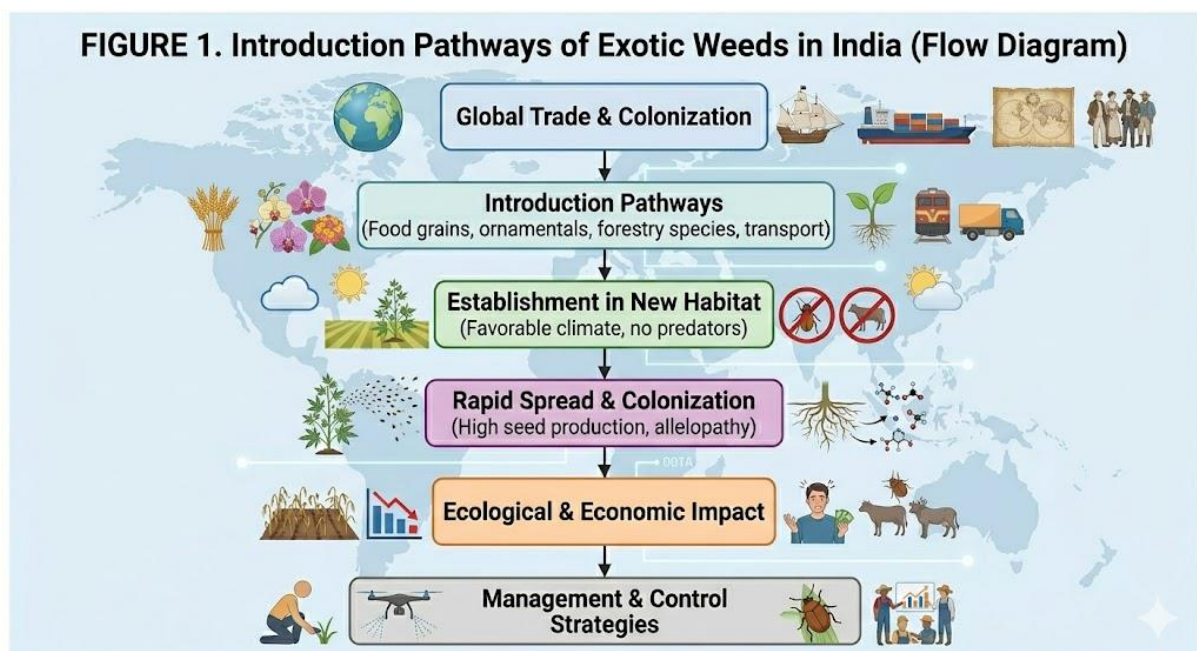


Exotic Weeds in India: History, Biology, Ecology, Impact, & Management Strategies – A Comprehensive Review

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Abstract

Exotic weeds, also known as alien or invasive weeds, have emerged as a major threat to agricultural productivity, biodiversity, and ecosystem stability in India. These weeds are introduced intentionally or unintentionally from other regions and often establish aggressively due to lack of natural enemies. Over time, several exotic species such as *Parthenium hysterophorus*, *Lantana camara*, *Eichhornia crassipes*, and *Chromolaena odorata* have spread widely across Indian agro-ecosystems. Their rapid proliferation is attributed to high reproductive capacity, phenotypic plasticity, allelopathy, and adaptability to diverse environmental conditions. This review critically examines the history of introduction, biological and ecological characteristics, economic and environmental impacts, and management strategies of exotic weeds in India. Integrated weed management approaches combining mechanical, chemical, biological, and ecological methods are emphasized as sustainable solutions. The paper also highlights future research needs and policy interventions for effective control of invasive weeds.



1. Introduction

The introduction of exotic weeds in India dates back to colonial times when several plant species were brought for ornamental, forestry, or agricultural purposes. Over time, many of these species escaped cultivation and became

invasive due to favorable climatic conditions, absence of natural enemies, and high adaptive capacity. India, with its diverse agro-climatic conditions, is highly vulnerable to the invasion of exotic weeds. These weeds are non-native species introduced beyond their natural range,

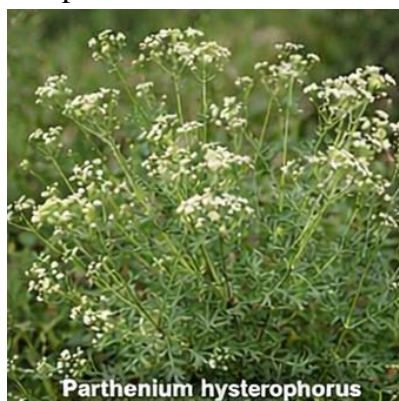
often becoming invasive due to favorable environmental conditions and absence of natural predators.

