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Invasion of *Parthenium hysterophorus*: Ecological Threats and Management Strategies in Kurram District, Khyber Pakhtunkhwa, Pakistan

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ABSTRACT

Parthenium hysterophorus L. (Asteraceae), commonly known as *Parthenium* weed, is an invasive annual herb that behaves as a perennial in Pakistan, severely impacting local biodiversity. In Khyber Pakhtunkhwa, particularly in District Kurram, it spreads across roadsides, waterways, and wastelands. A field survey was conducted from March 2022 to June 2023 assessed the distribution of *Parthenium* and its effects on native plants. Data was collected through 1m² quadrats, revealing 56 plant species from 21 families, including 18 annuals, 2 biennials, and 35 perennials. Three areas with significant *Parthenium* presence were selected, and three plant communities were identified: *Parthenium-Dichanthum-Cynodon*, *Parthenium-Cynodon-Xanthium*, and *Parthenium-Cynodon-Taraxacum*. The study recorded absolute density, relative density, absolute frequency, relative frequency, Cover and relative cover and importance values (IV) for *Parthenium* and other species. Asteraceae had the highest family importance value (FIV) of 478.16, followed by Poaceae (260.99), Fabaceae (24.8), and others. Soil analysis showed predominantly sandy loam and silty loam, with pH values between 7.10 and 7.15. Nutrient levels varied, with nitrogen (0.15-0.21%), phosphorus (1.99-7.50 mg/kg), potassium (105-131 mg/kg), and trace metals such as zinc (1.11-9.83 mg/kg) and iron (20.56-39.13 mg/kg). The study also examined control methods for *Parthenium*, including salt solution, urea, and herbicide, hand pulling, slashing, and burning. The findings provide valuable guidance for local farmers and communities on managing this invasive species. Given its rapid spread and poor management, *Parthenium* has become a major threat in Pakistan, especially in KPK, requiring immediate policy attention and quarantine measures to protect native plants and ensure optimal crop production.

Keywords: *Parthenium hysterophorus*, Invasive species, Weed Distribution, Allelopathic effects, Kurram, Pakistan.

INTRODUCTION

Parthenium hysterophorus L. a member of the Asteraceae, is native to Tropical and Sub-tropical America, including regions such as Mexico, Central and South America, and the West Indies (Masum *et al.,* 2022; Bashar *et al.,* 2023; Adhikari *et al.,* 2023). The name "*Parthenium*" is derived from the Latin word "parthenice" (meaning virgin), while "*hysterophorus*" comes from the Greek words for womb and bearing (Jaiswal *et al.,* 2022). This genus contains 16 species. In Pakistan, it is commonly known as "Bui" or "Gandi Booti," with regional names like Skha

Botay in Khyber Pakhtunkhwa and Sugar Botay in Kurram (Iqbal *et al.,* 2022; Hussain *et al.,* 2019; Boja *et al.,* 2022).

Parthenium hysterophorus has two growth stages: juvenile and adult. In the juvenile stage, it forms a basal rosette of large, dark green, deeply lobed leaves (5-20 cm long, 4-5 cm wide) that do not flower. These leaves spread on the ground, suppressing other plants. In the adult stage, the plant grows upright to 2-2.5 m, with a deep taproot, branching structure, and small white flowers covered by green bracts. It produces significant amounts of pollen and seeds, with flowering peaking in the rainy season. In Pakistan, *Parthenium* behaves as a perennial, producing 10,000–28,000 seeds per plant, with cypsela fruits that darken as they mature (Adnan *et al.,* 2021; Dukpa *et al.,* 2020; Oduor, 2021; Zareen *et al.,* 2021).

Parthenium is one of the top ten most problematic weeds globally, causing significant threats in countries like India, Nepal, Bangladesh, Pakistan, and others. Its spread to over 46 countries highlights its widespread impact. It is believed to have been introduced to the Asian subcontinent through wheat imports under the 1950s "Food for Peace" program. In Pakistan, 73 invasive plant species, including *Parthenium,* have been recognized. The weed was first recorded in Gujarat, Punjab, in the 1980s and spread across the country, particularly affecting Khyber Pakhtunkhwa and regions like Swabi, Mardan, and Peshawar (Costella *et al.,* 2022; Kumawat and Sharma, 2023).

