, can significantly affect our skin, eyes, respiratory system, central nervous system, endocrine system, and even reproductive system. Even some pesticides are potential carcinogens. They are also well known to cause acute and chronic poisoning in Organisms. Those who regularly use herbicides, especially farmers, are exposed to the dangers these chemicals represent. People commonly choose to forego wearing protective clothes or PPE (Personal Protective Equipment) when exposed to chemicals because of the uncomfortable hot, humid, and damp weather. The active ingredients in formulations can reach our bodies through a variety of channels. This is a worry for everyone not just the people applying them, but also nearby residents and onlookers. These have the potential to get inside of us through the food we consume, the water we drink, and the air we breathe. They can also be absorbed by our skin when they come into contact with it. The diverse toxic effects of herbicides are discussed below.

[30] Herbicides Market Size By Type and Geography | Forecast 2018 - 2025 (alliedmarketresearch.com)

7.4.1. Neurotoxicity of herbicides

Neurotoxicity refers to alterations in the normal activity of the nervous system from exposure to natural or man-made substances, otherwise called neurotoxicants[31]. The effect of herbicides on neural health has been a major research area among scientists all over the globe. There are studies that link the neurotoxic properties of herbicides and the incidence of neurodegenerative disorders like Parkinson's disease and Alzheimer's disease. Certain studies reveal that organophosphates are capable of inducing ADHD (attention deficit hyperactivity disorder) and muscle weakness. Glyphosate is an organophosphate. 2,4 D exposure has been reported to have associations with Parkinson's disease and autism (Gui et al, 2012). According to the data provided in the Pesticide Property Database, among the registered herbicides in India, 9 herbicides are considered neurotoxicants. Refer to annexure 5.

7.4.2. Respiratory toxicity of herbicides

Exposure to toxic chemicals or substances can cause irritations and damage to respiratory system (nasal passages, pharynx, trachea, bronchi, lungs etc). This is termed respiratory toxicity and substances which induce this is called respiratory toxicants[32]. Herbicides can also act as respiratory toxicants. They can enter our body through the nose (inhalational exposure) and can cause several respiratory defects and may disrupt the lining of the respiratory system. Respiratory toxicity can lead to breathing problems, wheezing, chronic obstructive pulmonary disease (COPD), chronic bronchitis, phlegm, chest tightness and impairments in lung function. A study conducted by He and other researchers highlighted that paraquat, if exposed, can accumulate in the human lungs and can cause oxidative injury and fibrosis in humans. It can also pose lethal effects. Other than this, it can also lead to kidney failure and hepatic lesions. He could also observe that its exposure led to the damage in mitochondria, oxidative stress, death of lung cells, production of cytokines, production of pro-fibro genic factors and transformation of myofibroblasts (He et al, 2012). It's been studied that the incidence of asthma, Chronic Obstructive Pulmonary Disease (COPD) and allergic rhinitis has increased among Korean farmers who applied the herbicide Paraquat (Cha et al, 2012). According to the data provided in the Pesticide Property Database, among the herbicides registered in India, 21 herbicides are respiratory toxicants. Refer annexure 5.

7.4.3. Endocrine toxicity of herbicides

Substances that are capable of interfering with endocrine or hormonal activity in animals are called endocrine disruptors. They can disrupt normal endocrine function and are capable of causing hormonal imbalances in humans. They change or disrupt the production of hormones by specific endocrine glands[33]. Herbicides acting as EDCs can cause abnormalities in sex organs, early puberty and cancers (Orton et al, 2009). Atrazine is a well-known herbicide that can induce endocrine disrupting effects, reproductive toxicity and oxidative stress. Organophosphates are one of the most commonly used herbicides which are known for endocrine-disrupting activity. According to the data provided in the Pesticide Property Database, among the herbicides registered in India, nine herbicides are considered endocrine disruptors. Refer to annexure 5.

The endocrine-disrupting activity of 11 herbicides and PCP (Pentachlorophenol) were tested by Orton et al in 2009. The receptor-mediated oestrogenic and androgenic activity was detected using a recombinant yeast screen. Xenopus oocytes were used for studying the effects on ovulatory response and ovarian steroidogenesis. The 11 herbicides used were 4-chloro-2-methylphenoxy acetic acid (MCPA), atrazine, bentazone, chlorpropham, diuron, isoproturon, linuron, mecoprop, PCP, simazine and trifluralin. After the study, they found that the herbicides, except 2,4 D, were active in at least one endpoint. They could observe the antiestrogenic, antiandrogenic and steroidogenic effects on ovulation. Antiandrogenic compounds are known to cause effects like delayed development, retarded growth of sex accessory

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[31] Neurotoxicity | National Institute of Neurological Disorders and Stroke (nih.gov)
[32] respiratory toxicity - Search (bing.com)
[33] Endocrine-disrupting Chemicals: Review of Toxicological Mechanisms Using Molecular Pathway Analysis - PMC (nih.gov)

glands, cryptorchidism and hypospadias in test organisms. Nine out of twelve herbicides had shown effects in ovulation assays. Isoproturon, linuron and diuron belonging to the phenyl urea herbicides were anti-estrogenic and antiandrogenic in the yeast screen. Isoproturon showed inhibitory activity in ovulation without affecting hormone levels. Linuron was reported to increase progesterone levels whereas diuron decreased testosterone levels (Orton et al, 2009). Glyphosate and glyphosate-based herbicides have endocrine-disrupting activity and can modulate oestrogen receptors and molecules in estrogenic pathways (Ingaramo et al, 2020).

7.4.4. Carcinogenic effects of herbicides

There are studies that reveal the potential carcinogenic effect of herbicides in animals. The two herbicides 2,4 D and glyphosate, are considered Group 2B (possible human carcinogen) and 2A (Probable human carcinogen) respectively by IARC (International Agency for Research on Cancer, 2015) for the fact that limited evidence on carcinogenic effects is available for these. According to the data provided in the Pesticide Property Database, among the herbicides registered in India, 8 herbicides are considered carcinogenic. Refer to annexure 5.

Terbuthylazine, which belongs to the chloro-s-triazine herbicides class, is suspected of causing non-Hodgkin lymphoma and lung cancer in humans (Mladinic et al, 2009). Chloroacetanilide herbicides like butachlor is reported to cause adenocarcinoma of the olfactory mucosa of mammals (Genter et al, 1998). There are evidences which demonstrate the induction of carcinomas in the bladder, kidney and mammary gland of rats along with an increase in urothelial cell proliferation after exposure towards the herbicide diuron (Nascimento et al., 2006; Cardoso et al., 2013).

Diuron is found to be cytotoxic to invitro human cells. Effects of diuron when studied in human MCF-7 (Human breast adenocarcinoma) and BeWo (Human placental choriocarcinoma) cells showed the genotoxic effects in MCF-7 cells with an increase in ROS production. Cytotoxic effects were marked in BeWo cells. P53 expression was also significantly increased (Huovinen et al, 2015).

Studies show that pendimethalin can alter tumour suppression genes. The carcinogenic effects of pendimethalin were studied by treating human non-small lung cancer cells with this herbicide. The expression levels of BCL-2, BAX, CAS3, CAS9, P53, BIRC, and PPIA (apoptosis-related genes) were examined with several concentrations and Reduced apoptosis in A549 cells was observed (Kilic and Bucurgat, 2018).

7.4.5. Reproductive toxicity of herbicides

Herbicides which are reproductive toxicants are capable of inducing toxic effects on sexual function, fertility in males and females and also teratogenicity in offspring[34]. Reproductive toxicological effects include ovarian dysfunction, reduced fertility, ovulation disturbances, low sperm concentration, stillbirths and changes in menstruation patterns. Some experimental studies have shown that high doses of atrazine can cause increased loss of body weight. Atrazine is known to induce mammary tumours in female Sprague- Dawley rats and are considered possibly carcinogenic for humans. It is known to cause abnormalities in the gonads of wild leopard frogs (*Rana pipens*) (Hayes et al, 2002). According to the data provided in the Pesticide Property Database, among the herbicides registered in India, 14 herbicides are considered reproductive toxins. (Refer to annexure 5).

Exposure to 2,4 D was reported to produce harmful effects on the germinal epithelium and cause alterations in spermatogenesis. In a study conducted among 32 male farm sprayers exposed to 2,4 D, significant levels of asthenospermia, necrospermia and teratospermia were observed (Lerda and Ruzzi, 1991 cha). In pregnant rats, delayed bone formation and reduced foetal body weight were observed when fed with diuron at moderate doses. Transplacental transfer of diuron in the human placenta has been studied which indicates the invivo fetal exposure and fetotoxicity when pregnant women are exposed to it (Mohammed et al, 2018).

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[34] **GHS Classification Criteria for Reproductive Toxicity (chemsafetypro.com)**

Paraquat dichloride has shown reproductive toxic effects in male Sprague-Dawley rats when they were treated with it, orally and dermally. Decrease in the reproductive organ weight, SEH (Seminiferous Epithelial Height) and EEH (Epididymal Epithelial Height) were observed along with epithelial sloughing and cell degeneration. Spermatogonia, spermatocytes, Leydig cells and spermatids were also observed to decrease in number (Zain and Anuar, 2007).

The consequences of pendimethalin exposure were studied in human umbilical vein endothelial cells (HUVECs) and results showed that it can lead to a decrease in the viability of the cells and loss of mitochondrial membrane potential. An increased proportion of necrotic cells, apoptotic cells and expression of BiP, p-elF2α, and ATF4, Repressed tube formation and migratory ability were also observed (Lee et al, 2022). When teleost *Clarias batrachus* (Linnaeus) were exposed to pendimethalin, a significant increase in plasma 17β-estradiol (E2) was observed in male fishes. It also increased Plasma vitellogenin (VTG) and Gonadal aromatase activity in them and reduced plasma testosterone levels (Gupta and Verma, 2020).

7.4.6. Genotoxic effects of herbicides

Genotoxicity is the ability of chemical substances to cause damage to genetic material and chromosomes[35]. Atrazine, which is used in maize seedlings in high concentrations, is capable of inducing breaks in chromosomes (Popa et al, 1986). A study conducted in the erythrocytes of the fish Gibel carp (*Carassius auratus*) resulted in an increase in the frequency of DNA breaks in erythrocytes. Another study was conducted to determine the influence of herbicides on occupationally exposed workers was carried out in 2002 and found that long term exposure to these can lead to an increase in the damage in the genome of somatic cells of the workers (Vrhovac and Zeljezic, 2002).

Butachlor was observed to induce cytotoxic and clastogenic effects[36] in mammalian cells and the process of apoptosis[37]. When the fate of human peripheral blood lymphocytes was observed upon treatment with butachlor, it induced micronuclei formation. It suggests the clastogenic nature of the herbicide hence indicating chromosomal damage. The fact that this herbicide is capable of causing genotoxicity suggests that it can induce cancers and birth defects. (Paneer Selvam et al, 1999). There are studies which report that butachlor can induce dose-dependent chromosomal aberrations in cultured human lymphocytes (Sinha et al, 1995). Pendimethalin was capable of inducing genotoxic effects in human peripheral lymphocytes and Chinese hamster lung fibroblast cells (V79). Results showed increased Reactive Oxygen Species (ROS) and DNA damage on human peripheral lymphocytes and V79 cells. The increase in micronucleus frequency suggested chromosomal damage in the cells (Kilic et al, 2018).

End note: This chapter examines the toxic effects imposed by herbicides on animals including humans. There are many myths regarding herbicides rendering them safe and efficient chemicals devoid of any side effects. But the fact that they can induce various acute and chronic health effects in animals is terrifying. These chemicals can enter our body via various routes and can disrupt our health by affecting the skin, eyes, respiratory systems, central nervous system, endocrine system and even our reproductive system. The chronic toxic effects are already been discussed in the chapter. The chemical groups and persistence of a herbicide account for its toxic effects. Many Highly Hazardous herbicides are approved for use in our country. Registration and approval of these HHPs are masking out their toxic hazards and can lead to misapprehensions in farming communities. Herbicides are potent toxic chemicals. Their use must be prohibited for the betterment of society and the environment.

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[35] **Genotoxicity: damage to DNA and its consequences - PubMed (nih.gov)**
[36] **Causing damage or breaks in chromosomes leading to mutation**
[37] **Programmed cell death in cells which occurs as a normal and controlled part of an organism's growth or development**.

CHAPTER 8

HERBICIDES AND PUBLIC HEALTH CONSEQUENCES

The previous chapter discussed the potential toxic effects of herbicides. By their very toxic nature, herbicides produce catastrophic impacts on both animal health and the environment and are responsible for inestimable cases of acute poisoning, with or without fatalities each year. In India, every day, many farmers, farm workers, women and children are unwittingly becoming sitting targets of herbicide exposure. People are blindly using these chemicals without any intact prior knowledge about them. These herbicides when erroneously and ignorantly used can lead to irreversible consequences. For those who use them as well as bystanders, residents, women, and children, this is a serious concern. On the number of people who have experienced acute herbicide poisoning, there are regrettably no trustworthy national figures. It is upsetting that despite this aspect, there hasn't been any regulation in the use, production, transport and consumption of herbicides in India. Such irresponsibility can have too many unanticipated effects on public health, particularly in rural communities. In this chapter, the threats herbicides pose to our society in whole are scrutinized.

8.1. Herbicides and Poisoning

Very alarmingly, herbicides are claiming a significant number of innocent lives in India, every year. A growing number of farmers, farm workers, children, women, and local inhabitants are at risk for frequent and direct exposure to herbicides every day. Uncertainty surrounds the prevalence and number of poisonings in other states. Even more, cases exist that are not being reported as cases of poisoning. The state of the farming community is increasingly of national concern as the numerous hazardous side effects of these herbicides are robbing farmers and people connected to them of their lives and livelihoods. This is becoming an alarming issue in the world and is in requirement of substantial vigilance.

There is no herbicide cure, which is a terrifying reality. Farmers have lost their lives in a large number of incidents across our nation as a result of inadequate preventive measures and safeguards being taken. Using herbicides improperly or accidentally ingesting food or water that has been polluted with herbicides are the main ways that people become poisoned. Farmers constitute the majority of the victims. These chemicals are being used even for intentional suicides because of how simple it is to obtain them from the market and the lack of regulations. Herbicide poisonings can be deadly and are usually followed by clinical manifestations including respiratory failure, stomach ache, vomiting, sore throat, headache, incoordination, blurred vision and in severe cases, organ failure depending on the type of herbicide.

Several incidences of herbicide-related poisonings have been reported in different parts of the world. Suicides by ingesting herbicides are recurrently occurring in India. Records of herbicide poisoning cases reported in a medical college hospital in Himachal Pradesh showed that between the years 2017-2019, nearly 20 patients were admitted following herbicide poisoning. The commonly ingested herbicides identified were HHPs like 2,4 D, paraquat, pendimethalin, glyphosate, metribuzin, butachlor and atrazine (Raina et al, 2019). Glyphosate poisoning cases were reported from Nagpur Medical College during the years 2014 and 2018 (Thakur et al,2014; Khot et al, 2018). Similar cases have also been reported in different parts of Kerala. In Punalur, a municipality in the Kollam district of Kerala state in India, 10 workers who were involved in applying herbicide to clear the weeds around a rubber estate office were hospitalized following severe vomiting, headache and weakness. In Kalpetta, a major town in the Wayanad district of Kerala state in India, the precipitous application of herbicide along the village roadside resulted in the mortality of around 7 goats that ingested the treated grass.

Paraquat is one of the controversial herbicides that is widely used for committing suicide. In Odisha, India, it is becoming a recurrent issue. Nearly 170 victims lost their lives in past years following poisoning alone. In 2019, a case was reported in the state where two victims who were 21-year-old and 24-year-old showed signs of kidney failure followed by the ingestion of paraquat. Paraquat has been banned in 58 countries following its toxic effect and is still being widely used in India. Paraquat is considered a highly acutely toxic and widely used herbicide in the world. It is the third most widely used herbicide in the world. Poisoning from this herbicide has been reported in the Tiruvallur district in Tamil Nadu. Similar cases were also reported in Odisha. Nearly more than 200 deaths have been registered since September 2017 at VIMSAR (Veer Surendra Sai Institute of Medical Sciences and Research), Burla, a major centre for public health in western Odisha and parts of Jharkhand and Chhattisgarh. They were mostly farmers who consumed the herbicide, Paraquat, a herbicide without specific antidote. To fight against this, young doctors conducted a two-day hunger strike, which ended on September 16, 2019 and held discussions with farmer's associations. Their efforts paid off as the State government of Odisha withdrew the subsidies on pesticides. Following this, even the number of paraquat poisoning cases were reduced in number[38][39].