Exotic weeds pose serious challenges in:

- Crop production
- Pasture management
- Forest ecosystems
- Aquatic environments

Their spread has accelerated due to globalization, trade, climate change, and human disturbances. According to research, invasive weeds reduce crop yields by **20–40% in major cropping systems**. India is one of the world's mega-biodiversity regions, yet it faces increasing threats from invasive alien plant species. These exotic weeds are non-

native species introduced intentionally or unintentionally and have become naturalized, spreading aggressively across ecosystems. Among the most dominant invasive weeds in India are *Parthenium hysterophorus*, *Lantana camara*, *Ageratum conyzoides*, *Chromolaena odorata*, and *Mikania micrantha*. These species significantly reduce crop productivity, alter ecosystem structure, and threaten biodiversity. Exotic weeds possess unique ecological advantages such as rapid growth, prolific seed production, allelopathy, and phenotypic plasticity, which enable them to outcompete native vegetation and dominate landscapes.



Parthenium hysterophorus



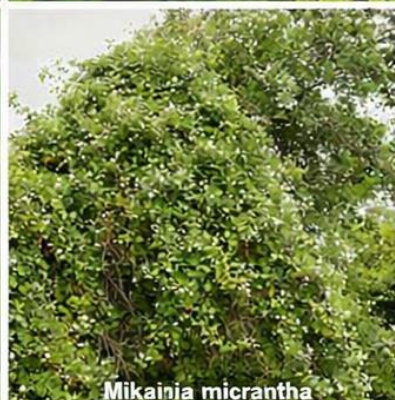
Lantana camara



Ageratum conyzoides



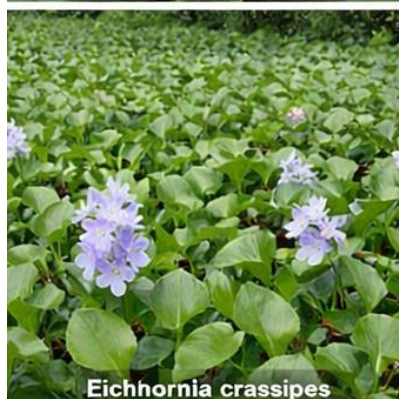
Chromolaena odorata



Mikania micrantha



Prosopis juliflora



Eichhornia crassipes



Ipomoea carnea



Senna spectabilis

FIGURE 2. Major Exotic Weed Distribution in India (Conceptual Map)

North India → Parthenium, Lantana, Ageratum
 Central India → Lantana, Parthenium, Prosopis
 Eastern India → Mikania, Chromolaena, Parthenium
 Western India → Prosopis juliflora, Parthenium
 Southern India → Lantana, Chromolaena, Ipomoea
 Wetlands → Eichhornia, Pistia

2. History of Exotic Weed Introduction in India

The invasion of exotic weeds in India is not a recent phenomenon but a historical byproduct of colonization, global trade, and shifting agricultural practices. These "alien" species, devoid of their natural predators, have successfully colonized diverse Indian landscapes.

2.1 Pre-Independence Period (The Botanical Imports)

During the British Raj, the introduction of non-native species was often intentional, driven by aesthetic desires or colonial forestry policies.

- **Ornamental Introductions (*Lantana camara*):** Introduced in 1809 at the Calcutta Botanical Garden as an ornamental hedge plant, *Lantana* escaped cultivation and now occupies millions of hectares of forest land, suppressing native biodiversity.
- **Forestry and Fuelwood (*Prosopis juliflora*):** Known locally as *Vilayati Babul*, it was introduced in the late 19th century to green the arid regions and provide fuelwood. Its invasive nature has since turned it into a threat to grasslands and semi-arid ecosystems.
- **Accidental Contaminants:** Even before formal post-independence imports, minor

weed seeds traveled via ship ballast and contaminated botanical shipments, establishing early footholds in coastal regions.

