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Research Article

Parthenium hysterophorus: A Silent Threat to Agricultural Productivity and Crop Sustainability

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Abstract | *Parthenium hysterophorous* is one of the most aggressive invasive weeds worldwide, posing a serious threat to agricultural productivity, crop sustainability, and ecosystem health. Owing to its rapid growth, prolific seed production, and strong competitive ability, this weed has extensively invaded cultivated lands, pastures, non-cropped area, particularly in tropical and subtropical regions. *Parthenium hysterophorous* adversely affects crop yield and quality through intense competition for nutrients water, and light, as well as through allelopathic effects mediated by toxic secondary metabolites such as parthenin. In addition, to agricultural losses, its invasion disrupts soil health, reduces biodiversity, and negatively impacts livestock and human health. This review critically examines the biology, distribution, and ecological impacts of *parthenium hysterophorous*, with a focus on its mechanisms of interference with crop growth and agricultural systems. Current management strategies, including chemical, mechanical and integrated weed management approaches, are comprehensively discussed, highlighting their effectiveness and limitations. This review article emphasizes the need for sustainable, ecofriendly, and region specific management practices to mitigate the spread and impact of *Parthenium hysterophorus* and to ensure long term agricultural productivity and crop sustainability.

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Introduction

Global emergence of *Parthenium hysterophorus*: Parthenium is a noxious annual herb that belongs to family Asteraceae. It is native to the north, south and central America (Cowie *et al*., 2020). It is recognized as invasive species in tropical and subtropical parts of world since the mid of 1970s with negative impacts on the agricultural, humans and animals. Parthenium is reported as invasive weed in more than 45 countries across the world (Bajwa *et al*., 2016). It is the wild herb that occupy almost every habitat including grass lands, wastelands, grazing lands, floodplains, summer crops and across the road lines (Adkins and Shabbir, 2014). The aim of the current review article is to provide a comprehensive and critical synthesis of existing knowledge on *Parthenium hysterophorous* as a major invasive weed threatening agricultural

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productivity and crop sustainability.

Invasiveness and ecological plasticity

Parthenium is aggressively spreading as a threat to important medicinal plants (Tamado and Milberg, 2000). It has rapid growth rate, tolerance to the biotic and abiotic stresses, allelopathic chemicals and phenotypic plasticity is the major reason behind its rapid invasion and competitiveness (Bajwa *et al*., 2016). Many reviews have been published on the invasive nature of Parthenium weed. Parthenium retards the growth and development of other agricultural crops. Research has shown that it will occupy the whole land if it keeps going on spreading. It is also called as "Anamalee" because of its aggressive coverage. It suppresses the physiological activity of other plants and leads to a decline in species heterogeneity due to its allelopathic effect, it can dominate the area while competing the neighboring weeds (Kumari *et al*., 2014). Parthenium losses the productivity and quality of many crops due to its allelopathic effect (Mirza *et al*., 2013). It is among the top five weeds that retards the growth of other crops.

Taxonomy, origin and global distribution

Taxonomic position and morphological characteristics: Parthenium is North American annual herb belonging to family Asteraceae and sub family Asteroidea within the order Asterales. It is a weed that has deep tap root system, stem is erect that turns woody and leaves are pale green. Young plant forms a rosette of leaves close to the surface of soil. When it matures it develops number of branches on its top and attains the height of 1.5-2 meters (Eppo, 2014). Flowering mainly occur within 6-8 weeks after germination and moisture is the major contributing factor to the flowering (Navie *et al*., 1996). Pollination occurs mainly by wind (Lewis *et al*., 1988) (Figure 1).

Centre of origin and pathways of introduction

Parthenium hysterophorus is generally native to North and South America. It invades nearly 50 countries of the world. It uses variety of pathways to facilitate its dispersal. It poses biological traits that allow its easy introduction into new landscapes and compete with neighboring species. Flower of parthenium produces 5 ray florets each producing single dry achene like single seeded fruit known as cypselae. The cypselae are ready to be dispersed by multiple mechanism such as wind and water, attachment to motor vehicles (Adkins and Shabbir, 2014), cattle dungs (Khan, 2012), in the residue of harvested products (Khan, 2012). However, the detail on wind and water dispersal is still incomplete (Shabbir *et al*., 2018).