Contamination from paraquat can lead to severe poisoning which can even cause death in exposed individuals. Lungs are considered the primary target of paraquat poisoning. Other than this, it can also affect the heart, liver and kidneys. When ingested, intentionally or unintentionally, it can cause severe burns to the mouth, throat, oesophagus and stomach. Necrosis, acute respiratory distress, multiple organ failure, lack of coordination, convulsions, excitability, diarrhoea, peripheral burning, rapid heartbeat, congested lungs, coughing frothy sputum, shortness of breath, nausea, abdominal pain, lethargy, cerebral oedema, pulmonary hypertension, metabolic acidosis, increased levels of blood amylase, glucose, creatinine; acute renal failure, jaundice and brain (Watts, 2010). An observational study was conducted regarding poisoning cases of paraquat admitted to the Trauma and Emergency Department of AIIMS, Bhubaneswar from July to November 2020. Among the poisoned victims, the cause of death was majorly attributed to multiple organ and respiratory failure. Most were intentional poisoning cases. Symptoms in victims included pain in the throat, vomiting, decreased urination, shortness of breath, icterus and difficulty in swallowing (Sahu et al, 2020).

In a study conducted on acute poisoning by alachlor/butachlor herbicides, results revealed that they were capable of causing mild to severe health effects in exposed individuals. In the case of alachlor poisoning, 7 among 133 patients were subjected to severe poisoning and fatalities through oral exposure. In the case of butachlor poisoning, 6 among 22 patients were subjected to dermal exposure and suffered from dermal pain with rashes, and eye pain. 26 patients were reported to develop CNS (Central Nervous System) associated manifestations like weakness, seizure, drowsiness and coma. Additionally, the occasional occurrences of miosis, bradycardia, salivation, incontinence and diaphoresis were also reported in patients (Lo et al, 2008).

Herbicides belonging to the chlorophenoxy chemical family are used for controlling the growth of broad-leafed weeds. They act through the disruption of Acetyl Coenzyme A metabolism and cause dose-dependent membrane damage. But they were capable of causing symptoms like vomiting, diarrhoea, abdominal pain, gastrointestinal haemorrhage and other neurotoxic effects like coma, hallucinations, miosis, nystagmus, ataxia, hyperreflexia, hypertonia, convulsions, fasciculation and paralysis in poisoned individuals. Nearly 66 poisoning cases following the ingestion of these herbicide are reported in the literature of the study conducted by Bradberry in 2000. Among them, 22 were reported as deceased. Respiratory failure was also noted in the affected individuals along with myopathic symptoms like weakened limb muscles, myotonia, loss of tendon reflexes and increased activity of creatine kinase. Metabolic acidosis, renal failure, rhabdomyolysis, pyrexia, hyperventilation and increased activity of aminotransferase were also reported in these individuals (Bradberry et al, 2000).

8.1.1. Herbicide and occupational exposure

Farmers working with herbicides are at higher risk of herbicide exposure. This can lead to acute to chronic symptoms. How do these chemicals enter the body? How do they affect our health? Highly toxic herbicides, when they enter our

[38] **Doctors turn activists to fight Paraquat poisoning in western Odisha - The Hindu**
[39] **Deadly Paraquat Dichloride Claims Over 200 Farmers In Western Odisha! (kalingatv.com)**

bodies, can lead to severe poisoning. Routes of exposure can be oral (through ingestion of herbicide-contaminated food or water), inhalational (through breathing contaminated air), and dermal (through the skin).

Oral exposure to herbicides can result from a variety of behaviours, including eating food right away after herbicide application, without practising good hygiene after the application of herbicides, storing herbicide containers in the kitchen or close to consumables, drinking or eating in the middle of an application, eating harvested products that have herbicide residues on them, and using your mouth to clear the nozzles of containers. When these compounds are consumed, they can produce a number of terrifying symptoms like mouthburn, stomach discomfort, vomiting, diarrhoea, and loss of consciousness, and in extreme situations, they can even result in fatality.

When a farmer is exposed to air contaminated with herbicides, inhalational exposure occurs. When a farmer applies herbicides with volatile components without wearing the proper respirators, as advised on the label, this may occur. Aerosols produced by spraying equipment can easily enter our respiratory system by breathing. Herbicide containers kept indoors, particularly those containing highly volatile chemicals, can contaminate the air. Herbicide drift, in which the herbicide particles travel away from the intended site through the air, causes bystanders and residents close to treated fields to be secondarily exposed to herbicides. Herbicides, when inhaled can cause a variety of spontaneous symptoms, including breathing problems, headaches, nose bleeds, nausea, shortness of breath, irregular heartbeats, and mild to severe respiratory tract irritations.

Herbicides can also irritate or cause mild to severe allergic reactions and skin burns when absorbed into our exposed skin. To prevent them from coming into contact with our skin while applying them, PPE that is chemical and water-resistant must be worn. We run a significant risk if we don't wear them during the entire herbicide usage process, from preparation to disposal. Using cotton clothing on farms is ineffective since doing so can cause the clothing to become moist with herbicide droplets, infecting our skin. Therefore, the complete body should be protected by waterproof and chemical-resistant PPE to prevent the herbicide from leaking onto our skin.

Several studies have been conducted on herbicides to understand their potential to cause health effects in humans when they are exposed to these chemicals for long term (WHO, 2016). A study was conducted among middle-aged paddy farmers in Padaviya farming colony, Sri Lanka, on the incidence of chronic kidney disease (CKD) with unusual characteristics in 1994. After the study, researchers found that farmers who handled the herbicide glyphosate always drank water from an abandoned well. Water samples collected from these abandoned wells had more than 1 μg/L of glyphosate content. Its presence was also detected in the surface water of two reservoirs. This indicated that these sources were contaminated by the wash-off water from nearby agricultural or paddy lands. Also, Bispyribac sodium, a weed killer increased the risk of developing CKD in farmers (Jaya Sumana et al, 2015). The above study clearly indicates the contamination risks posed by potent herbicides. Alachlor and butachlor are two herbicides which are widely used in the US, South America and Asia. Alachlor is a systemic herbicide which is slightly toxic to mammals. However, studies reveal that its long-term exposure can cause hepatotoxicity and hemosiderosis (iron overload disorder) in the liver, spleen and kidneys in individuals.

Maksuk conducted another study to analyse the level of paraquat contamination in water and soil in palm oil plantations, from which researchers detected the presence of the herbicide in the water samples thereby exposing its contamination risks (Maksuk et al, 2016). A study conducted by He et al, 2012, highlighted that paraquat, if exposed, can accumulate in the human lungs and can cause oxidative injury and fibrosis in humans. A study was conducted among Thai women on the presence of glyphosate and paraquat herbicides in maternal and foetal serums. Among the 82 women observed during the study, 39 % were farmers. From this study, they could analyse that glyphosate concentrations greater than LOD (Limit of Detection) were more likely to be found in the serum of pregnant women. The source of paraquat exposure in the women observed for the study was mainly through the ingestion of contaminated food and vegetables. (Kong tip et al, 2017).

Certain studies suggest that phenoxy herbicides are capable of causing potential health hazards. In 1974, a case study was conducted by Axelson and Sun dell regarding the exposure of phenoxy herbicides among Swedish railroad workers.

After six years, a statistical increase in cancer was reported in a follow-up study (Axelson and Sun, 1974). In a study conducted by the Environmental Protection Agency in Oregon, scientists examined that the rate of spontaneous abortion in women residing in the Alsea watershed area with exposure to phenoxy herbicides, was significantly higher than the reference areas selected for the study (Sterling & Arundel, 1986).

There are many other studies which prove the toxic effects of herbicides followed by exposure risks. Atrazine and simazine are known to cause testicular cancer. Butachlor is capable of causing weight changes in internal organs, weight loss and reduced brain size together with lesions. Prolonged or repeated exposure to trifluralin may cause allergic dermatitis. Other than this, it can also cause decreased red blood cell counts and increased methaemoglobin, total serum lipids, triglycerides, and cholesterol (Sondhia, 2014). Butachlor is also capable of causing intracellular ROS production, oxidative DNA damage, mitochondrial dysfunction and chromosomal damage. These eventually lead to necrosis in PBMN cells (Dwivedi et al. 2012). 2,4 D was also reported to be the causative factor of chromosomal aberration in human lymphocytes (Nair et al, 2005). From the two 24-hour urine samples and one semen sample collected from 97 farmers in Ontario who had been using the herbicide 2,4D, detectable levels of the herbicide were found. This study concludes that this can be toxic to sperm cells and can be transported to women (Arbuckle et al, 1999).

8.2. Children and herbicides

One of the stumbling blocks, that emerged as chemical herbicides dominated the agricultural sector, is compromising health of our children. Children too are becoming the victims of acute poisoning cases by these poisons. The incidence of cancers, birth defects, disorders, and other diseases among children as a result of herbicide exposure is elevating in the present-day world. A terrifying fact is that these incidences are recorded more among those children who are engaged in herbicide application or are living near farmlands, which makes them victims of herbicide exposure. In reality, our young generation is becoming sicker and sicker than in past decades. They are more vulnerable to these risks than adults, as they consume more air, water, and food per unit of body weight. This contributes to greater exposure to them in a herbicide-contaminated environment[40].

One of the most controversial herbicides, glyphosate has the ability to cause teratogenic effects in vertebrates (Antoniou et al, 2012). Unintentional poisoning among children when playing with herbicides is another matter of concern. In a study conducted by McDonagh and Martin (1970), 4 cases of child poisoning by the paraquat were reviewed. The poisoned victims were reported to have burns, extensive ulceration in the mouth and lips, vomiting of blood and jaundice.

8.3. Effects of herbicides on food resources

8.3.1. Impact on uncultivated food resources

Modern agriculture development has juxtaposed the existence of nature, between wanted and unwanted, cultivated and uncultivated plants. Herbicides are widely applied in many farms, large, and medium scale fields, small and marginal fields as well as even in homestead farms to kill unwanted plants. Moreover, herbicides are also applied along uncultivated areas such as road sides, railway tracks, backyards, and vegetation around building premises such as schools, anganwadies, hospitals, offices, houses and other constructions. The killing of 'unwanted plants' has become a habit of people nowadays. Many of these unwanted plants, both in cultivated fields and uncultivated areas had been used as food resources in the past, mostly by indigenous communities and villagers. In another way, it is these uncultivated greens, our valuable food sources which are being killed and removed by herbicide application, thereby eliminating valuable food resources. Thus, the application of weedicides has been contributing to the loss of food and

[40] **https://panap.net/resource/children-and-pesticides-protect-our-children-from-toxic-pesticides/?wpdmdl=3389&refresh=639824eb39cd91670915307**

nutritional security for a significant portion of the population. Further, the accumulation and biomagnification of herbicides in edible aquatic and terrestrial is also a major problem[41].

8.3.2. Herbicide Residues

Herbicides are applied either in the soil or in the foliage/shoots of the plants. They can persist in crops even after the application for the long term. There are many case studies which has shown that detectable amounts of herbicides are found in food resources including harvested vegetables, grains, cereals etc. The risk of ingesting toxic herbicide residues from food resources is rather low. But the prolonged and continuous ingestion can increase the risks. The steps for the analysis of herbicide residues involves its extraction, clean-up, determination and confirmation of herbicides through colorimetric and spectrophotometric methods.

In a study, the herbicide residues in cereals, fruits and vegetables were analysed, they could extract the residues of herbicides belonging to the chemical groups such as phenyl ureas, triazines, dinitroanilines, chloroacetamide, carbamates and uracils from foods through homogenisation. Glyphosate and bipyridylium herbicides, diquat and paraquat, were also extracted (Tadeo et al, 2000). The residues of metribuzin have been detected in harvested potato tubers from the fields treated with the herbicide (Callihan et al, 1976).

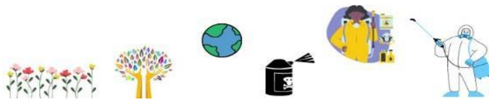
Some herbicides when applied to corn or soybean can persist and injure the vegetables grown in the same and following year. The effects of carryover of nicosulfuron (sulfonylurea herbicide) and flumetsulam (triazolo pyrimidine herbicide) one year after application to corn and from carryover of imazethapyr and imazamox one year after application to soybean on vegetable crops were studied by Richard G Greenland in 2003. From the studies, the author highlighted that imazethapyr delayed tomato maturity. Flumetsulam were observed to injure and reduce the yields of cabbage and squash. Nicosulfuron carryovers were also observed to injure cabbage, onion and tomato plants and reduced the yield of tomatoes. The number of injuries caused by herbicides is influenced by the type of herbicide, vegetable crop, soil properties, climate and tillage. He also suggested that the injury was due to adequate soil moisture, low soil organic matter, low clay content, slightly alkaline pH and warm soil temperatures. This enhances the rate of microbial degradation of herbicides and promotes their dissipation (Greenland, 2003).

Similar studies were conducted in India also. Sondhia in 2013 reported that residues of pendimethalin were detected in peas, chickpeas, tomatoes, cauliflower and radishes after pre-emergence application. Similarly, oxyfluorfen residues were reported in green onion and mature onion bulbs in 0.041–0.063 and 0.0034–0.0460 μg/g at 150–300/ha rates (Sondhia, 2019). In another field experiment, residues of pendimethalin and oxyfluorfen were noted in the edible parts of radishes (Kaur and Gill 2012; Sireesha et al. 2011). Residues of oxyfluorfen were detected in paddy grains. Straws, onion and indicates a risk for bioaccumulation in crop produces (Shobha and Anil, 2010; Sondhia, 2010).

In another study, the presence of glyphosate was determined in tea crops in mid-hill conditions of northwest Himalayas. Its presence in the tea leaves was also detected for up to fifteen days but found to be below the maximum residue limit (Bandana et al. 2015). The presence of alachlor was detected in trace amounts in cotton plants, oil and fish (Ramesh et al. 2007). Herbicides, at detectable concentrations, have also been found in medicinal plants. Residues of fluchloralin and fenoxycarb were detected in the roots and fruits of the Ashwagandha plant and the concentration of residues was higher in leaves and seeds (Sondhia, 2019).

[41] **Herbicides: What are Herbicides, It's Uses, Types & Advantages | UPL (upl-ltd.com)**

End note: This chapter scrutinizes the effect of herbicides on public health. Studies and researches reveal that it has been associated with various acute and chronic health issues in animals as discussed in the previous chapter. These highly hazardous chemicals are causing neurological, reproductive, dermatological, endocrine and carcinogenic effects in organisms. Herbicides are one of the major causes of several intentional poisoning cases in India. The plight of the farming community is becoming an overriding concern in our country as the multiple toxic outcomes of these chemicals are snatching away the lives and livelihoods of farmers and those associated with them. PAN India focuses on intentional poisonings, occupational exposure and the persistence of herbicide residues in post-harvest produce and calls out the responsible authorities to come forward for the regulation of herbicide use in the country. The act prevailing in the country is not enough to have an in-depth knowledge of potential hazards associated with herbicide use. The farming communities, women and children must be well aware of the dangers of ignorant usage of herbicides. Pesticide poisoning cases due to herbicide usage are becoming rampant across the countries. A plethora of cases involving casualties and death of farmers can be witnessed in different parts of our country due to inadequacies in partaking prophylactic measures and precautions. It is distressing that, after all this, still any rectification hasn't happened in its regulations. Such imprudence can lead to too many unforeseeable consequences on public health, especially in farming communities. Quality and sustainability concerns associated with herbicide use are important too.