2.2 Post-Independence Period (The Era of Contamination)

The most significant "accidental" introduction occurred during the mid-20th century, fundamentally altering the Indian agricultural landscape.

- **The Parthenium Crisis:** In the 1950s, India faced severe food shortages and imported "PL-480" wheat from the USA. This grain was contaminated with seeds of *Parthenium hysterophorus* (Congress Grass). Within decades, it became India's most notorious weed, causing health issues and massive yield losses.

• **Mechanization and Infrastructure:** The rapid expansion of road networks and the Green Revolution's focus on irrigation canals provided "highways" for weed seeds. Water hyacinth (*Eichhornia crassipes*) spread rapidly through newly constructed canal systems, choking waterways.

2.3 Modern Phase (Globalization and Climate Change)

In the 21st century, the rate of invasion has accelerated due to high-velocity global movement.

• **Globalization:** Increased international travel and e-commerce in seeds and plants have bypassed traditional quarantine barriers, introducing minor invasive species that quickly adapt to local niches.

• **Climate Change:** Rising \$CO_2\$ levels and shifting rainfall patterns have favored invasive C4 weeds over native C3 species. Invasive weeds are often more "plastic," meaning they adapt to extreme weather (droughts or floods) more effectively than native flora.

FIGURE 3. Timeline of Exotic Weed Invasion in India

The following timeline illustrates the key milestones in the introduction and escalation of invasive flora within the Indian subcontinent:

Era	Key Event / Species	Mode of Introduction
1800–1900	<i>Lantana camara</i> & <i>Prosopis juliflora</i>	Intentional (Ornamental & Forestry)
1950s	<i>Parthenium hysterophorus</i>	Accidental (Contaminated Wheat Imports)
1970–1990	Agricultural Expansion	Spread via Irrigation and Mechanization
2000–Present	Landscape-level Dominance	Accelerated by Globalization & Climate Change

Dominant Exotic Weeds in India				
Weed Species	Common Name	Origin	Habitat	Key Impact
<i>Parthenium hysterophorus</i>	Congress grass / Carrot weed	Tropical America	Croplands, roadsides	Causes allergies, severe yield loss
<i>Lantana camara</i>	Lantana / Wild sage	Central & South America	Forests, wastelands	Reduces biodiversity, forms dense thickets
<i>Ageratum conyzoides</i>	Billy goat weed	Tropical America	Crops, pastures	Competes with crops, reduces yield
<i>Chromolaena odorata</i>	Siam weed	Tropical America	Forests, plantations	Suppresses native vegetation
<i>Mikania micrantha</i>	Mile-a-minute weed	Central & South America	Plantations, forests	Smothers crops and trees rapidly
<i>Prosopis juliflora</i>	Vilayati babul / Mesquite	Mexico	Arid and semi-arid areas	Depletes groundwater, invasive spread
<i>Eichhornia crassipes</i>	Water hyacinth	Amazon Basin	Water bodies	Blocks sunlight, reduces oxygen in water
<i>Ipomoea carnea</i>	Bush morning glory / Besharam	Tropical America	Wetlands, roadsides	Toxic to livestock, invasive growth
<i>Senna spectabilis</i>	Golden shower tree (wild)	South America	Forest areas	Alters forest ecology, invasive

Impact Overview

Exotic weeds now dominate nearly **25% to 40%** of India's non-cropped lands. The ecological cost includes the "homogenization" of flora, where a few aggressive exotic species replace hundreds of diverse native plants, leading to a collapse in local insect and bird populations.