Parthenium hysterophorus thrives in diverse harsh environments, including areas with intense sunlight, drought, extreme temperatures, and waterlogging. It flourishes in urban areas, overgrazed pastures, industrial zones, and along roadsides, railway tracks, and irrigation systems. Preferring alkaline, fertile soils, it can adapt to sandy loam with varying nutrients and pH. *Parthenium* flowers from July to September, with seeds germinating in spring and autumn, completing 4 to 5 generations annually. *Parthenium* exhibits strong allelopathic properties due to the high levels of allelechemicals in its leaves and inflorescences, which are more potent than those in its stems and roots (Afzal *et al.,* 2022; Bashar *et al.,* 2023; Ali *et al.,* 2024). It contains toxic compounds like sesquiterpenes and lactones (e.g., parthenin, hysterin) and phytotoxic chemicals (e.g., anisic acid, caffeic acid). These allelochemicals inhibit the growth of nearby plants, aiding its invasive nature.

Agriculture, contributing 26% to Pakistan's GDP, is vital to the economy (Khan *et al.,* 2020; Iqbal *et al.,* 2022; Zeeshan *et al.,* 2023). The spread of *Parthenium* has severely impacted agricultural production. The parthenin compound has been shown to inhibit germination and growth in both monocots and dicots. Extracts from all parts of the plant significantly hinder germination and reduce the root and shoot length, as well as the dry weight of both.

The harmful weed *P. hysterophorus* poses serious risks to livestock, causing skin lesions, mouth ulcers, diarrhea, and gastrointestinal issues, leading to excessive salivation in horses and cattle. Controlling *Parthenium hysterophorus*, an invasive weed, is vital for biodiversity, ecosystem health, and agriculture. Methods like biological, chemical, mechanical, and competitive displacement using native plants can effectively limit its spread. A tailored combination of these approaches is key to managing the invasion. The objectives of this study were to assess the spread of *Parthenium hysterophorus* in Kurram District, Khyber Pakhtunkhwa, evaluate its impact on local flora, raise awareness about its harmful effects, and explore control and management strategies for its spread in the area (Kumawat and Sharma, 2023).

MATERIALS AND METHODS

Study area

Kurram is a scenic valley in Pakistan's Khyber Pakhtunkhwa province, located between 33° 20′ to 34° 10′ N and 69° 50′ to 70° 50′ E. Spanning 115 km and 3,380 square kilometers, it is named after the Kurram River, with historical roots tied to the silk trade. The district is divided into Lower, Central, and Upper Kurram, bordered by Orakzai, Khyber, Hangu, North Waziristan, and Afghanistan (Hussain *et al.*, 2012; Hussain *et al.*, 2018; Ali *et al.*, 2022; Shah *et al.*, 2025) (Figure 1). The 2017 census recorded a population of 619,553, with major tribes like Turi, Bangash, and Mamozai (Abbas *et al.*, 2020). Kurram history spans from 4000–2000 BC, serving as a migration route into India, with Sikaram peak rising to 4,728 m. The climate varies greatly with altitude, featuring hot summers and cold winters, with temperatures ranging from -13.4°C to 39.9°C (Hussain *et al.*, 2022; Hussain *et al.*, 2023).

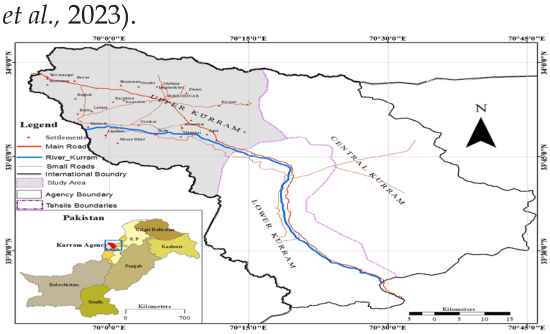

Figure 1: Map of the District Kurram

Phytosociological Study

A study was conducted between March 2022 and June 2023 to evaluate the distribution and effects of *Parthenium hysterophorus* on vegetation in the area. The research involved sampling of 15 randomly placed quadrats (1 × 1 m²) at three different sites. Key metrics, including density, relative density, cover, relative cover, frequency, relative frequency, and importance value, were calculated (Hussain *et al.*, 2019; Zareen *et al.*, 2021).