CHAPTER 9

HERBICIDES AND BIODIVERSITY

Modern agriculture is grappling with unwanted plants and weeds. Humans have been seeking less arduous strategies for the management of weeds ever since the beginning of agriculture. Handmade tools were devised first by primitive man which throughout the time, modified to mechanically powered weeders; harrows, finger weeders, blades, rotary weeders and rod weeders. The use of chemicals for the management of weeds actually started at the end of the 19th century in Western countries, especially from experience gained from chemical-spraying wars. Agent Orange used in the Vietnam War by the United States later became one of the herbicides to be used in agriculture. The commercial development of 2,4 D and MCPA in 1947 led to the development of herbicides paving the way for a new era of toxic chemicals. Over time, the concept of monoculture prompted the extensive production of the wide range of herbicide products now available in the global markets. Continuous use of these chemicals gradually led to issues like occupational hazards, air and water pollution, human diseases, improper disposal of the containers, their persistence in crops and soil and injuries to desired crops. Despite being toxic in nature and having the potential to cause irreversible damage, due to human fallibility they are now widely used wherever they can be used.

Biodiversity is crucial for preserving healthy ecosystems and preventing climate change by storing carbon in the soil and plants. Herbicide use is a serious danger to biodiversity. Herbicides have the potential to decrease the diversity of plants that offer food, cover, breeding grounds and habitats for a variety of creatures, including insects, amphibians, birds, and mammals. Herbicides can damage soil organisms that are vital to the cycling of nutrients, decomposition, and plant growth, as well as change the structure and quality of the soil. Herbicides have the potential to taint water supplies and harm aquatic life that is vulnerable to chemical exposure. Fish and other animals that are consumed by humans or other predators may also accumulate some herbicides. Additionally, herbicides can contaminate water resources through dispersion, volatilization, runoff, and leaching. The numerous impacts of herbicides on biodiversity are covered in this chapter.

9.1. Herbicide drift

Herbicide drift is the movement of herbicides from the site of application by the dispersion of spray droplets or herbicide vapours. Aerial or ground application of herbicides, high wind, faulty equipment and herbicide treatment methods can cause herbicide drift. Such drifts are known to cause damage to non-target plant species, water pollution and exposure to human beings and other animals. There are many factors that affect spray drift including the spray particle size, method of application, distance between nozzle and target or boom height, herbicide volatility, relative humidity, temperature, wind direction, velocity and air movement. A drift happens more when the equipment has a small nozzle orifice size as small droplets of herbicides will move faster along with the wind. Spray drifts from aerial applications and mist blowers are generally greater than ground applications. Volatile herbicides often produce damaging vapours and cause plant injuries. E.g., 2,4 D and MCPA. These vapours move over longer distances and are capable of producing off-target depositions. The effect of herbicide drifts in forestry and aquatic environments is discussed below.

9.2. Herbicides and Forestry

Herbicides are used in forestry for managing silvicultural weeds, scarification, and controlling the growth of plants of the same species and for clear-cutting forest lands, for a long time. The use of herbicides in forestry is regulated in many countries and applicators should acquire a Pesticide Application Permit and a license prior to the application. Different methods are followed for herbicide treatment including foliar spraying, basal spraying, stem injection, cut stump and aerial spraying (helicopter, drones etc.). The major problem that arises from the spraying of herbicides in forests includes herbicide drift and off-target depositions. Herbicide drift is the diffusion of herbicides from agricultural sites to other off-target sites during their application. It can occur from aerial spraying and ground spraying. This can lead to severe consequences for off-target vegetation, off-site wildlife and humans. Herbicides like glyphosate are widely used for this purpose. Studies reveal that glyphosate can cause habitat changes by secondarily affecting plant productivity and the distribution of biomass. This affects the abundance and reproductive success of wildlife, especially birds and mammals in spray zones (Freedman, 1990). The effects of herbicide drift were studied by Egan et al on non-target plants and arthropods in 2014. He suggested that non-target herbicide exposure can cause alterations in the plant and arthropod biodiversity under certain conditions.

Herbicide drift by spray drift and volatilisation can sometimes lead to its deposition to non-target crops which are away from the site of application. These can cause potential damage to these crops. In a study conducted by Nowak and Ballard (2005), they quantified the amount of off-target deposition by performing four different conventional herbicide application methods (Basal, cut-stamp, high volume-hydraulic foliar and low volume-backpack foliar). The higher deposition was observed for the cut-stamp method. The off-target deposition of basal and cut-stamp treatments was within 0.6 meters, 3.7 m with low-volume foliar and 7.3 for high-volume foliar treatment. Off-target depositions also resulted in damage to vegetation.

Forestry applications of herbicides is capable of altering the forest ecosystem at all trophic levels. The growth and functions of microorganisms are dramatically affected as a result of applications. Certain herbicides that are used in forestry can inhibit nitrogen-fixing essential bacteria and mycorrhizal fungi. In the presence of certain herbicides, sensitive plant species will also be eliminated. They can also sometimes interfere with the fruiting ability and seed germination of plants. This is a major concern in the case of rare and endangered native plant species. Herbicide exposure can cause various health effects in animals also. Glyphosate exposure is known to decrease sperm count and abnormal sperms in mammals. Also, it can induce direct cardiac electrophysiological changes, conduction blocks and arrhythmias in mammals. Forestry application of herbicides as well as agriculture application near forest areas can cause exposure to wild animals and poisoning, which will also have adverse effects on them.

9.3. Herbicide effect on Aquatic systems

Herbicides can also be seen used for controlling the growth of aquatic weeds and ditch bank weeds. However, their use is more limited than their terrestrial use because of the potential risks posed by them to non-target species. When applied to aquatic weeds, herbicides distribute to water, sediments, and plants in the aquatic environment. This when linked with their persistence increases the environmental exposure concentration, which can produce secondary effects on both non-target species and water quality. The effect of a herbicide on aquatic systems is greatly dependent on its water solubility as water solubility influences the persistence and the fate of herbicides in that particular environment. 2, 4 D, glyphosate and simazine are the commonly used aquatic herbicides all around the world.

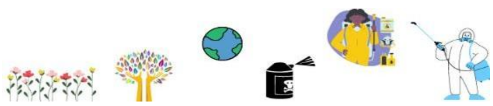
Studies reveal that 2,4 D and glyphosate have an environmental persistence of one month or less and simazine, 3-12 months (Reinert and Rodgers, 1987). According to a study conducted by Jayan and Sathyanathan (2012) in Kerala, 2,4 D, diuron, triazines, paraquat and glyphosate are listed among the common herbicides that are used for aquatic weed control. The above-mentioned herbicides are included in the list of Highly Hazardous Pesticides by PAN International. Herbicides when not properly applied can kill fish in the aquatic environment (Sarkar et al, 2021). Another study was conducted by Relyea in 2005 in which the effect of two herbicides glyphosate and 2,4 D on the biodiversity of aquatic communities containing 25 species of animals and algae were examined. From the study, it was clearly observed that 22 % of the species richness was reduced by the effect of glyphosate and also eliminated two species of tadpoles reducing 70 % species richness of tadpoles. This shows the impact of herbicides towards non-target organisms under ecologically relevant conditions.

Aquatic systems are not only contaminated by the herbicides used for the control of aquatic weeds but also streams and ungerground water sources by runoffs, drift and leaching from the agricultural sites. The high concentration of certain herbicides in the ground and surface water can cause potential health hazards to aquatic life, animals and human beings.

In a study conducted at Pantnagar, India, researchers collected water samples from ponds, wells, bore wells, canals, rivers, ditches and springs near the agricultural sites treated with butachlor, bispyribac sodium and 2, 4 D within one week and after one month. They could find the residues of herbicides below MRL limits.

A similar study was conducted at Ludhiana, where the researchers collected water, soil and crop samples from rice/wheat fields treated with pretilachlor, butachlor, anilophos, clodinafop-propargyl and pendimethalin. They could find the residues of butachlor, pretilachlor, anilophos, clodinafop-propargyl and pendimethalin from the water samples (AICRP, 2016). Another study by Yadav et al (2013), clearly demonstrates the genotoxic potential of butachlor. He suggested that even at low dose levels, butachlor interfered with the fish's cellular activities and induced chromosomal aberrations in them. Sondhia compared the mortality rate of fishes with different herbicides. She demonstrated that butachlor caused more mortality rate in fishes followed by anilofos and oxyfluorfen (Sondhia, 2014). Similarly, the ability to cause mortality in fishes by 2,4 D, paraquat and glyphosate was observed in a study conducted by Muniapa et al, 1995. Contamination of herbicides can not only cause chronic effects among organisms inhabiting the aquatic environment but also human beings depending on the resources which we have already discussed. The difference between herbicide-treated and untreated plots was demonstrated by Moreby and Southway (1999) in southern England. They could observe that in the herbicide-treated plots, along with the reduction of weeds, many invertebrates that were important in the diet of farmland birds were also reduced.

End note: Biodiversity has a significant and inevitable role in the functioning of different ecosystems on the earth. Plants are no doubt one of the key components of terrestrial ecosystems. They are the primary producers of our earth. They are the nurturer and nourishers of the living. Even the plants considered weeds play a significant role in the function of ecosystems and support various species associated with them. Weed management in forestry, agricultural lands and aquatic environments help in mitigating the growth of weeds that hinder the survival and growth of silvicultural crops, agricultural crops in farmlands and aquatic life respectively. But treating them with chemicals is not at all a sustainable solution. Herbicides are potent poisons that can create severe consequences towards biodiversity. We are in need of more sustainable and safe methods for the management of weeds which will not cause any impacts towards the biosphere. That is our only way to ward off future havoc.



CHAPTER 10

ALTERNATIVE WEED MANAGEMENT TECHNIQUES

The intractable predominance of herbicides is indeed inimical to the biosphere. In the previous chapters, herbicide toxicity and its public health consequences were discussed. The quest for non-chemical, economically efficient strategies for weed control is an indispensable need. Farmers who pursue organic farming and agroecology use various non-chemical strategies for the management of weeds. Such measures are essential for the protection of environmental quality, enhancement of biological processes, and replenishments of natural ecosystems and are sustainable and significant (Mohammadi, 2013). Some of the organic farming practices opted by farmers include,

1. Stale seed bed technique and tillage
2. Crop rotation and intercropping
3. Allelopathic crops
4. Nutrient management
5. Soil solarization
6. Cover crops and living mulches
7. Plant arrangement
8. Biological control measures

10.1. Stale seed bed technique and tillage

In this method, germinal weed seeds are flushed out before the crop is planted. Seedbeds are prepared several days prior to the planting of the crop. Flushing out of the weed seeds results in the depletion of seed banks in the soil surface thereby reducing the weed seedling. One of the major advantages of this method is that it is one of the best eco-friendly alternative strategies for weed management. As the primary step, the area for planting is selected. Sufficient irrigation must be ensured for the germination of weeds. After 7 to 10 days of irrigation, shallow tillage is performed to kill the weeds. Tillage is one of the most effective means for making the weed seeds germinate. Again, sufficient irrigation is ensured and the process is continued. For the successful management of weeds, several factors like tillage depth, the timing for stale seedbeds, accelerating germination, higher seeding rates play a critical role. Tillage can contribute to the mitigation of seed-propagated weeds, mainly perennial weeds by burying their propagules thereby slowing down their emergence. Different types of cultivators, harrows power take-off (PTO) powered machines can be used to perform tillage (Renu et al, 2007).

10.2. Crop rotation and intercropping

Crop rotation and intercropping are considered efficacious strategies to swap the use of toxic chemical herbicides. These techniques help in preparing an inhospitable environment for the emergence and proliferation of weed species. In crop rotation, different crops are sequentially planted on the same plot whereas in intercropping different crops are planted among others. Both of these contribute to both high crop yield and reduced weed growth. These are considered traditional strategies for pest control. Monoculture intensifies the dominance of weed species as weeds tend to emerge in the presence of crops whose growth requirements are similar to theirs. When crops are sequentially planted there happens to be a change in the competitive ability, growth habit, maturation dates and fertility requirements of crops which contributes to the disruption of weed growth (Mohammadi, 2013).

Intercropping simply means the spatial diversification of crops. In a study conducted by Sengupta et al in 1985, they intercropped black gram into the rice and noticed that this effectively suppressed the emergence of weed plants. Similar results were observed in the study conducted in India by Ali in 1988, when intercropped pigeon peas with mungbean (Mohammadi, 2013).

10.3. Allelopathy

Allelopathy in plants can be defined as a biological phenomenon in which one plant produces one or more biochemicals which can influence the germination, growth, survival, and reproduction of another plant. They chemically interact with each other. This phenomenon can be exploited to achieve effective weed control in certain agricultural systems (Mohammadi, 2013).

1. Use of crop cultivars with appropriate weed-controlling allelopathic properties: Ideal allelopathic cultivars release allelochemicals before the target weeds grow old because many weed species are most susceptible to them in their seed/seedling stages. Therefore, a thorough knowledge of the stage where the crop releases its allelochemicals and the critical sensitive stage of the target weeds is highly essential for this strategy (Inderjit and Olofsdotter 1998).

2. Application of residues of allelopathic crops into the soil: When the residues of allelopathic crops are applied as mulches into the soil, the compounds released during their decomposition can mitigate the emergence of weeds. In 1992, Petho reported that allelochemicals released from wheat residues were capable of controlling weed emergence.

Other strategies include,

1. . Use of an allelopathic crop in a rotational sequence or apply allelochemicals as herbicides

2. Another way is to modify the crops to enhance their allelopathic effects and efficiency.

10.4. Nutrient management

For the control and management of weeds, nutrient management programs are an effective tool. It is based on the fact that the target crop is in a competitive relationship with weeds for the availability of water and nutrients. The major aim of nutrient management strategies is to enhance the competitive ability of target crops and reduce the ability and growth of weed plants. Weed growth is directly related to the application rate of Nitrogen during planting crops (Mohammadi, 2013). Major nutrient management practices to reduce the emergence of weeds include,

- Delaying of nitrogen fertilisers
- Use slow-release Nitrogen fertilizers
- Placement of Nitrogen fertilisers below the weed-seed germination zone

10.5. Soil solarization

It is one of the non-chemical pest management practices also known as solar heating. Even though this technique was developed against soil-borne pathogens, it became an effective treatment against weed species. In this technique, solar energy is utilized to heat the soil by mulching it with a transparent polythene film. This creates a gradient of temperature from the upper to lower layers of soil. This is done for several weeks. This ultimately declines the viability of weed seeds. A study conducted among carrots in Sao Luis revealed that solarization for nine weeks not only increases the carrot yield, but also controlled more than half of weed species (Marenco & Lustosa, 2000).

10.6. Cover crops and living mulches

Cover crops are another strategy for weed management. They are grown in rotation during periods when the main crop is not cultivated so that they take up the space for the growth of weeds and these cover crops can be removed mechanically, when needed. Cover crops are known to have long and short-term weed control potential. The major reason why cover crops can mitigate the growth of weeds is that, the majority of open space between crops is occupied by these crops. Weeds won't be able to grow in limited spaces and thus the germination of weed seeds and their growth is highly restricted. Another reason is the allelochemicals released from living mulches or cover crops. Cover crops use all the resources including water, light and nutrients that are required for the effective growth of weeds and results in the inhibition of weed seed germination and their growth (Mohammadi, 2013).

10.7. Planting arrangement

Altering the pattern of planting arrangement can contribute to the suppression of weed emergence. Changing planting density, row spacing and orientation are major ways to attain this. Increasing crop density by minimizing row spacing can lead to increased light interception by crops and thereby reduce the growth of weeds. Higher seeding rates of crops can lead to size asymmetric competition between large-sized crops and small-sized weeds which will result in the suppression of the latter (Mohammadi, 2013).