Table 1: Important Exotic Weeds in India

Weed Species	Origin	Habitat	Impact
<i>Parthenium hysterophorus</i>	Central America	Croplands	Allergies, yield loss
<i>Lantana camara</i>	Tropical America	Forests	Biodiversity loss
<i>Eichhornia crassipes</i>	South America	Aquatic	Water blockage
<i>Chromolaena odorata</i>	South America	Wastelands	Soil nutrient depletion
<i>Ageratum conyzoides</i>	Central America	Fields	Crop competition

4. Biology of Exotic Weeds

By combining these traits, exotic weeds do not just "grow" in an area; they **re-engineer** the habitat to suit themselves, effectively creating a monoculture that excludes almost all other life forms. The success of invasive species in colonizing new territories is not accidental; it is driven by a suite of evolutionary advantages. Exotic weeds possess specific biological traits—often referred to as "invasive syndromes"—that allow them to outcompete, displace, and eventually dominate native flora.

4.1 High Reproductive Capacity (High Fecundity)

The primary strategy of exotic weeds is numerical dominance through massive seed production.

- **Prolific Seed Production:** A single plant of *Parthenium hysterophorus* can produce up to 25,000 seeds, while others like *Amaranthus* species can release hundreds of thousands. *Parthenium hysterophorus* can produce up to 25,000 seeds per plant, while species like *Amaranthus* can exceed 100,000.
- **Seed Dimorphism and Dormancy:** Many exotic weeds produce seeds with varying degrees of dormancy. This creates a "soil seed bank" where seeds remain viable for years, germinating in "flushes" whenever the soil is disturbed.
- **Seed Banks:** These seeds don't just germinate at once; they form a persistent "seed bank" in the soil. Some seeds can remain viable for 5–20 years, waiting for the perfect environmental trigger (like a plow or a rainstorm) to emerge.
- **Continuous Germination:** Unlike native plants that often follow strict seasonal cycles, invasive weeds can germinate throughout the year if minimal moisture is available, ensuring they occupy any available ecological niche.

4.2 Rapid Growth and Aggressive Architecture

Invasive weeds are often "r-strategists," focusing on rapid biomass accumulation early in their life cycle.

- **Early Canopy Formation:** By growing faster than native species during the seedling stage, they quickly establish a canopy that shades out slower-growing native plants. This "light competition" effectively kills off understory competitors.
- **Rapid Maturation:** Many exotic weeds can complete their life cycle from germination to seed production in as little as 4–6 weeks. This allows them to produce multiple generations within a single cropping season.
- **Extended Flowering:** They often flower over a long duration, ensuring that at least some seeds are produced even if weather conditions fluctuate.
- **Resource Efficiency:** Exotic weeds often exhibit higher photosynthetic efficiency and nutrient uptake rates. They are adept at extracting nitrogen and phosphorus from the soil even at low concentrations, leaving little for the crop or native vegetation.

Vegetative Propagation (Clonal Growth)

While seeds are for long-distance dispersal, vegetative growth is for local dominance.

- **Beyond Seeds:** Many weeds like *Lantana camara* or *Eichhornia crassipes* (Water Hyacinth) do not rely solely on seeds. They spread via rhizomes, runners, or stolons.
- **Regeneration Power:** A small fragment of a root or stem left in the soil after manual weeding can often regenerate into a full plant. This makes mechanical control extremely difficult, as tilling can accidentally chop up and spread the weed further.

4.3 Allelopathy: Biochemical Warfare

One of the most potent weapons in the biology of exotic weeds is **allelopathy**—the release of phytotoxic chemicals into the rhizosphere.

- **Chemical Interference:** These plants exude biochemicals (allelochemicals) from their roots, leaves, or decomposing tissue that inhibit the germination and growth of neighboring plants.
- **The Parthenium Factor:** *Parthenium hysterophorus* is a classic example. It releases toxins such as **parthenin**, **caffeic acid**, and **p-coumaric acid**. These chemicals:
 - **Inhibit Germination:** Prevent the seeds of native grasses and crops from sprouting.
 - **Stunt Growth:** Interfere with the nutrient uptake and chlorophyll synthesis of neighboring plants.
 - **Pasture Destruction:** By poisoning the soil and outcompeting native forage, *Parthenium* can reduce pasture productivity by up to **90%**, leading to starvation in livestock and severe economic losses for farmers.

4.5 Summary of Biological Traits

Trait	Biological Advantage	Impact on Agriculture
High Fecundity	Long-term soil infestation	Impossible to eradicate in a single season.
Short Life Cycle	Multiple generations per year	Rapidly builds up a massive population.
Vegetative Spread	High regeneration ability	Standard weeding often causes more spread.
Allelopathy	Chemical "clearing" of space	Direct yield loss and soil toxicity.