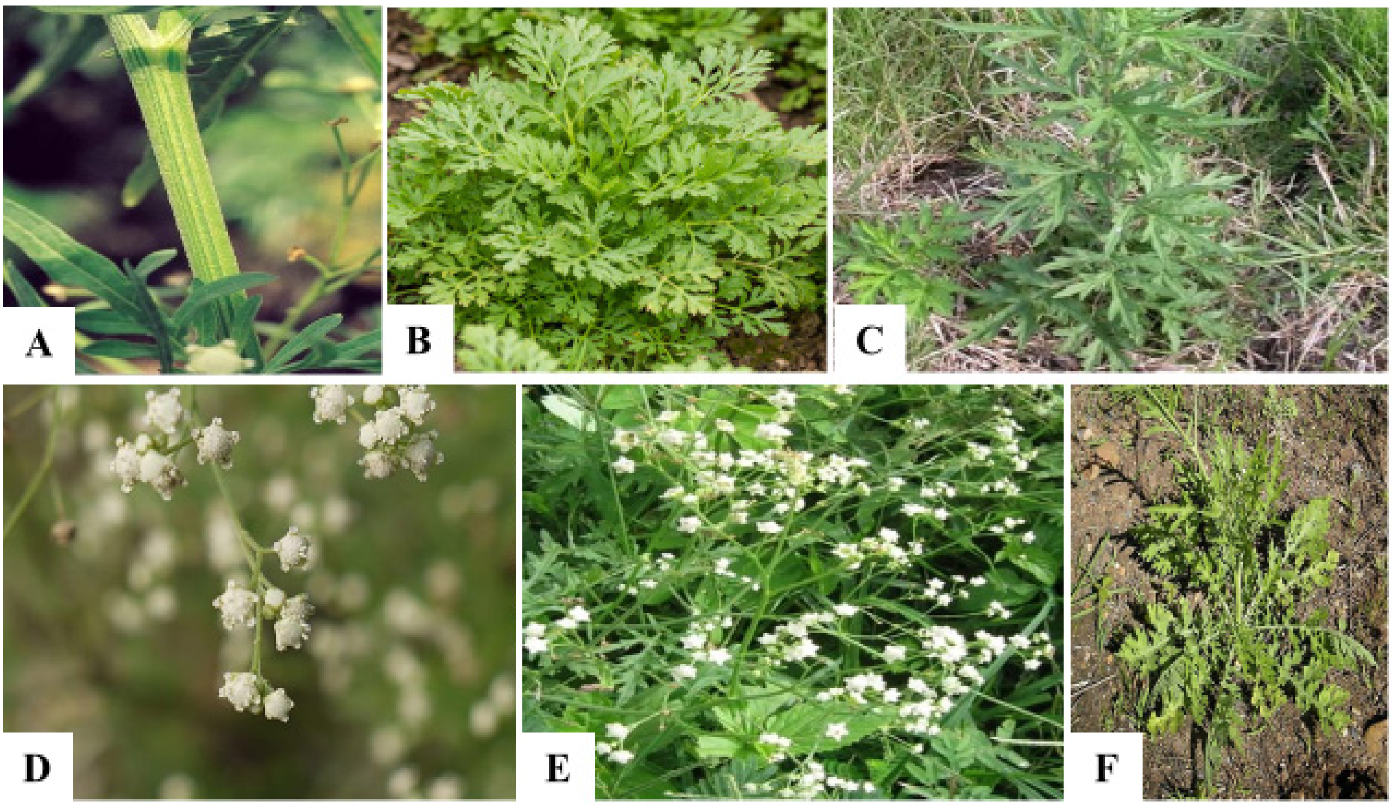

Figure 1: *Pictorial view of Parthenium hysterophorous.*

Current global distribution and invasion hotspots

Originally parthenium was native to North, South and Central America, however in the recent years it has invaded more than 49 countries of the world including Asia, Africa, Australia due to its high adaptability. This weed has declared as world's worst invasive alien species by International Union of Conservation of Nature (IUCN). It colonizes almost every habitat including grass lands, wastelands, grazing lands, floodplains, summer crops and found across the road lines, as a threat to global biodiversity, food security and rural livelihood (Rehman *et al*., 2020).

Biology and life cycle attributes facilitating invasiveness

Reproductive biology and seed ecology: A single parthenium plant can produce 15000-25000 seeds that remain viable for many years in soil enabling its dominance in diverse ecosystems (Safdar *et al*., 2015). Parthenium has efficient reproductive system that allow its rapid growth and invasion. The flower of parthenium possess one seeded fruit-cypsela that is attached to sterile florets known as air sacks or buoyancy sac that help in seed dispersal and germination (Navie, 2002). The seeds once ripe are dispersed by number of mechanisms. Moisture is one of the fundamental factor in seed germination. The seeds form persistent seed bank, the seeds on the upper surface remain viable for short time but the seeds that are buried remain viable for many years and germinate upon getting suitable conditions (Tamado et al., 2002).