10.8. Biological control measures

Biological weed control using biological control agents (BCAs), provides agriculture with effective tools for successful crop production by minimizing the disadvantageous impact on human health and the environment. Biological weed management includes the use of living organisms for the mitigation of weed plants intentionally. Bioherbicides are biological agents such as fungi, bacteria, viruses, protozoans, and nematodes or plant-derived phytotoxic chemicals which are used for the purpose of weed management. Microbes attack specific weed plants and mitigate their growth. Pathogenic fungi are also used for the same and these fungal preparations are referred to as mycoherbicides. The biological approach for weed management with plant pathogens falls into two categories:

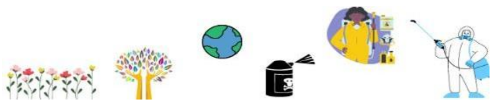
I. **Classical or inoculative strategy**: In this approach co-evolved pathogen is released over a small part of the target weed population as inoculums, and the target weed control occurs through self-perpetuation and natural dispersal of the pathogen. The first successful example of classical strategy is the introduction of *Puccinia chondrillina* from the Mediterranean (South Europe) to control *Chondrilla juncea* (Skeleton weed) in Australia (Aneja et al, 2013).

ii. **Mycoherbicide or inundative strategy**: In this approach, a pathogenic fungal agent that occurs as a pest (that normally causes diseases in specific weed populations) is cultured, mass-produced in fermentation tanks, registered, marketed, and applied like chemical herbicides. *Colletotrichum* species are fungal pathogens that are able to exist in the absence of a plant hosts saprophytically. Most mycoherbicides consist of this fungal pathogen. Rust fungus *Puccinia canaliculata i*s an obligatory foliar pathogen that can only proliferate directly on host plants. The major limiting factors of bioherbicides are their narrow host range, production of potent mammalian toxins, and their culture requirements. Multiple-pathogen strategy is an alternative method for a limited host range. A mixture of three pathogens, *Drechslera gigantea*, *Exserohilum longirostratum*, and *Exserohilum rostratum*, were isolated from three different host weeds which could successfully suppress the growth of weeds of citrus groves in Florida (Chandramohan and Charudattan, 2003).

The use of pathogens other than fungi as bioherbicides is limited. Use of hemibiotrophic fungi is another bioherbicide approach where it combines both biotrophic and necrotrophic strategies. During the former phase, host's immune system and cell death are actively suppressed and invasive hyphae are allowed to spread throughout the infected plant tissue. This phase is followed by a necrotrophic phase where toxins are secreted by the pathogen to induce host cell death (Koeck et al. 2011). *Colletotrichum lindemuthianum* and certain varieties of *C. gloeosporioides* are examples of hemibiotrophic bioherbicides. In India, three rust fungi, *Puccinia romagnoliana*, *Melampsora euphorbiae* and *Puccinia sp.* are formulated to control *Cyperus rotundus*, *Euphorbia geniculata* and *Lagascea mollis*, respectively. The major advantages of bioherbicides over chemical herbicides are.

- They are less harmful than chemical herbicides.
- They are required in very small quantities.
- They decompose very quickly.
- They are nontoxic to humans, domestic animals, and plants.
- They are economically feasible and safe.
- They pose no threat to non-target organisms.
- They are easy to isolate, mass produce, identify, and grow.

End note: This chapter majorly focuses on alternative organic ways for the management of weeds. This is highly necessary to maintain the soil quality and structure, nutritional quality of food and healthy ecosystem functioning. These enable us to safeguard the health of living things, maintaining agricultural diversity thereby improving environmental quality. This can only be achieved by introducing non-chemical methods. Managing weeds with an agroecological approach requires indigenous knowledge of traditional management systems, the creation of a harmonic balance of crops and weeds and maintenance of natural biodiversity/agrobiodiversity. The growth of modern scientific intensive agriculture has led to the loss of indigenous knowledge and the introduction of hazardous poisons. The purpose of this chapter is to give awareness to the farming communities and the society on various eco-friendly and effective alternative ways to manage weeds without disrupting the beneficial weed diversity.



CHAPTER 11

CONCLUSION

Many herbs, plants, grass and various other species of green vegetation considered weeds by modern agriculture are needed for food, energy and medicinal purposes for humans, animals and other species. The role of these diverse vegetation in the conservation of soils and soil biota is crucial. Killing them with chemicals is an obnoxious, unsustainable method. Differentiating invasive nasty weed species from the beneficial weeds is important. Undesirably, weed management has become a fundamental step in the growth of modern agricultural production systems. It includes mechanical, biological and chemical approaches with the goal of mitigating the emergence of weeds in modern agricultural systems. The use of chemical herbicides for this purpose, has been leading to many detrimental effects for both human, animals and the environment. Effectively, weed management using non-chemical methods can be employed. Some of the herbicides used in India are considered highly hazardous herbicides (HHP). Studies have proved and established their ability to cause various kinds of toxic effects including neurotoxicity, respiratory, endocrine, reproductive toxicity and genotoxicity in both humans and animals. Other than these, they cause poisonous effects even in cultivated crops because of their ability for 'persistence'. These herbicides act through various mechanisms according to their site of action.

In India, currently, 87 herbicides have been approved for use according to the Insecticide Act of 1968. Among them, 20 herbicides are considered HHP according to PAN international HHP criteria. It was noted that even though the production and consumption of herbicides are comparatively less in India than in other countries, indigenous consumption is high. The production, import and consumption rate for herbicides in India has increased in recent years regardless of their toxicity and hazards. This can no doubt lead to severe public health consequences and future havoc. Manufacturing companies are competitively producing these products for both nationally produced use and export despite the fact they are HHPs and are banned in many other countries. Even the package of practice approved for each state are carelessly recommending herbicides for the crops by contradicting the nationally approved usage. The incidence of intentional and unintentional herbicide poisoning cases in India are the evidence of the erroneous use of herbicides. The rise in the production, import and consumption statistics of herbicides, especially HHPs in India manifests the irresponsibility of the regulatory authorities and manufacturing companies towards public health and the environment. Also, the status of statistics for herbicides in India provided by official sources is inadequate and deficient. It is apparent that there is insufficient regulation of herbicides in India. Despite the increased incidence of herbicide poisoning and threat to life forms and biodiversity, herbicide usage is being continued and encouraged in our country.

Herbicides, being readily available at homes, are contributing to the ongoing public health burden of agrochemical poisonings. Several cases of intentional and unintentional poisonings have been reported in different parts of the country. The prevalence of these circumstances in our country is appalling and the continued use of herbicides has unquestionably put many lives at stake. Many herbicides also have ecotoxicological effects on terrestrial and aquatic organisms and disrupt ecosystem functions. They deplete our rich faunal assets and deteriorate soil quality, thereby affecting microbial diversity. Herbicides are also found to pose threat to the human population. They also cause acute and chronic effects in humans on long-term exposure. Conclusively, these herbicides are of major concern due to their severe toxic profile and need comprehensive regulation.

Major Recommendations

This study puts forth the following recommendations:

- Chemical means of weed management is destructive and unsustainable. They are capable of causing many mild to severe health problems in human beings, environmental and food safety issues. Many herbicides banned in other countries are still being registered and consumed extensively in India. These include 20 Highly hazardous herbicides. Ministry of Agriculture and Farmer's Welfare, Government of India, should evaluate the status of herbicides in the country and take necessary measures to ban the production, import, export and consumption of these chemicals promptly.

- The studies conducted on the toxicity, bioaccumulation and persistence of herbicides are limited in India and hence are in exigent need of thorough research on these contexts. The Central Sector Scheme, Monitoring of Pesticide Residues at the National Level should expand monitoring of the residues of herbicides in farm products and environmental samples across India to understand herbicide contamination.

- Legal actions should be taken against State agriculture Departments, universities and herbicide manufacturing companies for the erroneous recommendation of herbicides for crops that are not approved by the Central Insecticides Board and Registration Committee.

- The indiscriminate use of herbicides in the country should be properly addressed and should be regulated accordingly. The authorities should act responsibly and should be concerned about the plight of farming communities in the country. HHPs should be banned as they are violating national regulations as well as the international code of conduct on herbicide management.

- Agriculture Departments and universities should come forward in taking necessary measures for the elimination of synthetic herbicides from farming and promoting non-chemical weed management methods.

- Raising awareness of the potential hazards posed by herbicides and the alternatives that need to be adopted among the populace has become an indispensable task, especially among farming communities in India. The ignorance of the people on diverse products of herbicides can snatch away their lives and livelihood. Such a depressing scenario can be ameliorated by generating proper awareness and sensitization among the populace about the hazardous herbicides, their effects, safety measures to be adopted and available alternative means. This also helps in empowering the farming communities from rapacious exploitation by powerful corporations.

- Adoption of non-chemical strategies in public agricultural extension systems helps in harnessing the benefits of natural resources, improving the health of living things, enhancement of soil quality and fertility, ecosystem management, better water quality and improving environmental quality. It is also necessary to ensure sustainable availability of quality food for the people, especially for the poor and disadvantaged communities, including adivasis.

- Several alternative strategies need endorsement from public research institutions and scientists in agricultural extension. These strategies can substitute the use of chemical herbicides. These include cultural strategies like crop rotation, stale seedbed technique, utilization of allelopathic plants, crop cultivars and cover crops. Alien plants and weed emergence can be mitigated through mechanical weeding or by adopting biological control measures.

- Many plants categorized under “weeds’ have accentuating benefits and are major sources of food. Their mitigation can result in loss of beneficial biodiversity, habitat degradation and reduction of food resources and hence needs to be conserved. There is an urgent need to incorporate conservation strategies into farming practices for conservation of beneficial plant varieties and the sustainable management of habitats of biodiversity.

- Awareness among farmers and agricultural labour about herbicides has to increase too. Consumers needs to be alerted about the residues of herbicides in their food and water. All India Coordinated Research Network and network projects start sampling herbicide residues in food, water and air. ICAR should undertake periodical research to ascertain herbicide residues in intensive herbicide usage areas. Depending on the results of this research, appropriate measures can be taken.

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Annexure 1

Table showing Beneficial weeds in India

Sl. No	Beneficial weeds	Common names	Benefits
1	*Mimosa pudica*	Touch me not	Used as companion plant for tomatoes and peppers for ground cover.
2	*Urtica dioica*	Common nettle	Used to make herbal tea, it is grown for its fibre
3	*Allium vineale*	Stag's garlic	Repels slugs, aphids, carrot fly, cabbage worms
4	*Medicago sativa*	alfalfa	Used by farmers to mitigate cotton pests, improves soil through nitrogen fixation.
5	*Ammania baccifera* (Agnikuanri)	Fire leaf	Used for treating skin diseases, parasitic skin infection, fevers, swellings and stomach problems.
6	*Eclipta alba* (Bhringaraj)	Bhangra	Used for the treatment of hepatomegaly, splenomegaly, jaundice, piles, stomach ache, headache and skin diseases (leprosy, itching diseases).
7	*Sphenoclea zeylanica*	Chicken spike	Ii is used as a source of organic nitrogen for rice production
8	*Amaranthus spinosus*	Spiny amaranth	Edible (leaves and stems).
9	*Boerhaavia diffusa*	Spreading hogweed	It is used for the treatment of indigestion, anorexia, constipation. It has antidiabetic and diuretic properties.
10	*Chenopodium album*	Lamb's quarters	The leaves and young shoots are edible. It has anthelmintic, antiphlogistic and antirheumatic,
11	*Convolvulus arvensis*	Bindweed	It is used as a laxative and has ant angiogenesis and immunity stimulating effects.
12	*Tribulus terrestris*	Land caltrops	It is used in testosterone boosting health supplements. Cautions should be followed.
13	*Amaranthus viridis*	Pigweed	It is a medicinal herb used for the treatment of Asthma, fever, diabetes etc.
14	*Cleome viscose*	Tick weed	It is a digestive stimulant and expectorant.
15	*Acalypha indica,*	Kuppaimeni	It is used for treating intestinal worms, gum problems, stomach aches, hernia, rheumatism, bronchitis, asthma, pneumonia, scabies and skin diseases.
16	*Acanthospermum hispidum*	Bristly starbur	It has medicinal properties. Have antibacterial and anti-fungal properties.
17	*Achyranthus aspera*	Devils horsewhip	The decoction of plant is used for the treatment of pneumonia, insect bites, piles, ascites, skin diseases, kidney stones and cough. Has diuretic properties. Roots are used for the treatment of digestive problems.
18	*Ageratum conyzoides*	Goat weed	Medicinal plant. Used as blood coagulant (wound healing). Has antilithic and wormicidal properties.
19	*Alternanthera sessillis*	Sessile joyweed	Has galactogogue properties. Leaves are edible.
20	*Anagallis arvensis*	Scarlet pimpernel	Used for the treatment of epilepsy, leprosy, rheumatism, hepatic and renal diseases. It has diuretic, diaphoretic properties and is an expectorant.
21	*Argemone Mexicana*	Mexican prickly poppy	Laxative, expectorant and diuretic properties. Used for the treatment jaundice, skin diseases and respiratory problems.

22	*Asphodelus tenuifolius*	Wild onion	Has antilithic properties.
23	*Caesulia axillaris,*	Ghrilla	Has antimicrobial properties
24	*Cyanotis axillaris*	Cyanotis	Used for tympanitis and ascites (external application)
25	*Cynodon dactylon*	Bermuda grass	It is diuretic. Used for the treatment of epilepsy and body pain. Has anti-bleeding properties.
26	*Cyperus iria*	Rice flat sedge	It is used as astringent and a digestive stimulant.
27	*Cyperus rotundus*	Purple nutsedge	Used for the treatment of vomiting, fever, dysentery and urinary contractions. Has diuretic properties.
28	*Emillia sonchifolia*	Sadhimodi	Used as febrifuge and for digestive problems.
29	*Euphorbia hirta*	Australian asthma herb,	Effective treatment for respiratory problems (bronchitis, asthma). Has anthelminthic problems.
30	*Fumaria parviflora*	Thura	Has diuretic, aperient and laxative properties.
31	*Gynandropsis pentaphylla*	Caravella	Used for anthelmintic treatment.
32	*Imperata cylindrica*	Cogongrass	Used for snake bites, fever, diarrhoea, dysentery and gonorrhoea.
33	*Lantana camara*	Tiger shrub	Used for the treatment of tetanus, fistulae, rheumatism and itching.
34	*Leucas aspera*	Maldoda	Used for anorexia, headache and chronic rheumatism. It is also used as an antipyretic.
35	*Melilotus Indica*	Banmethi	Used for digestive problems
36	*Monochoria vaginalis*	Kakapola	Used for the treatment of cough, toothache, digestive problems and liver complaints.
37	*Phyllanthus niruri*	Gripe weed	Medicinal weeds. Used for the treatment of respiratory problems, jaundice, tubercular ulcers, ringworm, anaemia, leprosy and urinary discharges.
38	*Physalis minima*	Sun berry	Used for the treatment of urinary disorders and earache.
39	*Polygonum hydropiper*	Pepperwort	Used to treat skin infections and uterine disorders. Has diuretic and antihelmintic properties.
40	*Portulaca oleracea*	Common purslane.	Used for the treatment of scurvy, cardio-vascular diseases, haematuria, dysentery and ulcerations in mouth. Seeds have diuretic, astringent, demulcent and vermifuge properties.
41	*Solanum nigrum*	Black night-shade	This plant has antiseptic, antidiabetic, diuretic and antidysenteric properties.
42	*Trianthema portulacastrurm*	Black pigweed	Used for the treatment of respiratory problems, oedema and rheumatism
43	*Tridax procumbens*	Foul chrysanthemum	Used for the treatment of dysentery, diarrhoea and bronchial catarrh
44	*Xanthium strumarium*	Burweed	Has diuretic properties. Used for the treatment of malaria, and various other diseases.