5. Ecology of Exotic Weeds

4.4 Phenotypic Plasticity

Phenotypic plasticity is the ability of a single genotype to produce different phenotypes in response to varying environmental conditions. This "biological flexibility" is a hallmark of successful invaders.

- **Environmental Adaptation:** An exotic weed may grow as a small, prostrate plant in poor, dry soil but transform into a lush, tall shrub in fertile, irrigated conditions.
- **Climatic Resilience:** This trait allows exotic weeds to thrive across diverse geographical zones—from the humid tropics of Kerala to the arid regions of Rajasthan. They can adjust their leaf area, root depth, and flowering time based on the immediate environment, making them nearly impossible to eradicate using a single management strategy.

The ecological success of exotic weeds is rooted in their extraordinary resilience and their ability to exploit habitats where native species struggle. They are often the "**pioneer species**" of the modern era, thriving in the wake of human-induced environmental changes. Their dominance is not merely a matter of growth but a complex interaction between their unique adaptations and the vulnerabilities of the local ecosystem.

5.1 Ecological Resilience and Stress Tolerance

Exotic weeds often possess physiological "superpowers" that allow them to occupy harsh environments where native flora cannot survive.

- **Abiotic Resistance:** Many invasive species, such as *Prosopis juliflora*, are highly tolerant to drought, salinity, and extreme temperatures. They can maintain photosynthesis under water stress that would cause native plants to wilt.

- **Broad Environmental Amplitude:** Unlike native species that are often specialized for a specific niche, exotic weeds are generalists. They can thrive across a vast range of altitudes, soil types, and moisture levels, allowing a single species to infest both tropical wetlands and arid wastelands.

5.2 Exploitation of Anthropogenic Disturbance

Exotic weeds are "disturbance lovers." They have evolved to follow human activity, which frequently "resets" an ecosystem and removes established native competition.

- **Colonization of Disturbed Sites:** Roadside construction, overgrazing, deforestation, and urbanization create "empty" ecological spaces. Exotic weeds, with their rapid germination, are the first to arrive and claim these territories.
- **The "Enemy Release" Hypothesis:** In their home range, these plants are kept in check by specific insects, fungi, and bacteria. When they are introduced to a new continent (like India), they leave these "natural enemies" behind. Without predators to eat them or diseases to slow them down, their population growth becomes exponential.

5.3 Nutrient Cycling and Ecosystem Engineering

Invasive weeds do not just live in an environment; they actively change it to favor their own survival.

- **Altering Soil Chemistry:** Some exotic weeds can change the pH of the soil or the rate at which nitrogen is processed. For example, nitrogen-fixing invaders can flood a low-nutrient soil with nitrogen, which sounds beneficial but actually kills off native plants adapted to poor soils, allowing only other high-demand weeds to grow.
- **Hydrological Impact:** Invasive aquatic weeds, such as *Eichhornia crassipes*

(Water Hyacinth), increase evapotranspiration rates significantly. This leads to the drying up of small water bodies and the depletion of oxygen (hypoxia) in the water, which destroys local fish populations and aquatic biodiversity.

5.4 Seed Dispersal and Spatial Ecology

The "spatial strategy" of exotic weeds ensures they are always moving into new territories.

- **Multi-Modal Transport:** They utilize a combination of wind (anemochory), water (hydrochory), and animals/humans (zoo-anthropochory). *Parthenium* seeds are light enough to travel miles on a breeze, while also being sticky enough to hitch a ride on the tires of a truck.
- **High Connectivity:** The modern world's infrastructure—highways, railway tracks, and irrigation canals—acts as a "green corridor" for weed expansion, allowing seeds to bypass natural barriers like mountains or dense forests.

5.5 Summary of Ecological Success Factors

Ecological Factor	Mechanism of Success	Impact on Native Flora
Pioneer Status	First to colonize bare or disturbed soil.	Prevents native seedlings from establishing.
Enemy Release	Absence of natural pests and pathogens.	Unlimited energy for growth and reproduction.
Niche Breadth	Ability to survive in diverse climates.	Out-competes specialized native species.
Engineering	Modifying soil and	Creates a habitat

	water properties.	unsuitable for local life.
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5.1 Ecological Adaptations

Exotic weeds are biological opportunists. Their physiological makeup allows them to survive in conditions that would be lethal to more sensitive native flora.