Allelopathy and competitive interference in cropping systems

Allelochemicals and their modes of action: Allelopathy involves biochemical interaction among plants and other organisms through allelochemicals that can stimulate or inhibit neighboring plant growth (Inderjit and Duke, 2003). These secondary metabolites include phenolic, alkaloids, terpenoids and other compounds that affect membrane, phytohormones, enzymes and oxidative enzymes (Weston and Duke, 2003). Their modes of action are complex and often target photosynthesis, respiration and cellular integrity (Einhellig, 1995). Environmental conditions and soil factors strongly influence the expression and ecological significance of allelopathy, making it a dynamic process in plant communities.

Effects on seed germination and crop establishment

Seed germination and early crop establishment are particularly vulnerable to allelochemicals released from plant residues, which ca interfere with water uptake, enzyme activity, and energy metabolism (Inderjit and Duke, 2003). Compounds such as benzoxazinoids from rye and phenolic acids from sorghum residues often inhibit germination and root growth, leading to poor stand establishment in rotation or intercropping systems (Weston, 1996). However, these effects are concentration dependent, with low doses sometimes stimulating germination (Table 1).

Influence on crop growth yield and quality

Allopathy influence crop performance beyond germination by altering nutrient availability, root architecture, photosynthesis, and hormonal balance, often reducing plant rigor and biomass. Yield losses may occur due to fewer reproductive structures and reduced seed size, as observed in some intercropping systems with allelopathy sunflower cultivars (Putnam *et al*., 1983). Allelochemicals can also modify crop quality by affecting biochemical composition, sometimes increasing phenolic or antioxidants, but severe stress generally lower quality and productivity (Chou, 1999). Effective agricultural use of allelopathy requires integrated management to balance weed suppression benefits with risks of crop interference.

Impact on agricultural productivity and food security

Crop specific field losses: *Parthenium hysterophorus* has a negative effect on agricultural crops. It acts as a suppressor against the growth of wheat (Khan *et al*., 2013). It causes huge economic losses to the crops.

Table 1: *Allelopathy and competitive interference in cropping systems.*

S. No	Materials	Components	Mechanism	Cropping systems	Agronomic implications	References
1	Allelochemicals and their mode of action	Secondary metabolites	Inhibit cell division	Sorghum, Rice and Wheat residues	Suppress weed	Inderjit and Duke, 2003
2	Effects on seed germination	Decomposing biomass	Reduce seedlings	Poor emergency of legumes	Effect establishment and uniformity	Weston and Duke, 2003
3	Effects on crop growth, yield and quality	Allelochemicals in soil plant system	Reduce nutrient uptake	Yield reduction in sensitive crops	Decreased yield and quality	Farooq *et al*., 2011

These losses occur due to their allelopathic effect and their ability to compete for nutrients uptake, water and sunlight. Parthenium can grow throughout the year under all conditions by utilizing the available soil moisture. It is dangerous to crop production, livestock and diversity of plant in ecosystem (Hussain *et al*., 2017). It is a threat to the population of indigenous plants as it produces chemicals that are noxious to the activity of important plant. It badly affects their photosynthetic activities, protein synthesis, chlorophyll production and respiratory processes (Jayaramiah *et al*., 2017). Parthenium losses and its coverage is increasing rapidly over Asia and Africa. It effects number of crops such as wheat and maize in different parts of the world. Parthenium releases number of chemicals such as parthenin, phenolic acids and phytotoxic compounds which are deleterious to other crops. Other chemicals that are responsible for its invasive nature include, caffeic acid, anisic acid, p-coumaric acid, vanilic acid, chlorogenic acid and ferulic acid etc (Kapoor, 2016).

Effect on soil health and nutrient cycling

Parthenium release allelochemicals that play ecological role beyond weed suppression such plant Defence mechanism, nutrient chelation and regulation of soil microorganism that play important role in increasing soil fertility. The addition of allelopathic parthenium compost increases physicochemical, biological and nutritional quality of soil and resist fluctuations in soil PH (Sonwane and Ustad, 2016). The biomass of parthenium compost can used for composting and mulching help in carbon sequestration in soil. Parthenium compost increases organic matter content of soil, improves pore space, reduces bulk density and result in soil compaction. Parthenium compost has a higher concentration of micronutrients including zinc, manganese, iron and copper (Kishore *et al*., 2010).