Compiled by PAN India, from various sources

Annexure 2

Table showing Major crops in India and associated weeds

Sl. No	Crop	weeds	Beneficial weeds
1	**Rice**	*Alternanthera sessillis, Ammania baccifera, Bergia capensis, Caesulia axillaris, Commelina Benghalensis, Cyperus spp., Cyanotis cucutata, Dapatorium juncecum, E. crusgalli, Eclipta alba, Digera arevensis, Enchinochloa colonum, Echinocloa crusgali, Fimbristylis miliacea, Ischaemum rugosum, Ludwigia parviflora, Marsilea quadrifoliata, Marsilea minuta, Monochoria vaginalis, Panium ischaemum, Oxalis minima, Phyllanthus niruri, Scirpus royeli, Sphenoclea zeylanica, Spilanthes sp,*	*Alternanthera sessillis* *Ammania baccifera* *Caesulia axillaris,* *Cyperus iria* *Eclipta alba* *Monochoria vaginalis* *Phyllanthus niruri* *Spilanthes sp*
2	**sugarcane**	*Ageratum conyzoides, Amaranthus spinosus, Amaranthus viridis, Anabalis servensis, , Astodelus fistulosis, Boerhaavia diffusa, Brachiaria repens, Celosia Argentea, Chenopodium album, Cleome viscosa, Convolvulus arvensis, Cynodon dactylon, Cyperus esculentus, Cyperus rotundus, Dactyloctenium aegyptium, Digera arvensis, Digitaria spp., Euphorbia spp., Enchinochloa colonum, Ipomea spp, Parthenium hysterophorus, Phyllanthus niruri, Protulaca oleracea, Portulaca racea, Setaria spp, Trianthema monogyna, Trianthema portulacastrum, Tribulus terrestris, Xanthium spp.*	*Ageratum conyzoides* *Amaranthus spinosus* *Amaranthus viridis,* *Boerhaavia diffusa* *Chenopodium album* *Cleome viscose* *Convolvulus arvensis* *Cynodon dactylon* *Cyperus rotundus* *Phyllanthus niruri* *Tribulus terrestris* *Xanthium spp*
3	**maize**	*Alternenthera sp, Amaranthus viridis, Amaranthus spinosus, Boerhaavia diffusa, Brachiaria sp, Celotia argentea., Chenopodium album, Chloris barbata, Cleome viscose, Cleome chelidonii, , Convolvulus arvensis, Cyperus sp., Digera arvensis, Digitaria sp, Echinochloa spp, Eleusine Spp, Euphorbia hirta, Lagasca mollis, Melilotus alba, Phyllanthus niruri, Polygonum spp, Portulaca oleracea, Trianthama monogyna Trianthema portulacastrum, Tribulus teristeris, Xanthium strumarium*	*Amaranthus spinosus* *Amaranthus viridis,* *Boerhaavia diffusa* *Convolvulus arvensis* *Cleome viscose* *Chenopodium album* *Cyperus sp* *Euphorbia hirta* *Phyllanthus niruri* *Polygonum hydropiper* *Portulaca oleracea* *Tribulus territris* *Xanthium strumarium*
4	**Soybean**	*Acalypha indica, Alternanthera philoxeroides, Amaranthus viridis, Ammannia baccifera, Boerhaavia hispada, Brachiaria reptans, Caesulia auxillaris, Celosia argentea, Commelina benghalensis, Commelina diffusa, Commelina communis, Cucumis trigonus, Cyanotis axillaris, Cyperus rotundus, Cyperus difformis, Cyperus iria, Dactyloctinum aegyptium, Digera arvensis, Digitaria sanguinalis, Dinebra retroflexa, Echinochloa colonum, Echinochloa sp, Echinolchloa crusgalli, Eclipta alba, Eclipta prostrate, Eleusine indica, Euphorbia geniculate, Euphorbia hirta, Fimbristylis miliaceae, Hemarthria compressa, Leersia hexandra, Lindernia ciliate, Ludwigia parviflora, Marsilea quadrifolia, Monochoria vaginalis, Panicum repens, Parthenium hysterophorus,, Paspalum discichum, Paspalum scrobitulatum, Phyllanthus niruri, Portulaca oleracea, Setaria glauca, Sphenoclea zeylanica, Trianthema portulacastrurm,*	*Acalypha indica* *Amaranthus viridis* *Ammannia baccifera* *Caesulia auxillaris* *Cyanotis axillaris* *Eclipta alba* *Euphorbia hirta* *Monochoria vaginalis* *Portulaca oleracea,* *Trianthema portulacastrurm*

5	**cotton**	*Acanthospermum hispidum, Acalypha indica, Achyranthus aspera,, Amaranthus spp, Anagallis arvensis, Asphodelus temifolius, Bracharia reptans, Cenchrus cathorticus, Chenopodium album, Cleome enticu, Convolvulas arvensis Cynodon dactylon, Commelina communis, Corchorus spp, Dactylocteneum Aegyptium, Datura sp, Digitaria sp, Dinebra Arabica, Dinebra retroflexa, Eleusine sp, Eragratis minor, Echinochloa colonum, Euphorbia hirta, Gynandropsis pentaphylla, Lagasca mollis, Panicum sp, Parthenium hysterophorus, Paspalum conjugatum, Portulaca oleracea, Portulaca spp, Setaria glauca, Trianthema monogyna Tridax procumbens, Vicia sativa, Xanthium strumerium,*	*Acanthospermum hispidum Amaranthus spp Acalypha indica Achyranthus aspera Chenopodium album Cynodon dactylon Euphorbia hirta Gynandropsis pentaphylla Portulaca oleracea Tridax procumbens Xanthium strumerium*
6	**wheat**	*Amaranthus spinosus, Anagalis arvensis, Argemone maxicana, Asphodelus tenuifolius, Avena fatua, Avena ludoviciana, Carthamus oxyacantha, Chenopodium album, Circium arvense, Convolvulus arvensi, Coronopus didymus, Fimbristylis miliacea, Fumaria parviflora, Lathyrus aphaca, Leucas aspera, Malwa sp, Medicago denticulate, Melilotus Indica, Melillotus alba, Phalaris minor (Canary grass), Phyllathus niruri, Pluchia lanceolata, Poa annua, Polypogom monspliensis, Rumex spp., Spergula arvensis, Solanum nigrum, Vicia sativa.*	*Amaranthus spinosus Argemone mexicana Asphodelus tenuifolius Chenopodium album Fumaria parviflora Leucas aspera Melilotus Indica Phyllathus niruri Solanum nigrum*
7	**Sorghum**	*Convolvulus arvensis, Cyperus iria, Digera arvensis, Euphorbia hirta, Phyllanthus niruri, Striga sp, Trianthema sp, Tridax procumbens.*	*Convolvulus arvensis Euphorbia hirta Phyllanthus niruri Tridax procumbens.,*
8	**Potato**	*Anagallis arvensis, Argemone mexicana, Asphodelus tenuifolius, Bathyrus aphaca, Brachiaria ramose, Chenopodium album, Convolvulus arvensis, Cyperus iria, Fumaria parviflora, Melilotus spp, Parthenium hysterophorus, Phalaris minor, Portulaca oleracea, Trianthema monogyna,*	*Anagallis arvensis Argemone Mexicana Asphodelus tenuifolius Convolvulus arvensis Chenopodium album Cyperus iria Fumaria parviflora Melilotus spp Portulaca oleracea*
9	**Citrus**	*Amaranthus viridis, Cocumis trigonus, Commelina nudiflora, Convolvulus arvensis, Coronopus didymus, Digera arvensis, Euphorbia spp, Fumaria parviflora, Oxalis corniculata, Sonchus arvensis, Tribulus terrestris.*	*Amaranthus viridis Convolvulus arvensis Fumaria parviflora Oxalis corniculate Sonchus arvensis Tribulus terrestris*
10	**Grapes**	*Alternanthera echinata, Amaranthus spp, Argemone maxicana, Asphodelus tenuifolius,Chenopodium album, Cleome viscose, Convolvulus sp, Convolvulus spp, Cynodon dactylon, Cyperus iria, Cyperus rotundus, Eleusine aegyptia, Euphorbia hirta,Fumeria parviflora,Ipomoea spp, Medicago denticulate, Portulaca sp, Tridax procumbens, Tridax sp, Xanthium strumerium,*	*Amaranthus spp Argemone maxicana Asphodelus tenuifolius Convolvulus arvensis Cleome viscose Chenopodium album Cynodon dactylon Cyperus iria Cyperus rotundus Euphorbia hirta Fumeria parviflora Ipomoea spp Portulaca sp Tridax procumbens Xanthium strumerium,*

11	**Banana**	*Amaranthus spp, Chloris barbata, Commelina benghalensis, Cyperus iria, Dactyloctenium, Digitaria sp, Eragrostis zeylenica*	*Amaranthus spp Cyperus iria*
12	**Rubber**	*Digitaria sp., Eragrostis sp., Fimbristylis sp.*	
13	**Onion**	*Amaranthus viridis, Anagallis arvensis, Chenopodium album, Commelina sp, Dactyloctenium aegyptium, Digitaria sanguinalis, Digera arvensi, Dinebra Arabic, Echinochloa colonum, Eleusine indicia, Eragrostis sp, Euphorbia spp. Parthenium hysterophorus, Physalis minima, Portulaca oleracea, Trianthema spp, Trianthema portulacastrum*	*Amaranthus viridis Anagallis arvensis Chenopodium album Euphorbia spp Physalis minima Portulaca oleracea Trianthema portulacastrum*
14	**Tea**	*Acalypha indica, Ageratum Conyzoides, Arundinella bengalensis, Axonopus compressus, Bidens spp, Borreria sp, Chromolaena odorata, Commelina benghalensis, Conyza spp, Crassocephala integrifolia, Crassocephalum crepidiodes, Cychorium intybus, Cynodon sp, Cynodon dactylon, Cyperous sp, Digitaria sp, Drymaria diandra, Eleusine indica, Emillia sonchifolia, Eragrostis spp, Euphorbia spp, Galinsoga parviflora, Imperata cylindrica, Imperata Setaria, Imperata, Paspalum, Ipomea digitarea, Lantana camara, Mimosa pudica , Mitracarpus verticilatus, Paspalum conjugatum, Paspalum scrobiculatum, Polygonum perfoliatum, Oxalis spp.,*	*Acalypha indica Ageratum Conyzoides Bidens spp Emillia sonchifolia Euphorbia spp Imperata cylindrica Lantana camara Mimosa pudica Oxalis spp.,*
15	**Groundnut**	*Aeluropus villosus, Amaranthus viridis, Bracharia reptans, Commelina benghalensis, Chloris barbata, Cleome viscose, Cyperus difformis, Dactylactenium aegypticum, Digera arvensis, Digiteria longiflora, Echinochloa colonum, Eleusine indica, Eragrostis Pilosa, Euphorbia spp,, Indigofera glandulosa, Parthenium hysterophorus, Phyllanthus niruri, Physalis minima, Portulaca oleracea, Trianthema portulacasturm.*	*Amaranthus viridis Cleome viscose Euphorbia spp Phyllanthus niruri Physalis minima Portulaca oleracea Trianthema portulacasturm*
16	**Black gram**	*Amaranthus viridis, Brachiaria eruciformis, Commelina benghalensis, Dactyloctenium aegyptium, Digitaria sanguinalis, Dinebra ratroflexa, Echinochloa sp., Eleusine indica, Eragrostis sp., Euphorbia hirta, Paspalidium sp.,*	*Amaranthus viridis Euphorbia hirta*
17	**Green gram**	*Amaranthus viridis, Euphorbia hirta, Trianthema portulacastrum*	*Amaranthus viridis, Euphorbia hirta, Trianthema portulacastrum*
18	**Red gram**	*Amaranthus viridis, Digitaria sanguinalis, Dinebra relroflexa, Euphorbia spp.*	*Amaranthus viridis Euphorbia spp.*
19	**Sugarbeet**	*Cynodon dactylon, Cyperus rotundus, Dactylactenium aegyptium, Convolvulus arvensis, Chenopodium album, Digera arvensis, Gynandropsis pentaphylla, Parthenium hysterophorus*	*Chenopodium album Convolvulus arvensis Cynodon dactylon Cyperus rotundus Gynandropsis pentaphylla*
20	**Tomato**	*Amaranthus viridis, Commelina benghalensis, Dactylactonium aegypticum, Digera arvensis, Eleusine indica, Euphorbia frustrate, Gynandropsis pentaphylla, Portulaca oleracea, S.glauca, Trianthema portulacastrum*	*Amaranthus viridis Gynandropsis pentaphylla Portulaca oleracea Trianthema portulacastrum*

(Source; major uses of herbicides- Directorate of Plant Protection, Quarantine and storage- compiled by PAN India)

Annexure 3

Table showing herbicide recommendation by DWR and contradictions to national approved usage

Sl. No	Herbicides	Crop recommendation by DWR	Nationally approved crops	Crops not in compliance with Nationally approved crops
1	2,4 D (HHP)	Rice (dry seeded, puddle seeded, puddle-transplanted, wheat, maize, sorghum, pearlmillet, sugarcane,	Maize, wheat, sorghum, potato, sugarcane, citrus, grapes, paddy, transplanted rice	Pearlmillet
2	Anilophos	Rice (dry seeded, puddle seeded, puddle-transplanted)	transplanted rice	-
3	Atrazine	Sorghum, pearlmillet, sugarcane,maize,	Maize, sugarcane	Sorghum, pearlmillet
4	Azimsulfuron	Rice (dry seeded, puddle transplanted),	Rice (direct seeded, transplanted)	-
5	Bispyribac sodium	Rice (dry seeded, puddle transplanted),	Rice (direct seeded, transplanted)	-
6	Butachlor (HHP)	Rice (dry seeded), groundnut, cotton, Potato, Onion, garlic, sunflower,	transplanted rice	groundnut, cotton, Potato, Onion, garlic, sunflower
7	Carfentrazone	Wheat	Wheat, Rice	-
8	Chlorimuron	Rice, soybean,	Rice, soybean,	-
9	Clodinafop	Wheat	wheat	-
10	Cyhalofop-butyl	Rice (dry seeded, puddle seeded, puddle transplanted)	Rice	-
11	Diuron (HHP)	Cotton, sugarcane	Cotton, banana, rubber, maize, citrus, sugarcane, grapes	-
12	Ethoxysulfuron	Rice (puddled-seeded, puddled-transplanted)	Rice	-
13	Fenoxaprop	Rice (dry seeded, puddle -seeded, puddled-transplanted), wheat, soybean, jute,	Rice, Soybean, Wheat, black gram, cotton, onion, groundnut	Jute
14	Fluchloralin	Cumin, coriander, fennel, fenugreek, beetroot, radish, carrot, onion, garlic, tomato, brinjal, chilli, green pepper, cotton, jute, linseed, sesamum, niger, rapeseed,	cotton, soybean	Cumin, coriander, fennel, fenugreek, beetroot, radish, carrot, onion, garlic, tomato, brinjal, chilli, green pepper, jute, linseed, sesamum, niger,

		mustard, sunflower, soybean, groundnut, chickpea, lentil, field pea, green gram, blackgram, pigeonpea,potato, cabbage, cauliflower,		rapeseed, mustard, sunflower, groundnut, chickpea, lentil, field pea, green gram, blackgram, pigeonpea,potato, cabbage, cauliflower,
15	Glufosinate ammonium (HHP)	Cotton,	Tea, cotton	-
16	Glyphosate (HHP)	Rice puddle transplanted, Cotton, sugarcane,	Tea, Non-crop area	Rice. Cotton, sugarcane
17	Imazethapyr	Soybean, groundnut,	Soybean, Groundnut, black gram, green gram, red gram	-
18	isoproturon	Potato, linseed, sesamum, niger, rapeseed, mustard, wheat,	wheat	Potato, linseed, sesamum, Niger, rapeseed, mustard.
19	metolachlor	Groundnut, chickpea, lentil, field peas	Soybean	Groundnut, chickpea, lentil, field peas
20	Metribuzin (HHP)	Wheat, Chickpea, lentil, field peas, soybean, sugarcane, potato, tomato, brinjal, chilli, green pepper, cucurbits	Soybean, wheat, sugarcane, potato, tomato	Chickpea, lentil, field peas, brinjal, chilli, green pepper, cucurbits
21	Metsulfuron methyl	Wheat,	Wheat, rice, sugarcane,	-
22	Oxadiargyl	Rice (dry seeded, puddle seeded, puddle transplanted), onion, garlic	Rice, cumin, mustard	Onion, garlic
23	Oxadiazon (HHP)	Rice (dry seeded), tomato, brinjal, chilli, green pepper, cotton, linseed, sesamum, niger, rapeseed, mustard, sunflower, soybean, groundnut, green gram, blackgram, pigeonpea, onion, garlic,	Rice	Tomato, brinjal, chilli, green pepper, cotton, linseed, sesamum, niger, rapeseed, mustard, sunflower, soybean, groundnut, green gram, blackgram, pigeonpea, onion, garlic,
24	Oxyfluorfen (HHP)	Rice (dry seeded), green gram, blackgram, pigeonpea, chickpea, lentil, field peas, sunflower, onion, garlic, cucurbits, groundnut,	Rice, tea, onion, potato, groundnut, mentha	Green gram, blackgram, pigeonpea, chickpea, lentil, field peas, sunflower, garlic, cucurbits.
25	Paraquat (HHP)	Cotton, sugarcane,	Tea, Potato, cotton, rubber, coffee, rice, wheat, Maize, Grapes, Apple	Sugarcane
26	Pendimethalin (HHP)	Rice (puddle transplanted, puddle seeded), Cumin, coriander, fennel, fenugreek, beetroot, radish, carrot, onion, garlic, tomato, brinjal,	Wheat, rice, cotton, Soybean, Pigeon pea, chilli, Onion,	Coriander, fennel, fenugreek, beetroot, radish, carrot, garlic, tomato, brinjal, green pepper, cabbage, cauliflower, potato,