- **Abiotic Stress Tolerance:** * **Drought & Salinity:** Many invasive species, such as *Prosopis juliflora*, possess deep taproot systems and specialized leaf cuticles to minimize transpiration. They can maintain metabolic functions even in highly saline soils or during prolonged dry spells.
 - **Thermal Range:** These weeds often have a wide thermal window, allowing them to remain active from the scorching heat of Indian summers to the chilly winters of the north.
- **Colonization of Disturbed Lands:**
 - Exotic weeds thrive on "anthropogenic disturbance." Construction sites, overgrazed pastures, roadside verges, and abandoned agricultural fields are prime targets.
 - They utilize a "sit-and-wait" strategy; their seeds remain dormant in the soil until a disturbance (like tilling or clearing) removes competition and provides the light hit needed for mass germination.

5.2 Spread Mechanisms

The rapid expansion of exotic weeds across the Indian subcontinent is facilitated by a multi-modal dispersal strategy.

- **Anemochory (Wind Dispersal):** Species like *Parthenium* and *Chromolaena odorata*

produce light, buoyant seeds equipped with pappus (hair-like structures). These can travel several kilometers in a single wind gust, allowing them to leapfrog across landscapes.

- **Hydrochory (Water Movement):** Irrigation canals and seasonal floods act as conveyor belts for weed seeds. *Eichhornia crassipes* (Water Hyacinth) spreads primarily through water currents, infesting entire river basins and dam reservoirs downstream.
- **Zoochory and Anthropochory (Animals and Humans):** * **Animals:** Many seeds have hooks or sticky coatings (e.g., *Xanthium strumarium*) that attach to animal fur.
 - **Humans:** This is perhaps the most significant modern vector. Seeds hitchhike on vehicle tires, agricultural machinery (harvesters), and even in the treads of shoes, moving across state borders in a matter of hours.

Flowchart: Ecology and Spread of Exotic Weeds

The life cycle of an invasion follows a predictable ecological trajectory. Each stage represents a hurdle that the exotic weed must overcome to reach a state of dominance.

Stage	Process Description
1. Seed Production	High-volume output ensures a massive soil seed bank.
2. Dispersal	Movement via wind, water, or human activity to new sites.
3. Germination	Rapid response to environmental triggers (moisture/light).
4. Establishment	Successful seedling survival and root system development.

5. Competition	Using rapid growth and toxins (allelopathy) to suppress neighbors.
6. Dominance	Formation of monocultures where native biodiversity is eliminated.

6. Socio-Economic and Ecological Impacts of Exotic Weeds

The proliferation of invasive species in India is not merely an aesthetic or botanical concern; it is a multi-dimensional crisis that bleeds into the economy, public health, and environmental stability.

6.1 Agricultural Impact: The Economic Drain

Invasive weeds are often described as "silent yield robbers."

- **Yield Reduction:** Competition for resources—moisture, nutrients, and sunlight—leads to significant crop losses. In staples like wheat, rice, and mustard, yield reductions often range between **30% and 50%**, but in cases of heavy infestation, total crop failure can occur.
- **Increased Cultivation Costs:** Farmers are forced to spend more on labor for manual weeding and expensive chemical herbicides. This increases the "input-to-output" ratio, pushing small-scale farmers into debt cycles.
- **Quality Degradation:** Weed seeds (like those of *Parthenium* or *Argemone*) often contaminate the harvest, leading to lower market prices and potential health hazards in the food chain.

6.2 Environmental Impact: Ecological Homogenization

- **Loss of Biodiversity:** Exotic weeds create monocultures. By releasing allelochemicals and growing aggressively, they displace native flora. This leads to a "bottom-up" collapse of the food web, as native insects

and birds find no food or habitat in weed-infested lands.