Ecological consequences beyond farmlands

Intensive agricultural systems influence not only cultivated fields but also surrounding landscapes and ecosystem, creating a cascade of ecological effects that extend well beyond farmland boundaries. Conversion of natural habitats to larger, simplified agricultural units reduces habitat complexity and connectivity, ultimately lowering the carrying capacity for many wild species and altering nutrient and water cycles in adjacent ecosystems. Agricultural pollutants like fertilizers and pesticides can be transported through air and water, affecting distant habitats and contributing to issues such as algal blooms and decline aquatic biodiversity, highlighting the far reaching environmental footprint of modern farming practices (Foley *et al*., 2005) (Figure 2).

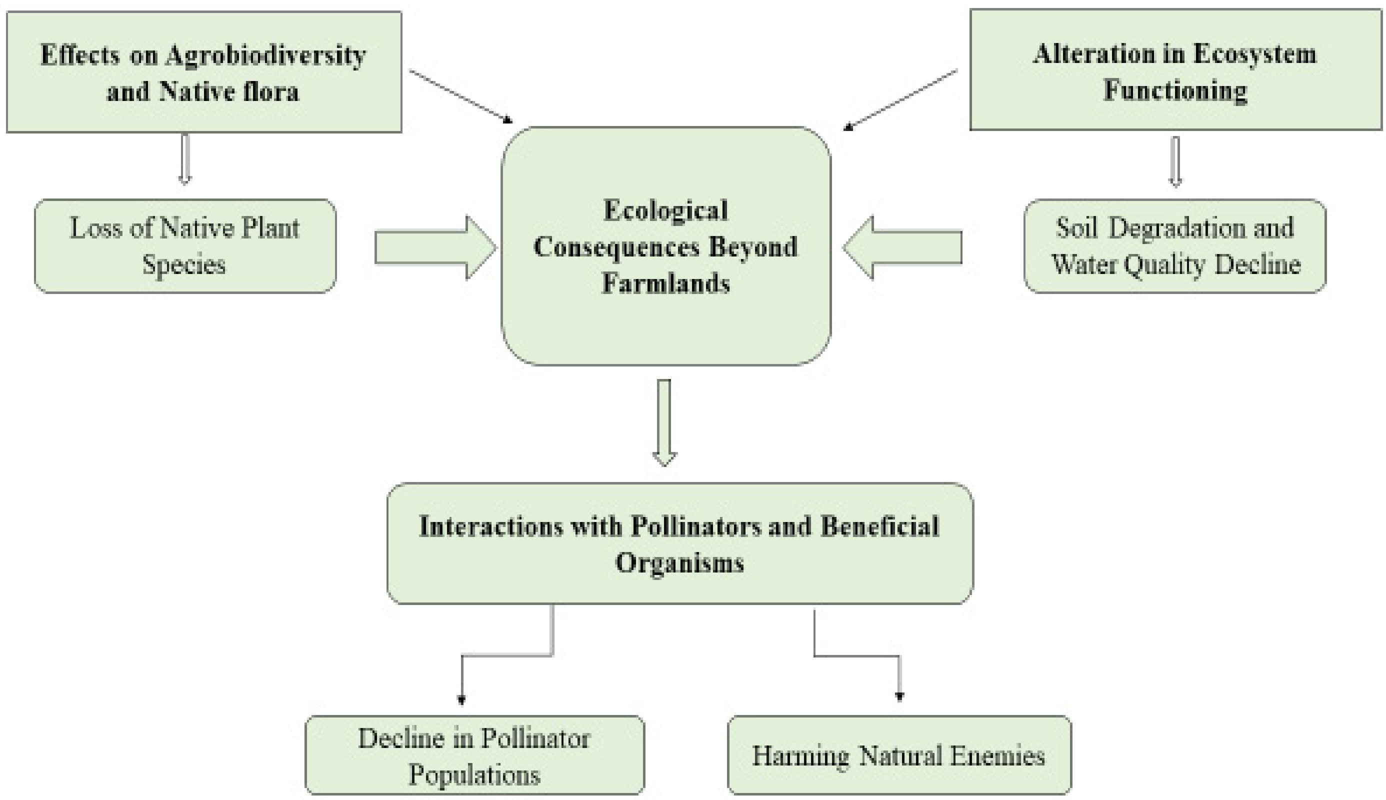

Figure 2: *Ecological consequences beyond farmlands.*

Effects on agrobiodiversity and native flora

Agrobiodiversity the variety of crops, associated wild plants, microorganisms and generic resources is a cornerstone of resilient agroecosystems, yet modern agricultural intensification has sharply reduced this diversity through habitat loss, mono-cropping, and wide spreading use of agrochemicals. The simplification of landscapes into uniform crop fields diminishes the presence of native plants and their wild relatives, undermining genetic diversity that supports pest resistance, soil health, and adaptive capacity to climate change. Maintaining diverse crop varieties and native flora within and around farmland strengthens ecosystem functions and helps buffer against environmental stressors (Lin, 2011).