		chilli, green pepper, cabbage, cauliflower, potato, cotton, linseed, sesamum,niger, rapeseed, mustard, sunflower, soybean, groundnut, chickpea, lentil, field peas, green gram, black gram, pigeonpea, pearlmillet, sorghum, maize, wheat, jute,	Mustard, cumin, groundnut	linseed, sesamum,niger, rapeseed, sunflower, chickpea, lentil, field peas, green gram, black gram, pearlmillet, sorghum, maize, jute,
27	Pinoxaden	Wheat,	Wheat	-
28	Pretilachlor	Rice (puddled-transplanted, puddle-seeded, dry seeded)	Rice	-
29	Pyrazosulfuron	Rice (puddled-transplanted, puddle-seeded, dry seeded)	Rice	-
30	Pryithiobac sodium	Cotton	Cotton	-
31	Quizalofop-ethyl	Green gram, blackgram, pigeon pea, chickpea, lentil, field peas, groundnut, soybean, rapeseed, mustard, jute, tomato, brinjal, chilli, green pepper, onion, garlic, cumin, coriander, fennel, fenugreek,	Soybean, cotton, groundnut, black gram, onion	Green gram, pigeon pea, chickpea, lentil, field peas, rapeseed, mustard, jute, tomato, brinjal, chilli, green pepper, garlic, cumin, coriander, fennel, fenugreek,
32	Quizalofop-p-terfuryl (HHP)	soybean	Soybean	-
33	Sulfosulfuron	Wheat,	Wheat	-
34	Thiobencarb	Rice dry seeded, puddle seeded, puddle transplanted,	No recommendation	-
35	Trifluralin (HHP)	Groundnut, soybean, sunflower, cotton,	No recommendation	-

(Source; handbook on herbicide recommendation- Directorate of Weed Science Research, Jabalpur-compiled by PAN India)

Annexure 4

Table: Acute toxicity classification by WHO of Herbicides registered in India

	Herbicides	Toxicity based on WHO Classification		
	2,4 D (IARC- Group 2B- Possibly carcinogenic to humans)	Class II	Moderately hazardous	**HHP**
	2,4-D sodium salt	Not classified	Not specified	**-**
	2,4-D Amine salt	Not classified	Not specified	**-**
	2,4 D ethyl ester	Not classified	Not specified	**-**
	Ametryn	Class II	Moderately hazardous	-
	Anilophos	Class II	Moderately hazardous	-
	Atrazine (IARC-Group 3- Not classifiable as to its carcinogenicity to humans)	Class III	Slightly hazardous	-
	Azimsulfuron	Class U	Unlikely to present acute hazard in normal use	-
	Bensulfuron-methyl	Class U	Unlikely to present acute hazard in normal use	-
	Bentazon	Class II	Moderately hazardous	-
	Bispyribac-sodium	Class III	Slightly hazardous	-
	Butachlor	Class III	Slightly hazardous	**HHP**
	Carfentazone-ethyl	Not classified	Not specified	-
	Chlorimuron-ethyl	Class III	Slightly hazardous	-
	Chlorpropham (IARC-Group 3- Not classifiable as to its carcinogenicity to humans)	Class U	Unlikely to present acute hazard in normal use	**HHP**
	Clethodim	Not classified	Not specified	-
	Cinmethylin	Class III	Slightly hazardous	-
	Clodinafop -propargyl	Not classified	Not specified	-
	Clomazone	Class II	Moderately hazardous	-
	Cyhalofop -butyl	Class U	Unlikely to present acute hazard in normal use	-
	Dazomet	Class II	Moderately hazardous	-

	Diclofop-methyl	Class II	Moderately hazardous	**HHP**
	Diclosulam	Class U	Unlikely to present acute hazard in normal use	-
	Diuron	Class III	Slightly hazardous	**HHP**
	Ethoxysulfuron	Not classified	Not specified	-
	Fenoxaprop -P-ethyl	Class III	Slightly hazardous	-
	Florasulam	Class U	Unlikely to present acute hazard in normal use	-
	Florpyrauxifen	Not classified	Not specified	-
	Fluazifop-P-butyl	Class O	Obsolete for use as herbicide	**HHP**
	Flucetosulfuron	Not classified	Not specified	-
	Fluchloralin	Class II	Moderately hazardous	-
	Flufenacet	Class II	Moderately hazardous	-
	Flumioxazin	Class III	Slightly hazardous	**HHP**
	Flupyrimin	Not classified	Not specified	-
	Flurochloridon	Class III	Slightly hazardous	-
	Fluroxypyr meptyl	Class U	Unlikely to present acute hazard in normal use	-
	Fluthiacet methyl	Class U	Unlikely to present acute hazard in normal use	**HHP**
	Fomesafen	Class II	Moderately hazardous	-
	Glufosinate-ammonium	Class II	Moderately hazardous	**HHP**
	Glyphosate (IARC-Group 2A- probably carcinogenic to humans)	Class III	Slightly hazardous	**HHP**
	Halauxifen methyl	Not classified	Not specified	-
	Halosulfuron	Not classified	Not specified	-
	Haloxyfop-methyl	Class II	Moderately hazardous	**HHP**
	Hexazinone	Class II	Moderately hazardous	-
	Imazethapyr	Class U	Unlikely to present acute hazard in normal use	-
	Imazamox	Class III	Slightly hazardous	-
	Indaziflam	Not classified	Not specified	-
	Isoproturon	Class II	Moderately hazardous	-

	Methabenzthiazuron	Class III	Slightly hazardous	**HHP**
	Methyl bromide	F M	fumigant	
	Metolachlor	Class III	Slightly hazardous	
	Metribuzin	Class II	Moderately hazardous	**HHP**
	Metamifop	Not classified	Not specified	-
	Metamitron	Class II	Moderately hazardous	-
	Methyl chlorophenoxy acetic acid	Class II	Moderately hazardous	-
	Metsulfuron -methyl	Class U	Unlikely to present acute hazard in normal use	-
	Mesosulfuron methyl	Not classified	Not specified	-
	Mesotrione	Class III	Slightly hazardous	-
	Orthosulfamuron	Not classified	Not specified	-
	Oxadiargyl	Not classified	Not specified	-
	Oxadiazon	Class U	Unlikely to present acute hazard in normal use	**HHP**
	Oxyfluorfen	Class U	Unlikely to present acute hazard in normal use	**HHP**
	Paraquat dichloride	Class II	Moderately hazardous	**HHP**
	Pendimethalin	Class II	Moderately hazardous	**HHP**
	Penoxsulam	Class U	Unlikely to present acute hazard in normal use	-
	Pretilachlor	Class U	Unlikely to present acute hazard in normal use	-
	Pinoxaden	Class III	Slightly hazardous	-
	Propanil	Class II	Moderately hazardous	-
	Propaquizafop	Class U	Unlikely to present acute hazard in normal use	-
	Pyrazosulfuron-ethyl	Class U	Unlikely to present acute hazard in normal use	-
	Pyriftalid	Not classified	Not specified	-
	Pyrithiobac-sodium	Class III	Slightly hazardous	-
	Pyroxasulfon	Not classified	Not specified	-
	Quizalofop-ethyl	Class II	Moderately hazardous	-

	Quizalofop p terfuryl	Class II	Moderately hazardous	**HHP**
	Saflufenacil	Class III	Slightly hazardous	-
	Sodium acifluorfen	Not classified	Not specified	-
	Sulfentrazone	Not classified	Not specified	-
	Sulfosulfuron	Not classified	Not specified	-
	Tembotrione	Not classified	Not specified	-
	Thiobencarb	Class II	Moderately hazardous	-
	Topramezone	Not classified	Not specified	-
	Triafamone	Not classified	Not specified	-
	Triallate	Not classified	Not specified	**HHP**
	Triasulfuron	Class U	Unlikely to present acute hazard in normal use	-
	Trifloxysulfuron sodium	Not classified	Not specified	-
	Trifluralin (IARC-Group 3- Not classifiable as to its carcinogenicity to humans)	Class U	Unlikely to present acute hazard in normal use	**HHP**

(Table developed by PAN India, based on *The WHO recommended classification of pesticides by hazard and guidelines to classification 2019*, World Health Organization, 2020) – compiled by PAN India

Annexure 5

Table 4: Toxic effects of herbicides registered in India

Sl. No	Herbicides	Toxic effects	
1	2,4 D	Endocrine disruptor, reproductive, neuro toxicant, Irritant to eyes, skin and Respiratory tract	**HHP**
2	Ametryn	Irritant to eyes and skin	-
3	Anilophos	Acetyl cholinesterase inhibitor, neurotoxicant, respiratory and skin irritant.	-
4	Atrazine	Endocrine disruptor, Irritant to eyes, skin and respiratory tract	-
5	Azimsulfuron	No sufficient data	-
6	Bensulfuron-methyl	No sufficient data	-
7	Bentazon	Skin sensitizer and eye irritant	-
8	Bispyribac-sodium	Skin sensitizer	-
9	Butachlor	Skin irritant and sensitizer	**HHP**
10	Carfentrazone-ethyl	No sufficient data	-
11	Chlorimuron-ethyl	No sufficient data	-
12	Chlorpropham	Possible spleen, bone-marrow & red blood cell toxicant	**HHP**
13	Clethodim	Skin irritant, Possible liver and blood toxicant	-
14	Cinmethylin	Skin sensitizer, may cause damage nasal cavity, liver and gastrointestinal toxicant	-
15	Clodinafop -propargyl	Skin sensitizer and eye irritant, Possible ovaries, prostrate and blood toxicant	-
16	Clomazone	Reproductive and liver toxicant	-
17	Cyhalofop -butyl	Potential gall bladder, liver & kidney toxicant	-
18	Dazomet	Skin and eye irritant, skin sensitizer, liver toxicant	-
19	Diclofop-methyl	Skin sensitizer, respiratory irritant, kidney and liver toxicant	**HHP**
20	Diclosulam	Irritant to eyes and skin,	-
21	Diuron	Carcinogen, endocrine disruptor, respiratory irritant, Possible blood, kidney, bladder, spleen and liver toxicant	**HHP**
22	Ethoxysulfuron	Skin and eye irritant,	-
23	Fenoxaprop -P-ethyl	Respiratory, eye and skin irritant, possible liver and kidney toxicant.	-

24	Florasulam	Respiratory tract irritant, Potential blood, adrenals, kidney and liver toxicant.	-
25	Florpyrauxifen	No available data	-
26	Fluazifop-P-butyl	Skin sensitizer, possible kidney and liver toxicant.	**HHP**
27	Flucetosulfuron	No available data	
28	Fluchloralin	Skin and eye irritant,	-
29	Flufenacet	Skin sensitizer, possible thyroid, spleen and liver toxicant.	-
30	Flumioxazin	Reproductive toxicant, Eye irritant.	**HHP**
31	Flupyrimin	No available data	-
32	Fluchloridon	No available data	-
33	Fluroxypyr meptyl	Reproductive toxicant, possible kidney toxicant	-
34	Fluthiacet methyl	Carcinogen, eye irritant, Possible liver and pancreas toxicant	**HHP**
35	Fomesafen	Respiratory tract, eye and skin irritant, possible liver toxicant	-
36	Glufosinate-ammonium	Reproductive and neurotoxicant, possible lungs, kidney and bladder toxicant.	**HHP**
37	Glyphosate	Eye irritant, possible bladder and liver toxicant, carcinogen	**HHP**
38	Halauxifen methyl	Reproductive toxicant, possible kidney, liver and bladder toxicant	-
39	Halosulfuron	Respiratory tract irritant	-
40	Haloxyfop-methyl	Skin irritant	**HHP**
41	Hexazinone	Skin irritant	-
42	Imazethapyr	Respiratory tract, eye and skin irritant	-
43	Imazamox	Reproductive toxicant, eye and skin irritant	-
44	Indaziflam	Neurotoxicant, eye irritant, possible liver and thyroid toxicant	-
45	Isoproturon	Carcinogen, endocrine disruptor, skin and eye irritant	-
46	Methabenzthiazuron	Respiratory tract, eye and skin irritant	**HHP**
47	Metolachlor	Endocrine disruptor, eye and skin irritant, possible carcinogen	-
48	Metribuzin	Endocrine disruptor, reproductive toxicant, thyroid toxicant	**HHP**
49	Metamifop	No available data	-
50	Mesotrione	Skin and eye irritant, neurotoxicant, may damage corneal opacity	-
51	Metamitron	Endocrine disruptor, possible thyroid toxicant	-
52	Methyl chlorophenoxy acetic acid	Eye irritant, Possible liver, kidney & blood toxicant	-

53	Methyl bromide	Reproductive and neurotoxicant, eye, skin and respiratory irritant, kidney toxicant.	-
54	Metsulfuron -methyl	Respiratory tract irritant	-
55	Mesosulfuron methyl	Respiratory tract and eye irritant	-
56	Novaluron	Possible spleen toxicant	-
57	Orthosulfamuron	Reproductive tract irritant, neurotoxicant, Possible liver, spleen and kidney toxicant	-
58	Oxadiargyl	No available data	
59	Oxadiazon	Reproductive toxicant, respiratory tract irritant, liver toxicant.	**HHP**
60	Oxyfluorfen	Carcinogen, possible Liver and spleen toxicant	**HHP**
61	Paraquat dichloride	Respiratory tract, eye and skin irritant, Potential liver, kidney, stomach, intestine and respiratory system toxicant	**HHP**
62	Pendimethalin	Reproductive, thyroid, liver and neurotoxicant, skin, eye, and respiratory tract irritant.	**HHP**
63	Penoxsulam	Possible blood, liver and kidney toxicant	-
64	Pretilachlor	Respiratory tract, eye and skin irritant	-
65	Pinoxaden	Respiratory tract, eye and skin irritant, skin sensitizer	-
66	Propanil	Endocrine disruptor, Eye irritant, Possible liver, kidney, spleen and testes toxicant	-
67	Propaquizafop	skin sensitizer	-
68	Pyrazosulfuron-ethyl	No available data	-
69	Pyriftalid	No available data	-
70	Pyrithiobac-sodium	Possible liver toxicant, possible human carcinogen	-
71	Quizalofop-ethyl	No available data	-
72	Quizalofop p terfuryl	Skin sensitizer, eye irritant, possible liver toxicant	**HHP**
73	Saflufenacil	No available data	-
74	Sodium acifluorfen	No available data	-
75	Sulfentrazone	Eye irritant, possible liver and kidney toxicant	-
76	Sulfosulfuron	Eye irritant, possible kidney and urinary system toxicant	-
77	Tembotrione	Eye irritant, skin sensitizer	-
78	Thiobencarb	Neurotoxicant, acetyl cholinesterase inhibitor, possible liver and kidney toxicant	-
79	Topramezone	Reproductive toxicant, skin irritant, possible liver, thyroid toxicant	-

80	Triafamone	Liver and thyroid toxicant	-
81	Triallate	Skin sensitizer, possible human carcinogen, possible liver, spleen and kidney toxicant	**HHP**
82	Triasulfuron	Possible blood and liver toxicant, Respiratory tract irritant	
83	Trifloxysulfuron sodium	Skin and eye irritant, cause protein metabolism disturbances, emphysema and weight loss.	
84	Trifluralin	Endocrine disruptor, reproductive, liver, blood, kidney and neurotoxicant, respiratory tract irritant, skin sensitizer.	**HHP**