- **Soil Degradation:** Weeds like *Prosopis juliflora* can significantly alter soil salinity and nutrient profiles, making the land unsuitable for future native forest regeneration or agricultural use.
- **Altered Ecosystem Processes:** Invasive aquatic weeds like Water Hyacinth change the very nature of water bodies by depleting dissolved oxygen, leading to mass fish kills and the "death" of local ponds and lakes.

6.3 Human and Animal Health

- **The Parthenium Menace:** The pollen and dust from *Parthenium* are potent allergens. Constant exposure causes **allergic rhinitis**, **asthma**, and **dermatitis** (skin rashes) in humans.
- **Livestock Toxicity:** When cattle graze on infested pastures, they may accidentally consume toxic weeds. This can lead to sores in the mouth, tainted milk (bitter taste), and in extreme cases, internal organ failure and death of the livestock.

7. Management of Exotic Weeds: The Integrated Approach

Managing exotic weeds requires a shift from "eradication" (which is often impossible) to "sustained management."

7.1 Mechanical and Physical Control

- **Hand Weeding & Hoeing:** The most traditional method, effective for small areas but labor-intensive and expensive.
- **Mowing and Burning:** Used for large-scale infestations in non-cropped areas. However, burning can sometimes trigger the germination of fire-adapted weed seeds.

7.2 Chemical Control

- **Herbicides:** Modern chemicals like **Glyphosate**, **2,4-D**, and **Paraquat** provide rapid knockdown of weed populations.
- **The Trade-off:** While highly effective, over-reliance leads to soil toxicity, water contamination, and the development of

"super-weeds" that are resistant to chemicals.

7.3 Biological Control: Nature's Check

- **The Bio-Agent Strategy:** This involves introducing natural enemies from the weed's home country.
- **Example:** The Mexican beetle (*Zygogramma bicolorata*) has been successfully released in India to control *Parthenium*. The larvae and adults feed exclusively on the leaves, weakening the plant and preventing seed production.

7.4 Cultural and Agronomic Practices

- **Competitive Cropping:** Planting "smother crops" like cowpea or sunn hemp that grow faster than weeds.
- **Mulching:** Using organic residues (like paddy straw) or plastic sheets to block sunlight from reaching weed seeds.

8. Case Study: *Parthenium hysterophorus* (The Scourge of India)

Known as "Congress Grass," this weed is a classic example of a "perfect invader."

- **The Problem:** It infests almost every state in India, thriving in both urban vacant plots and fertile agricultural fields. It is toxic to both humans (causing respiratory issues) and animals.
- **Control Paradox:** Cutting it often leads to faster regeneration from the base.
- **The IWM Solution:** Successful management involves a combination of the *Zygogramma* beetle, the application of strong herbicides in non-crop areas, and the planting of competitive species like *Cassia tora* to out-compete it naturally.

9. Challenges in Modern Weed Management

Despite decades of research, the weed problem is escalating due to:

- **Herbicide Resistance:** Constant use of the same chemical has led weeds to evolve

resistance, making traditional sprays useless.

- **Climate Change:** Warmer temperatures and increased CO₂ actually act as "fertilizer" for invasive weeds, making them even more aggressive.
- **Policy Gaps:** Lack of strict "Quarantine Laws" at state borders allows the free movement of contaminated seeds and machinery.

10. Future Research Directions

The next generation of weed management will be driven by technology:

- **Precision Agriculture:** Using AI-powered drones to detect weed patches and spray herbicides only where needed, reducing chemical use by 80%.
- **Genomic Studies:** Sequencing the DNA of invasive species to find "genetic off-switches" that can prevent them from flowering or producing seeds.
- **Bio-Herbicides:** Developing weed-killing chemicals derived from natural fungi and bacteria that are non-toxic to humans and soil.

Conclusion

Exotic weeds represent a catastrophic threat to India's "Evergreen Revolution." They are biological pollutants that degrade our land, health, and economy. A sustainable future requires an **Integrated Weed Management (IWM)** framework that moves away from heavy chemical use toward a smarter, science-based approach. The success of this strategy depends on a tripartite alliance: **Scientists** (to innovate), **Farmers** (to implement), and **Policy Makers** (to regulate and support). Only through this unified front can we protect our native biodiversity and ensure food security for the coming generations.

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