Alterations in ecosystem functioning

Agricultural practices transform fundamental ecosystem processes such as nutrient cycling, energy flow, and species interactions, often diminishing ecological resilience and function. The removal of natural features like hedgerows and wetlands, combined with chemical inputs, reduce structural and biological complexity at the landscape level, leading to lower wildlife abundance and impaired soil and water regulation. Such changes ripple through food webs and ecosystem services, with long term consequences including decreased soil fertility, altered hydrological patterns, and reduced capacity of ecosystems to recover from disturbances (Foley *et al*., 2005; Altieri et al., 1999).

Interactions with pollinators and beneficial organisms

Pollinators and other organisms such as natural pest predators play critical roles in both natural ecosystems and agricultural productivity by facilitating plant reproduction and controlling pest populations. However, pesticide exposure, habitat loss, and floral resource depletion from intensive agriculture have contributed to widespread declines in these organisms, disrupting pollination services and ecological balance. Loss of pollinators not only jeopardizes the reproduction of many wild plant species but also threatens food security, since a large proportion of global crops depend on animal pollination for yield and quality (Klein *et al*., 2007).

Socio-economic and public health implications

Economic losses in agriculture production: Parthenium invasion has caused 50 percent reduction in crops production across the world. It has threatened natural ecosystems and agroecosystems in over 30 countries (Adkins and Shabbir, 2014). It competes directly with neighboring plants for space, nutrients, water and sunlight's (Roy and Shaik, 2013). Aqueous leachate of parthenium cypsela inhibit the growth of wheat. The root exudates of parthenium contain toxins that retard the growth of tomato, bean, wheat and indigo era plants (Gunaseelan, 1987).

Human health and livestock health risk and occupational exposure

In humans parthenium and its pollens causes many health problems such as asthma, diarrhea, hay fever, skin, nose and eye allergy and dramatic diseases (Patel, 2011). The weed causes respiratory disorders, dermatitis and mutagenesis in humans and animals (Lalita and Kumar, 2018). The pollens contain secondary metabolites such parthenin that lead to rhinitis in humans (Towers, 1981). The major toxin being 'parthenin' and other phenolic acids such as, vanillic acid, anisic acid, caffeic acid, p-anisic acid, and parahydroxy benzoic acid and chlorogenic acid which are harmful to human and animals (Oudhia, 1998). These chemicals taint the meat of animals and make the milk unpalatable for drinking (Tudor *et al*., 1982).

Current management strategies and their effectiveness

Mechanical and physical control approaches: Most common mechanical methods used for controlling the parthenium includes manual weeding and tillage that mainly focus on the practice to retard its further distribution and growth (Khan *et al*., 2013). However, the best method for controlling the parthenium is uprooting it before flowering and seed setting. This practice is very easy when the soil is wet enough. If we pull the plant during flowering it will lead to allergic reaction due to dispersal of pollen grains. Similarly flowering, fruiting and fruit ripening lead to ultimate death of the plants.

Chemical control: Herbicide resistance and environmental risks

Modern herbicides can rapidly reduce the parthenium biomass in emergency condition. However, they require cash, proper equipment and training, correct and repeated applications due to persistent seed banks in soil (Shabbir *et al*., 2023). Use of glyphosate and metribuzin has wonderful result in controlling parthenium along wasteland, railway track, water channels and roadsides. But the use of herbicides is not actually an effective strategy because of their harmful effects on the environment so there is a need to develop alternative methods of management that should be environment friendly (Ojija *et al*., 2019). The chemical control requires regular follow up treatment that should be repeated continuously by effective use of herbicide (Lorraine and Lin, 2015). Chemical treatment is most effective at rosette stage. Chlorimuron and Trifloxysulfuron are chemical agent to control parthenium. However, under field conditions saflufenacil and hexazinone are very much effective in controlling the growth of flowering parthenium giving 100% control at all elevation timings (Fernandez, 2013).