(Table compiled by PAN India, Information collected from Pesticide Property Database; University of Hertfordshire)-compiled by PAN India

Annexure 6

Table 5: Herbicide manufacturers in India

Sl. No	Name of Herbicides	Indigenous manufacturers	
1	2,4-D Ethyl Ester Technical 97% min.	1. Insecticides India Ltd, Delhi 2. Swati Chlorides Pvt Ltd, Vadodara 3. Ambey Laboratories Pvt Ltd, New Delhi 4. Crystal Phosphates, Delhi. 5. Atul Ltd., Valsad 6. Bharat Rasayan Ltd., Delhi 7. Megmani Organics Ltd., Ahmedabad	**HHP**
2	2,4-D Sodium Salt Technical 94.5% min. 80% min Dichlorophenoxy acetic acid	1. Insecticides India Ltd, Delhi 2. Atul Ltd., Valsad 3. Megmani Organics Ltd., Ahmedabad 4. Bharat Rasayan Ltd. Delhi (80%) 5. Excel Phosphate Pvt. Ltd. Delhi 6. AgroAlliedVenturePvt.Ltd. 7. Bhanshidhar Chemicals, Bhaskar Agrochemicals Ltd., Hyderabad	-
3	Ametryn 80% WG (FI-WRT), *95% min.	M/s Meghmani Industries Ltd.	-
4	Anilophos Technical 93% min.	1. Bayer Crop Science Ltd., Mumbai. 2. Gharda Chemicals Ltd., Mumbai. 3. Hyderabad Chemical Pvt Limited	-
5	Atrazine Technical 80%, 95% min*, 97% min. (418)	1. Rallis India Ltd., Bangalore 2. Pesticides India, Udaipur 3. Nagarjuna Agrichem, Hyderabad 4. GSP Crop Science Pvt. Ltd. Ahmedabad 5. Insecticide India Ltd 6. Megmani Industries Ltd. 7. Best Crop Science LLP, Gajraula, UP 8. Maheshwari Biochemicals Pvt. Ltd 9. HPM Chemicals & Fertilizers Ltd.,	-
6	Bispyribac - sodium Technical 95% min, 96% min*	1. Gharda Chemicals Ltd. 2. Insecticides India Ltd. 3. Godrej Agrovet Ltd. 4. Excel Crop Care Ltd. 5. ADAMA India Pvt. Ltd. Hyderabad, 6. Indofil Industries Ltd., Mumbai, 7. PI Industries ltd, Udaipur 8. M/s Coromandel International Ltd., 9. M/s Best Crop Science LLP 10. M/s Punjab Chemicals and Crop Protection Ltd 11. M/s. Cropnosys India Pvt. Ltd	-
7	Butachlor Technical 95% min.	1. Insecticides India Ltd. 2. Jaishree Agro Industries Ltd, Delhi 3. Hyderabad Chemical Products Ltd. 4. Coromandel International Ltd., Secunderabad 5. Bharat Rasayan Ltd., Delhi 6. Sudarshan Chemical Industries Ltd., Pune	**HHP**
8	Butachlor Technical 85% min	1. Hindustan Insecticides Ltd., Delhi.	**HHP**

		2. Montari Industries Ltd., Delhi. 3. Siris India Ltd., Hyderabad.	
9	Clodinafop -propargyl Technical 93% min (Piroxofop - Propinyl)	1. United Phosphorus Limited, Gujarat 2. Atul Limited, Gujarat 3. Gharda Chemicals Ltd, Mumbai 4. Bhagiradha Chemicals & Industries Ltd., Prakasham District (A.P.) 5. Excel Phosphate Pvt. Ltd., Delhi 6. Hyderabad Chemical Products Ltd 7. Crystal phosphate Limited, Delhi 8. Rotam India Ltd, Mumbai 9. Ravi Organics Ltd 10. Bharat Rasayan Ltd 11. Punjab Chemicals & Crop Protection Ltd 12. Sharda Worldwide Exports Pvt Limited 13. Meghmani Industries Limited 14. Modern Insecticides Ltd., Ludhiana 15. Chemtura Chemical India Pvt. Ltd, New Delhi 16. GSP Crop Science Pvt. Ltd. Ahmedabad 17. Insecticides India Ltd 18. Sundew Life Science Pvt Ltd, Coimbatore. 19. Sabero Organics Gujarat Ltd. 20. Gharda Chemicals Ltd. 21. HPM Chemicals & Fertilizers Ltd. 22. M/s. Crystal Crop Protection Pvt. Ltd., N. Delhi 23. Best Crop Science LLP, Gajraula, UP 24. Agrico Organics Ltd., New Delhi 93%mi	-
10	Chlorpropham technical 98% w/w min	M/s UPL Ltd. Mumbai, u/s 9(3), 98.0% w/w Min. in 398th RC (TIM vs TI)	**HHP**
11	Chlorimuron ethyl Technical 95% min.	1. Atul Limited, Valsad, Gujarat 2. JaiShree Rasayan Udyog Ltd., Delhi 3. Ambey Labs Pvt. Ltd., New Delhi 4. M/s UPL Ltd 5. M/s Best Crop Science LLP	-
12	Dazomet tech 94% min	Margo Bio Controls Pvt. Ltd. Bangalore	-
13	Dichlorophenoxy Acetic Acid Sodium salt (2,4-D) 80.3% acid	1. Atul India Limited, Valsad 2. Artee Minerals, Faridabad 3. Dhanuka Pesticides 4. Meghmani Organics Ltd. 5. Heranba Industries Ltd.	-
14	Glufosinate Ammonium Technical 50% min. (LC)	M/s UPL Limited, Mumbai	**HHP**
15	Glyphosate Tech. 95% min.* Glyphosate IPA Salt Technical 62%min.	1. Atul Ltd., Valsad 2. Excel Crop Care Ltd. Ltd., Mumbai 3. Gharda Chemicals Ltd., Mumbai 4. Chemtura Chemicals India Pvt. Ltd. 5. Ravi Organics Ltd. 6. Meghmani Industries Ltd. 7. Insecticide India Ltd. 8. Crystal Phosphates Ltd 9. Hyderabad Chemicals Products Ltd., Hyderabad 10. Krishi Rasayan Pvt. Ltd., Kolkata 11. United Phosphorus Ltd., Vapi 12. Punjab Chemicals & Crop Protection Ltd	**HHP**

		13. Rotam India Ltd 14. G S P Crop Science Ltd 15. Siris Crop Science Ltd., New Delhi 16. Jai Shree Rasayan Udyog Ltd, Nathupur, Sonepat (Haryana) 17. Heranba Industries Ltd, Mumbai 18. Shivalik Rasayan Ltd, New Delhi 19. Sharda worldwide Exports Pvt Ltd, Mumba, 20. Cheminova India Ltd., Gujarat 21. Sabero Organics Gujarat Ltd. 22. Bharat Rasayan Ltd., Delhi 23. Excel Industries Ltd., ROHA (Maharashtra) 24. HPM Chemicals & Fertilizers Ltd., N. Delhi 25. Best Crop Science LLP, Gajraula, UP 26. Sonachi Industries Ltd. 27. Samradhi Crop Chemicals 28. Sun Pesticides Pvt. Ltd 29. Hemani Industries 30. Agrisol (India) Pvt. Ltd 31. Agrico Organics Ltd., New Delhi 32. Baroda Agro chemicals Ltd., Gujarat 33. M/s Aristo Biotech Life Science Pvt. Ltd., 34. M/s Ichiban Crop Science Ltd. 35. Maheshwari Biochemical Pvt. Ltd., Sirsa	
16	Halosulfuron Methyl 75% WG (FI -WRT), *97%min.	M/s. Coromandel International Ltd.	-
17	Hexazinone 13.2% + Diuron 46.8% WP	M/s Insecticides India Ltd., (Diuron Technical)	-
18	Imazethapyr Technical 90% min, 93% min.*, 98% min **, 97.00% w/w min., 95% w/w min.,	1. Astec Life Sciences Ltd. Mumbai 2. Insecticides India Ltd, Delhi, 3. Best Crop Science LLP 4. M/s Agrow Allied Venture Pvt. Ltd 5. Agric Organics Ltd New Delhi 6. Gharda Chemicals Ltd Mumbai, 7. Meghmani Industries Ltd 8. Krishi Rasayan Exports, New Delhi, 9. GSP Crop Science Pvt. Ltd 10. Maheshwari Biochemical Pvt. Ltd., Sirsa 11. UPL Limited, Mumbai. 12. M/s Godavari Farm Chemicals Industries Ltd. 13. M/s Shivalik Rasayan Ltd 14. M/s Ichiban Crop Science Ltd 15. M/s. Sahib Pesticides, 16. M/s. Bhagiradha Chemicals & Industries Ltd.	-
19	Isoproturon Technical 95% min	1. Bayer Crop Science Ltd., India (TIM) 2. Agrevo India Ltd., Mumbai 3. Atul Ltd., Valsad 4. Gharda Chemicals Ltd., Mumbai 5. Montari Industries Ltd., Delhi. 6. Siris India Ltd., Hyderabad 7. Agrico Organics ltd, New Delhi. 8. Cheminova India Ltd., Bangalore 9. Bharat Rasayan Ltd., Delhi 10. Bayer Crop Science Ltd., Mumbai.	-

20	1. Metsulfuron methyl Technical 93% min. 96% min. 2. Metsulfuron Methyl20% WG* 3. Metsulfuron methyl 10% w/w + Carfentrazone Ethyl 40%w/wDF**	1. Atul Ltd., Valsad 2. GSP Crop Science Pvt. Ltd., Ahmedabad 3. Siris Crop Science Limited, New Delhi 4. Indofil Industries Ltd, Andheri(E) 5. Meghmani Industries Limited 6. Punjab Chemicals and Crop Protection Pvt Limited 7. Sharda Worldwide Pvt Limited 8. Insecticides India Ltd. 9. Hindustan Pulversing Mills, Delhi 10. Bharat Rasayan Ltd., Delhi 11. Shahib Pesticides, Karnal 12. Crystal Phosphates Ltd, Delhi. 13. M/s Best Crop Science LLP 14. M/s Godavari Farm Chemical Industries Pvt.Ltd	
21	Methyl bromide Technical 99%m min. & 98% min.	1. Tata Chemicals, Mithapur 2. Intech Pharma Pvt. Ltd., New Delhi 3. Central Warehousing Corporation, New Delhi	
22	Metamitron Technical 98.00% w/w min.(w/w)	M/s Punjab Chemicals & Crop Protection Ltd., Mumbai	
23	Metribuzin Technical 88% min., 95% w/w Min	1. Rallis India Ltd., Mumbai 2. Meghmani Industries Ltd. 3. Siri Crop Science Limited, New Delhi 4. Punjab Chemicals and Pharmaceutical Ltd, Chandigarh 5. Ravi Organics Ltd 6. GSP Crop Science Pvt Ltd, Ahmedabad 7. Bharat Rasayan Ltd., Delhi 8. Coromandel International Ltd 9. Best Crop Science LLP, Gajraula, UP 10. Atul Ltd., Valsad 11. Jai Shree Rasayan Udyog Ltd 12. Hindustan Pulverising Mills, Delhi,	**HHP**
24	Oxadiargyl Technical 96% min.,	Bayer Crop Science Ltd., Mumbai	-
25	Oxyfluorfen Technical 97% min.	M/s Best Crop Science LLP approved in 425th RC	**HHP**
26	Paraquat dichloride Technical 40% min.,**42% min**. (418RC)	1. Crystal Phosphate Ltd., New Delhi 2. United Phosphorus Ltd., Mumbai	**HHP**
27	Pendimethalin Technical 90% min.	1. Shivalik Rasayan Ltd., New Delhi 2. Siris Crop Science Ltd., New Delhi 3. Punjab Chemicals & Crop Protection Limited, Chandigarh 4. Magma Industries Ltd. 5. Heranba Industries Limited, 6. United Phosphorus Limited, Mumbai 7. Megmani Industries Ltd. 8. Bharat Rasayan Ltd, Delhi 9. Rallis India Limited 10. GSP Crop Science Pvt. Ltd. Ahmedabad 11. Coromandal International Ltd. 12. M/s Hindustan Insecticides Ltd. 13. M/s. Crop Life Science Ltd.,	**HHP**

		Ankleshwar, 14. M/s. Coromandal Agricao Pvt. Ltd., 15. JaiShree Rasayan Udyog Ltd., New Delhi 16. M/s. Godavari Farm Chemical Industries Ltd., 17. M/s. Crystal Crop Protection Ltd., 18. M/s. Himani Industries Ltd	
28	Penoxsulam Technical 97.0% min	Crystal Crop Protection Pvt. Ltd	-
29	Pinoxaden tech 95.0% Min	M/s Insecticides India Ltd. u/s 9(3) approved in 427th RC	-
30	Pretilachlor Technical 94% min., **96% min (414), 97% min.**	1. Nagarjuna Agrichem Ltd., Hyderabad. u/s 9 (3) in220thRC 2. GSP Crop Science (P) Ltd., Ahmedabad 3. Hyderabad Chemical Product Limited, Hyderabad 4. Siris Crop Science Limited, New Delhi 5. Atul Limited, Vapi 6. Sudarshan Chemical Industries Ltd, Pune 7. United Phosphorus Ltd 8. Chemtura Chemicals India Pvt. Ltd 9. Crystal phosphate Limited 10. Meghmani Industries Limited 11. Indofil Industries Ltd., Andheri(E), Mumbai 12. Ravi Organics Ltd 13. Deccan Fine Chemicals (India) Ltd., 14. Insecticides India Ltd 15. Punjab Chemicals and Crop Protection Ltd., Mumbai 16. Bharat Rasayan Ltd., Delhi 17. HPM Chemicals & Fertilizers Ltd., N. Delhi 18. Best Crop Science LLP, Gajraula, UP 19. Samardhi Crop Chemicals Ltd. 20. Agrico Organic Ltd, 96.0% min. 21. Bhagiradha Chemicals & Industries Ltd., Hyderabad. 22. Excel Phosphates Ltd., Meerut. 23. M/s.Mahamaya Life Sciences Pvt. Ltd. Delhi (TIT vs TIM)	-
31	Propanil Technical 88% min., 97% w/w min	M/s UPL Ltd., Mumbai, RC (TIM vs TIT)	-
32	Pyrazosulfuron ethyl Technical 97.00% w/w min., **98% min**	1. M/s UPL limited, Mumbai, 2. Meghmani Industries Ltd. 3. M/s. Bharat Rasayan Ltd., 97.00% Min. 9 (4) in 393rd RC 4. M/s Ichiban Crop Science Ltd. u/s 9(4) in 421st RC	-
33	Pyrithiobac Sodium 95% min	Goldmuhar Agrochem & Field Ltd., Vikhroli (Mumbai),	-
34	Quizalofop ethyl Technical, 98% w/w	1. M/s.Crystal Crop protechion Pvt. Ltd., 9(3) 98% w/wmin. In 380thRC (TIM vsFI) 2. M/s. Godrej Agrotech Ltd, 9(3)98% w/wmin. In 380th RC (TIMvsFI) 3. M/s. Atul Ltd., 9(3), 98%w/wmin in 387th RC (TIMvsFI)	-
35	Sulfentrazone Technical 91% Min., 95.00% w/w min. *	M/s. Tagros Chemicals India Ltd. 95.00% w/w min. TIM, 9(3), 395th RC.	-
36	Sulfosulfuron Technical 98% min., 98.5% min.	1.United Phosphorus Limited u/s9(3)in 227thRC 2. Gharda Chemicals, Mumbai,	-

		3. Hyderabad Chemical Products Ltd., Hyderabad 4. Atul Limited, Gujarat 5. Tagros India Ltd, Chennai 6. Meghmani Industries Limited, Ahmedabad 7. Crystal Phosphate Ltd, Delhi 8. GSP Crop Science Private Limited, Ahmedabad 9. Insecticide India Limited 10. Indofil Industries Ltd., Andheri(E) 11. Bharat Rasayan Ltd 12. Sharda Worldwide Exports Pvt Limited 13. Excel Crop Care Ltd., Mumbai 14. Punjab Chemicals and Crop Protection Ltd., Mumbai 15. Heranba Industries Ltd. 16. Indofil Industries Ltd., Andheri(E), Mumbai 17. HPM Chemicals & Fertilizers Ltd., N. Delhi, 98.5 %min.9(4) 18. Best Crop Science LLP, Gajraula, UP, 98.5 %min.9(4) 19. Excel Phosphate Pvt. Ltd. 98.5% min.9(4) 20. M/s Godavari Farm Chemical Industries Pvt. Ltd, 98.5%min.9(4), in 408th RC Ahmedabad	
37	Tembotrione Technical 94% min	M/s Insecticide India Ltd. approved in 425th RC	
38	Topramezone Technical 95.8% w/w min.	M/s Lonza AG Muenchensteinerstrasse 384002 Basel, Switzerland (by M/s BASF India Ltd. in 423rd RC)	
39	Trifluralin Technical 85% min. 95% min	De-nocil Crop Protection Ltd., Mumbai Sudarshan Chemicals industries Ltd	**HHP**

(Source-Directorate of Plant Protection, Quarantine and Storage)- compiled by PAN India

Manufacturers and their herbicide products

Manufacturer name	Trade name of the product	Active ingredient	Target crop	
Adama India pvt ltd	Agil	Propaquizafop 10% ec, 15 % WP	Black gram, chickpea, cluster bean, groundnut, jute, onion, potato, soybean, tomato and chilli	-
	2,4 d agan, 2,4 d main	2,4 d	Not specifically mentioned	**HHP**
	Atranex-,	Atrazine 50% WP	Maize and sugarcane	-
	Clodinagen	Clodinafop-propargyl	Wheat	-
	Dekel-	Propaquizafop 5% + oxyflurofen 12% w/w EC	Onion	-
	Galigan-	Oxyfluorfen 23.5 % EC	Onion, tea, potato, groundnut, rice.	**HHP**
	Glyphogan-	Glyphosate 41% SL	Tea and non-cropped areas	**HHP**
	Metriagan-	Metribuzin 70 % WP	Soybean and wheat	**HHP**
	Narkis-	Bispyribac sodium 10% SC	Rice	-
	Oximain-	Oxadiargyl 80 % WP	Transplanted rice	-
	Paranex-	Paraquat dichloride 24% SL	Tea and potato	**HHP**
	Pendigan	- pendimethalin 30% EC	Transplanted rice	**HHP**
	Pretigan-	Pretilachlor 50 % EC	Transplanted rice	-
	Shaked-	Propaquizafop 2.5%+ imazethapyr 3.75% w/w m	Soybean	-
	Tamar-	Ametryn 80 % WDG	Sugarcane	-
Amba chem industries	Esteron 20	2,4-d ethyl ester 20% WP	Not specifically mentioned	**HHP**
	Esteron-g	Paraquat dichloride 24% SL	Not specifically mentioned	**HHP**
	Esteron p	Pendimethalin 30 EC	Potato, coffee & cotton, rubber, sugarcane, rice, wheat, tapioca, sunflower, grapes	**HHP**
	Esteron-58	2,4-d amine salt 58% SL	Cereals, tea, wheat, rice, maize, millets, grasslands, grass seed crops, orchards, cranberries, sugarcane, rice, forestry and non-crop land	**HHP**

	Esteron 38	2,4-d ethyl ester 38 EC	Cereals, tea, wheat, rice, maize, millets, grasslands, established turf, grass seed crops, orchards, cranberries, sugarcane	**HHP**
	Knock down	Glyphosate 41% SL	Not specifically mentioned	**HHP**
	Knock down-71	Glyphosate 71% SG	Not specifically mentioned	**HHP**
	Metrizin	Metribuzin 70% WP	Sugarcane and maize	**HHP**
Bayer crop science ltd.	Adora	Bispyribac-sodium 10% SC (9.5% w/w	Transplanted rice Direct seeded rice	-
	Alion plus	Indaziflam 20 + glyphosate IPA 540 SC	Tea	
	Council active	Triafamone 20% + ethoxysulfuron 10% WG	Transplanted rice Direct seeded rice	-
	Laudis	Tembotrione 42% SC (34.4% w/w)	Corn	-
	Lucifer	Clodinafop - propargyl 15% WP	Wheat	-
	Momiji	Pyroxasulfone 85% WG	Wheat	-
	Raft	Oxadiargyl 6 EC (6 % w/w)	Transplanted rice, cumin, mustard	-
	Ricestar	Fenoxaprop-p-ethyl 6.9 EC (6.7% w/w)	Transplanted rice Direct seeded rice	-
	Sencor	Metribuzin 70 WP (70% w/w)	Sugarcane, potato, tomato, wheat and soybean	**HHP**
	Sunrice	Ethoxysulfuron 15% WDG	Transplanted rice	-
	Topstar	Oxadiargyl 80% WP	Transplanted rice	-
	Whip super	Fenoxaprop-p-ethyl 9 EC (9.3% w/w)	Soybean, rice, cotton, black gram, onion.	-
Crystal crop protection Pvt. Ltd.	Allquit	Paraquat Dichloride 24% SL	Not specifically mentioned	**HHP**
	BANGO	Quizalofop ethyl 10 % EC	Soybean	-
	Clinton	Glyphosate 41% SL	Tea	**HHP**
	Guard	Imazethapyr 10 % SL	Soybean, groundnut	-
	Penoxa	Penoxsulam 21.7% SC	Transplanted paddy	-
	Ronaldo	Oxyfluorfen 23.5% EC	Tea, Onion, Groundnut	**HHP**
	Shift	Pretilachlor 50% EC	Transplanted Rice	-
	Srizone	Atrazine 50% WP	Maize, Sugarcane	-
	Topper 77	Glyphosate 71% SG	Tea and non-crop	**HHP**

	Weedor	2,4D Amine Salt 58% SL	Sorghum, Maize, Wheat, Sugarcane	**HHP**
	CUTOUT-38	2,4D Ethyl Ester 38% EC	Sorghum, Maize, Wheat, Sugarcane, Paddy	**HHP**
Dhanuka Agritech ltd	Barrier	Metribuzin 70% WP	Sugarcane, potato, tomato, soybean, wheat	**HHP**
	Chempa	Pyrazosulfuron-ethyl 70% WDG	Paddy	-
	Craze	Pretilachlor 50% EC	Paddy	-
	Dhanutop	Pendimethalin 30% EC	Onion, cotton, soybean, wheat, paddy, black gram, green gram, garlic	**HHP**
	Fenox	Pinoxaden 5.1% EC	Wheat	-
	Max-soy	Quizalofop-ethyl 10% EC	Soybean	-
	Nabood	Carfentrazone ethyl 40% DF	Wheat and direct seeded rice	-
	Noweed	Glyphosate 41% SL	Tea and open fields	**HHP**
	Ozone	Paraquat dichloride 24% SL	Tea, potato, cotton, rubber, paddy, wheat, grapes and aquatic weeds.	**HHP**
	Sakura	Quizalofop ethyl 10% EC	Soybean	-
	Sempra	Halosulfuron methyl 75% WG	Sugarcane and maize	-
	Weedmar super	2,4-d amine salt 58% S	Sorghum, maize, wheat, sugarcane, potato.	
	Targa super	Quizalofop ethyl 5% EC	Soybean, cotton, groundnut, blackgram, onion.	-
Excel crop care ltd.	Casanova	Glyphosate 54% SL	Non-crop area	**HHP**
	D cel	2,4 d sodium salt 80% WP	Citrus	**HHP**
	Excel mera 71	Ammonium salt of glyphosate 71% SG	Tea & non-crop area	**HHP**
	Glycel	Glyphosate 41% SL (ipa salt)	Tea	**HHP**
	Junoon	Bispyribac sodium 10% SC	Rice	-
	Sugam	Imazethapyr 10% SL	Soybean and groundnut	-
	Vidhavans	Clodinafop propargyl 15% WP	Wheat	-
	Weedcel super	2,4 d amine salt 58% SL	Maize, sorghum, wheat, potato, sugarcane and aquatic weeds.	**HHP**
	Atrahit	Atrazine 50% WP	Maize	-

HPM chemicals & fertilizers ltd	Al-vida	Pyrazosulfuron ethyl 10% WP	Paddy	-
	All clear	Paraquat dichloride 24% SL	Tea, Potato, Cotton, Rice	**HHP**
	Biochlor	Chlorimuron-ethyl 25% WP	Soybean, Rice	-
	Cheetah	Imazethapyr 10% SL	Soyabean, Groundnut	-
	Clodino super	Clodinafop-propargyl 15% WP	Wheat	-
	Freedom	Metsulfuron methyl 20% WP	Wheat, Rice	-
	Gadar	Pendimethalin 30% EC	Cotton, Soyabean, Wheat, Paddy	**HHP**
	Heera-44	2-4-d ethyl ester 38% EC	Sorghum, Maize, Wheat, Sugarcane etc	**HHP**
	Heera-77	2-4-d amine salt 58% SL	Sorghum, Maize, Wheat, Sugarcane etc	**HHP**
	Heera super	2,4-d sodium salt 80% WP	Citrus, Wheat, Sugarcane	**HHP**
	Hifit	Pretilachlor 50% EC	Rice	
	Hunter	Butachlor 50% EC	Rice	**HHP**
	Hunter 5g	Butachlor 5% GR	Rice	**HHP**
	Stump	Metribuzin 70% WP	Sugarcane, Potato, Tomato, Soybean	**HHP**
	Target	Sulfosulfuron 75% WG	Wheat	-
	Tiger	Oxadiargyl 80% WP	Rice	-
	Waada	Oxyfluorfen 23.5% EC	Rice, Groundnut	**HHP**
Indofil industries limited	Atrafil	Atrazin 50 % WP	Maize	-
	Clean up	Glyphosate 41% SL	Tea	**HHP**
	Offset	Pretilachlor 50% EC	Rice	-
	Oxygold	Oxyflurofen 23.5 % EC	Ground nut, onion, potato, rice, tea	**HHP**
	Society	Propaquizafop 10% EC	Black gram, soyabean	-
JU Agri sciences pvt. Ltd.	Atrazine	Atrazine 50 WP	Sugarcane, paddy	-
	Burn out	2,4-d amine salt 58 SL	Not specifically mentioned	**HHP**
	Chancellor	Haloxyfop methyl 10.5% EC	Soybean	-
	Farak	Pinoxaden 5.1% EC	Wheat	-
	Glypho 71	Glyphosate 71 SG	Crop & non- crop situation	**HHP**

	Glypho-41	Glyphosate 41 SL	Tea & non- cropped areas	**HHP**
	Laathi	Pyrazosulfuron ethyl 10% WP	Paddy	-
	Metri	Metribuzin 70% WP	Tomato, sugarcane, potato, soybean, wheat	**HHP**
	Oxy plus	Oxyfluorfen 23.5% EC	Paddy, tea, onion, peppermint, potato	**HHP**
	Pendiplus	Pendimethalin 30 EC	Not specifically mentioned	**HHP**
	Pretilachlor	Pretilachlor 50% EC	Transplanted paddy	-
	Ribac-gold	Bispyribac sodium 10% SC	Paddy	-
	Weed out	Paraquat dichloride 24 SL	Not specifically mentioned	**HHP**
	Win super	Fenoxaprop-p-ethyl 9.3% EC	Soybean, paddy, cotton, black gram	-
	Jugrip	Metsulfuron methyl 20% WP	Wheat, sugarcane and transplanted paddy	-
Multiplex Agricare pvt. Ltd	Fast out	Pendimethalin	Soybean, wheat, groundnut, cotton, mustard	**HHP**
	Fulfill	Metsulfuron methyl 20% WP	Wheat, transplanted rice and sugarcane	-
	Karta	Pendimethalin 38.7% CS	Soya bean and onion	**HHP**
	Nagat	Paraquat dichloride 24% SL	Tea, coffee, rubber, orchards of fruit crops.	**HHP**
	Nagrodar	2, 4-d amine salt 58% SL	Maize, wheat, sorghum, sugarcane & potato	**HHP**
	Remove	Glyphosate 41% SL	Not specifically mentioned	**HHP**
	Target	Pretilachlor 50% EC	Transplanted paddy	-
	Weedout	Sulfosulfuran 75% WG	Wheat, barley & oats	-
P I industries limited	Awkira	Pyroxasulfone 85%g WG	Wheat, maize and soybean	-
	Elite	Topramezone 33.6% SC	Maize	-
	Legacee	Fenoxaprop-p-ethyl 6.9% EC	Rice	-
	Melsa	Pinoxaden 5.1% EC	Wheat	-
	Nominee gold	Bispyribac sodium 10% SC	Rice	-
	Solaro	Atrazine 50% WP	Maize, sugarcane	-
	Wicket	Clodinafop-propargyl 15% WP	Wheat	-
Rallis India ltd -TATA enterprise	Atrataf	Atrazine 50 % WP	Maize, sugarcane	-
	Cylo	Cyhalofop butyl 10 EC	Paddy	-

	Duton	Penoxsulam 21.7 % SC	Paddy	-
	Glytaf	Glyphosate 41 % SL	Tea and non-cropped area	**HHP**
	Impeder	Pinoxaden- 5.1 % EC	Wheat	-
	Panida grande	Pendimethalin 38.7 % CS	Chilli	**HHP**
	Paralac	Paraquat dichloride 24 % SL	Tea, coffee, rubber, grapes and apple	**HHP**
	Preet	Pretilachlor 37 % EW	Transplanted paddy	-
	Taarak	Bispyribac sodium 10 % SC	Rice	-
	Tata metri	Metribuzin 70 % WP	Soybean	**HHP**
	Tata panida	Pendimethalin 30 % EC	Cotton, soybean, wheat, rice, pigeon pea	**HHP**
	Trimbo	Tembotrione 34.4 SC	Maize	-
Syngenta India ltd.	Axial	Pinoxaden 5.10 % w/w	Wheat	-
	Calaris xtra	2.27% w/w mesotrione + 22.7% w/w SC atrazine	Corn and sugarcane	-
	Fusilade	13.4 % EC fluazifop-p-butyl	Not specifically mentioned	-
	Fusiflex	11.1% w/w fomesafen 11.1% w/w SL fluazifop-p-butyl	Soybean and groundnut	-
	Rifit-plus	Pretilachlor 37 % w/w	Transplanted rice	-
	Topik	15% WP clodinofop-propargyl	Wheat	-
	Verona	5.1 % EC pinoxaden	Not specifically mentioned	-
Total Agri care concern Pvt. Ltd.	Blade	Pretilachlor 50 % EC	Not specifically mentioned	-
	Eraser	Glyphosate 41 % SL	Not specifically mentioned	**HHP**
	Finish	Paraquat dichloride 24 % SL	Not specifically mentioned	**HHP**

***compiled by PAN India from various sources**

This book dispenses various information on hazardous chemicals called herbicides which have been widely used in India for a very long time for the management of weeds. It primarily pinpoints the particulars of use, toxicity, public health consequences and environmental effects of herbicides. The various non-chemical weed management strategies that can be adopted in lieu and the need for preserving beneficial weeds are also underscored in the study. Currently, 87 herbicides are registered in India as per the Insecticides Act of 1968 of which 20 are Highly Hazardous Pesticides (HHPs) and 9 are Deemed to be Registered Pesticides (DRPs). The overall herbicide use in India is poignant and are inherently harmful to people and environment. The very purpose of this book is to reveal the loopholes in the regulation of herbicides which has not been effective in India and gaps in national approved uses of the pesticides and recommendation given by state agriculture authorities. This requires debate and discussions. Many Highly Hazardous herbicides are being manufactured and dumped into markets. This would have undesirable impacts on soil health, farm productivity, food safety, agriculture trade, public health, as well as environmental wellbeing in the country. Registration and approval of these herbicides are masking out their toxic hazards and can lead to misapprehensions in farming communities. Herbicides are potent toxic chemicals. Their use must be prohibited for the betterment of society and the environment

Savitri
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