Biological control agents and their field performance

Australia is the first country who initiated the biological control of parthenium in 1976. This method has been progressed in other countries including Pakistan, India, Africa, Uganda, Ethiopia and Tanzania (Maharjan *et al*., 2020). *Puccinia abrupta* Var. parthinicola that is the native of Brazil, Argentina and central America acts as efficient biocontrol agent against the population of *Parthenium hysterophorus* (Dhileepan *et al*., 2019). Biological control is the most effective way for controlling Parthenium. This method is most sustainable, cost effective and is used to check the growth of parthenium. There are number of biological control agents that need additional research to control the population of this specie. Cladosporium is the spray that is used as an herbicide against parthenium because it suppresses the embryo development and lead to the formation of sterile seeds, having no adverse effect on other crops that grow under same habitat. There has been a significant reduction in the population of parthenium weed by use of winter rust in Ethiopia and Pakistan (Iqbal *et al*., 2020). Biological control needs proper regulatory oversight and monitoring to protect non-targeted species (Naderi *et al*., 2024).

Botanical control

In this method aqueous extract and methanol extract is obtained from the leaves of *Nerium oleander* that inhibit seed germination, speed of germination, germination value, formation of root hairs and length of shoot seedling of *Parthenium* plant. Many natural products are obtained from plants that are bioactive in nature and are used against the management of this weed (Mishra *et al*., 2018). Legume of Butterfly pea, Buffle grass and purple pigeon grass is very effective Against the growth of *Parthenium hysterophorus* (Khan *et al*., 2019). *Argemone mexicana* is a plant species that grows along with parthenium in competition and is used for parthenium eradication. Parthenium can also be eradicated by increasing the grassland and decreasing livestock densities Many plant species release allelochemicals that suppress the growth of parthenium species by altering their physiological and biochemical activities (Kong *et al*., 2019). Mango leaves contain flavonoids that are very effective against the growth of Parthenium species (Javaid *et al*., 2010). Similarly, *Rumex dentatus*, *Calotropis procera* and *Withania somenifera* Shows herbicidal activity against *Parthenium hysterophorus.* Germination and seedling growth of parthenium can be inhibited by *Cassia occidentalis* (Jai *et al*., 2010). *Coronopus didymus* contain phenolic compounds (Noreen *et al*., 2017) that are responsible for reducing the Parthenium germination (John, 2012).

Integrated management approaches for sustainable control

Integrated management of *Parthenium hysterophorous* L.required and integrated weed management approach that combines preventative, cultural mechanical, biological, and chemical control strategies. Preventive measures, including the use of certified weed free seeds, sanitation of farm machinery, and regular surveillance of infested areas, help limit the introduction and spread of the weed. Cultural practices such as timely sowing, optimum crop spacing, competitive crop cultivars, crop rotation, and mulching enhance crop competitiveness by suppressing weed emergence, reducing light availability, and limiting soil moisture favourable for *parthenium* establishment.

Mechanical methods, such as hand weeding and mowing before flowering, effectively reduce seed production and are particularly useful for controlling localized pests. Biological control agents provide long-lasting suppression by weakening plant vigor and reducing its reproductive capacity, especially when integrated with other management measures. Selective herbicides allow for rapid control of the most damaging pests if applied at the appropriate growth stage; however, repeated use of the same mode of action should be avoided to minimize the development of herbicide resistance.

Alternating herbicides with different modes of action and using them in conjunction with non-chemical methods are essential for sustainable weed management. Furthermore, community-based management, involving coordinated monitoring, public awareness campaigns, and synchronized control measures in adjacent agricultural and non-agricultural areas, is essential to prevent re-infestation and achieve long-term suppression. Therefore, holistic and integrated strategies constitute the most effective and environmentally friendly approach to combating *P. hysterophorus* while preserving agricultural productivity and ecosystem health.

Integrated Weed Management frameworks emphasizes decision-making based on weed ecology, economic thresholds, and continual monitoring to enhance long term control efficacy (Holm *et al*., 1997). Practices such as crop rotation, cover cropping, and the use of competitive crop cultivars disrupt weed life cycles and improve resource capture, thereby lowering weed pressure while supporting soil health. At larger scales, community based and landscape level coordination of management actions fosters shared stewardship and reduce weed reinvasion across farms and natural areas.

Integrated weed management frameworks

Integrated Weed Management Frameworks combines cultural, mechanical, biological, nd chemical tactics in a systems approach to sustainably suppress weed populations while reducing reliance on herbicides and delaying resistance evolution (Kaur *et al*., 2024) (Table 2).

Role of crop rotation, cover crops, and competitive crops

Diverse crop rotations, cover cropping, and the use of highly competitive cultivars disrupt weed life cycles, improve soil health, and enhance crop competitiveness, thereby lowering weed pressure and input costs (Liebman *et al*., 2001).

Community based and landscape level management

Community based and landscape level management encourages cooperation among neighboring landowners and stakeholders to implement coordinated control strategies that address weed spread across property boundaries and ecological gradients (Yung *et al*., 2015) (Figure 3).

Table 2: *Integrated management Approaches for sustainable control.*

S. No	Elements	Management components	Key strategies	Benefits for sustainability	Applications	References
1	Integrated weed management	Preventive methods	Combining multiple control tactics	Long term weed	Biological agents	Norsworthy *et al*., 2012
2	Role of crop rotation, cover crops and competitive crops	Diverse cropping systems	Competitive cultivars	Enhances crop resilience	Competitive crops in rotation systems	Liebman *et al*., 1993
3	Community based and landscape level management	Farmer participation	Area wide management	Cost effective	Community weed removal campaigns	Wickramasinghe *et al*., 2023

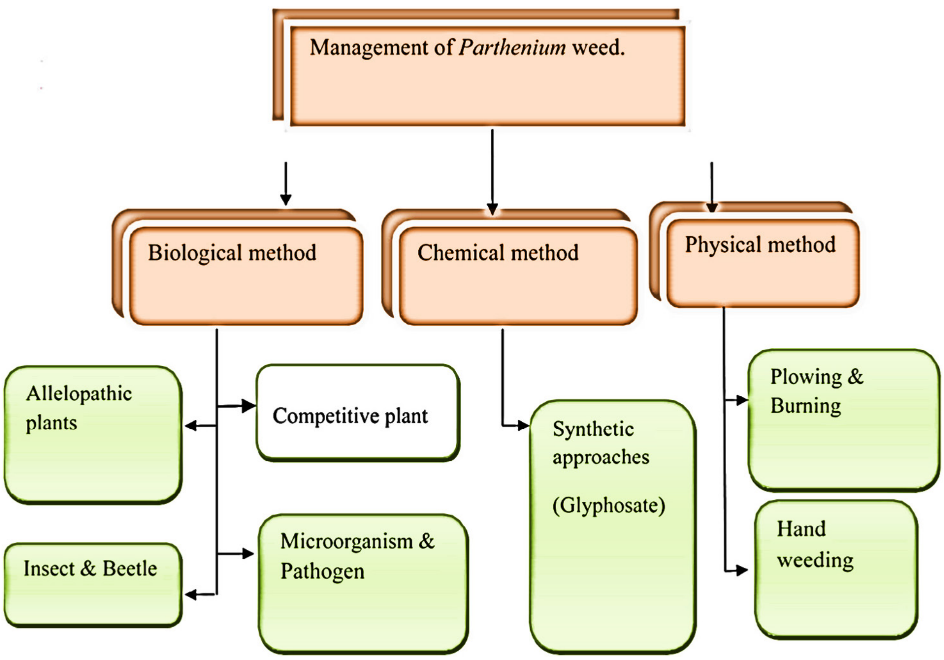

Figure 3: *Schematic presentation of the management of Parthenium hysterophorous.*

Table 3: *Climate change and future spread of Parthenium hysterophorous L.*

S. No	Aspects	Climate change influence	Future trend	Agricultural significance	References
1	Climate-driven shifts in distribution	Rising temperature	Increased invasiveness	Greater weed pressure in previously unaffected cropping systems	Bellard *et al.*, 2012
2	Growth and establishment	Enhanced tolerance to heat and drought	Improved survival, faster growth	Stronger competition with crops for nutrients	Adkins and Shabbir, 2014
3	Predictive modeling and risk mapping	Species distribution modelling	Identification of future invasion hotspots	Enable early warning	Thuiller *et al.*, 2005
4	Impact on crop productivity	Increased competitiveness under climate stress	Higher yield losses reduced crop performance	Threatens food security and farm profitability	Navie *et al.*, 1996
5	Implications for crop sustainability	Reduce effectiveness of conventional control methods	Increased management costs and reliance on integrated approaches	Necessitates climate smart and sustainable weed management strategies	McFadyen *et al.*, 1992

Climate change and the future spread of Parthenium hysterophorous

Climate driven shifts in distribution: Climate change is predicted to expand the geographic range of *parthenium hysterophorus*, enabling it to colonize higher latitudes and previously unsuitable regions due to warming and altered precipitation patterns, as shown by species distribution models under future climate scenarios. This shifts suggests a northward expansion and increased invasion risk in temperate zones (Adhikari *et al.*, 2023).

Predictive modeling and risk mapping

Predictive modeling tools like MaxEnt and CLIMAX project future habitat suitability and risk maps for *parthenium hysterophorus*, highlighting areas that may become climatically favorable by 2081-2100 and informing monitoring and management strategies. These risk maps are critical for anticipating invasive spread under diverse climate projections (Adhikari *et al.*, 2023).

Implications for future crop sustainability

The anticipated expansion of *Parthenium hysterophorus* under climate poses serious threats to crop sustainability by increasing competition with crops for resources, reducing yields, and complicating weed management in agronomic systems. This could undermine food security and agricultural productivity in affected regions (Adhikari *et al.*, 2023) (Table 3).

Knowledge gaps, research priorities, and emerging technologies

Despite notable advances, substantial knowledge gaps remain in understanding long term impacts, system level interactions, and context specific effectiveness of existing interventions. Current research priority emphasizes interdisciplinary frameworks and the application of emerging technologies to support sustainable, evidence based management strategies.

Limitation of current control strategies

Many control strategies are limited by the development of resistance, inadequate scalability, and insufficient integration of ecological and socio-economic considerations (Pretty and Pervez, 2015). Furthermore, reactive implementation and fragmented management approaches often undermine long term effectiveness.

Molecular, genomics, and biotechnological insights

Recent advances in genomic and molecular technologies have improved understanding of biological mechanisms and enabled more accurate diagnostics and targeted interventions. However, challenges remain in translating these biotechnological innovations into cost effective, field applicable solutions at scale.

Policy Awareness, and Early warning systems

Robust policy framework, enhance public awareness, and effective early warning systems are essential for timely risk detection and mitigation (WHO, 2012). Nevertheless, limitations in data integration, institutional coordination, and stakeholder participation continue to reduce the effectiveness of existing surveillance and response systems (WHO, 2012).

Conclusion

Parthenium hysterophorous is one of the most aggressive invasive weeds, posing significant threats to agricultural productivity, crop productivity, crop sustainability, biodiversity ecosystem functioning, and human and animal health. Its rapid growth, prolific seed production, allelopathic effects, and adaptability to diverse agro ecological conditions enable widespread establishment, making management with a single control method ineffective. Therefore, sustainable management requires an integrated and science based approach rather than reliance on herbicides alone.

Integrated weed management (IWM), combining preventive, cultural, biological, mechanical, and judicious chemical control measures, offers the most effective strategy for long term suppression of *P. hysterophorous* L. Practices that enhance crop competitiveness, reduce the soil seed bank, and restore invaded ecosystems can improve management outcomes while minimizing environmental impacts. Successful implementation also depends on farmer awareness, extension services, regular monitoring, and coordinated community participation to support early detection and prevent reinfestation.

Future efforts should focus on developing cost effective and climate resilient management strategies, improving biological control agents, and integrating precision agriculture, remote sensing, and molecular tools for early detection and targeted management. Strong policy support, effective regulatory frameworks, and collaboration among researchers, government agencies, extension organizations, and farming communities will be essential for limiting the spread of *P. hysterophorous* L. Such coordinated actions are critical to protecting agricultural productivity, conserving biodiversity, and ensuring long term food security under changing environmental conditions.

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Novelty Statement

This innovative review summarizes the agronomic, ecological, and allelopathic effects of *Parthenium hysterophorus* L. in a single framework, with a focus on agricultural productivity and crop sustainability. The article offers an original perspective on the impact of *P. hysterophorus* L. on crop yields, soil health, biodiversity, and agricultural systems, and goes beyond the traditional approach of viewing it merely as a weed. Furthermore, the article provides an integrated overview of sustainable management, prevention, and control strategies, making it relevant for both researchers and policymakers in the agricultural sector.

Author's Contribution

Gulnaz Parveen, Huma Gul and Saba Iqbal: Collected and analyzed the data.
Tariq Nadeem, Nazara and Roseena: Wrote the text.
Huma Gul: Wrote the final version of the text.
All authors approved the final version version of the manuscript.

Generative AI and AI assisted technology statement
The authors declare that no generative AI and AI assisted technology was used in the creation of this manuscript.

Conflict of interest
The authors have declared no conflict of interest.

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