Density

The species density and its relative value were calculated using standard formula (Hussain *et al.*, 2019).

$$Absolute\ densi\ ty, AD = \frac{\text{Total number of individual of a particular species in all quadrats}}{\text{Total number of quadrats placed}}$$

$$Relative\ density, RD = \frac{\text{Absolute density for a specfic species}}{\text{Total absolute density for all species}} \times 100$$

Cover

The cover and relative cover of species were determined with specified formula (Ali *et al.*, 2022).

$$Canopy\ Cover = \frac{\text{Sum of the mid points of a species}}{\text{Total area sampled}}$$

$$Relative\ Cover = \frac{\text{Cover of a species}}{\text{Cover of all the species in a stand}} \times 100$$

Frequency

The frequency and relative frequency of the plants were determined by using the formula given (Haq and Badshah, 2021; Zareen *et al.*, 2021).

$$Absolute\ frequency, AF = \frac{\text{Number of quadrats in which species occurs}}{\text{Total number of quadrats}} \times 100$$

$$Relative\ frequency, RF = \frac{\text{Absolute frequency value for a specific species}}{\text{Total absolute frequency values for all species}} \times 100$$

Importance Value (IV)

Importance Value of each species was calculated by the entire relative of RD, RF, RC. The communities were named after three leading species having the highest important values (Hussain *et al.*, 2019).

IV= RD + RC + RF

Family Importance Value (FIV)

Importance value of every species in a specific family was added together to give rise FIV for all the quantitatively recorded families (Hussain *et al.*, 2019).

Cluster analysis

The PAST application and Principal Component

Analysis (PCA) were used for cluster analysis, a method to group similar objects. The resulting dendrogram is a hierarchical tree structure, representing different biotic communities through cluster sampling units. (Haq and Badshah, 2021; Bashar *et al*., 2023).

Soil analysis

Soil samples were collected from the four corners and center of each quadrant at a depth of 15 cm. The samples were sealed in labeled plastic bags, dried at 250-300°C, and cleared of impurities like stones and roots. Analysis was conducted at the Department of Agriculture Research and Soil and Water Testing Laboratory, Parachinar Kurram, Pakistan (Hussain *et al*., 2019).

Experimental materials and equipment's

The materials used in the experiments included Glyphosate herbicide, urea (a type of fertilizer), and common salt. The equipment utilized during the experiments consisted of a plastic spray bottle, a calibrated knapsack sprayer, a water beaker, a funnel, and personal protective equipment (PPE), such as a mask, gloves, and eyewear.

Chemical control strategies

Application of Urea (a type of fertilizer) solution

A solution was prepared by dissolving 50 g of urea in 500 mL of water, which is equivalent to 1 kg of salt dissolved in 12 L of water. This solution was then sprayed on *Parthenium* plants in a designated area using a watering can. The spraying was done twice, with a one-week interval between each application during the experiment (Million *et al.,* 2021).

Application of Common salt solution

A solution was prepared by dissolving 50 g of table salt in 500 mL of water, equivalent to dissolving 1 kg of salt in a 12 L container for use with a knapsack sprayer. This solution was then sprayed onto Parthenium plants in a designated area using a watering can. The application was repeated twice, with one-week intervals between each spraying, throughout the course of the experiment (Natukunda *et al.,* 2020).

Application of Herbicide solution

In our study, we used a properly calibrated knapsack sprayer to apply Glyphosate to the targeted area. For each application, 100 mL of the herbicide were mixed with 12 L of water. Protective gear was worn during the spraying process. The herbicide was applied twice, with a one-week interval between each application, as part of the experiment (Natukunda *et al.,* 2020).

Physical Control Strategies

Manual uprooting

In this designated area, *Parthenium* weed was manually removed and placed in a designated spot to decompose naturally. For the purpose of our study, the weeds were pulled out three times from the area, with each removal occurring every two weeks throughout the duration of the experiment (Natukunda *et al.,* 2020; Dukpa *et al.,* 2020).

Slasher

Throughout the experiment, we used a slasher, a handheld tool with metal blades, to manually cut the *Parthenium* weed in the designated area. The weeds were slashed three times, with a two-week interval between each session. According to Mekonnen, (2017) and Natukunda *et al.* (2020) slashing is considered an effective weed management technique.

Burning

Burning is another common method for controlling *Parthenium hysterophorus*, as it effectively eliminates large volumes of the weed's vegetation (Natukunda *et al.,* 2020; Dukpa *et al.,* 2020; Sharma and Kumawat, 2023; Khan and Gurjar, 2023).

RESULTS

The study, conducted in District Kurram, Khyber Pakhtunkhwa, Pakistan, from March 2022 to June 2023, covered three monitoring sites: Upper Kurram, Central Kurram, and Lower Kurram. Field observations recorded 56 angiosperm species, including 12 monocots and 44 dicots, from 21 families. The invasive *Parthenium hysterophorus* was identified along with other plant species using quadrat sampling (Table 1). During this extensive survey, we identified and collected seven common weed species from all the three sites (Figure 2).

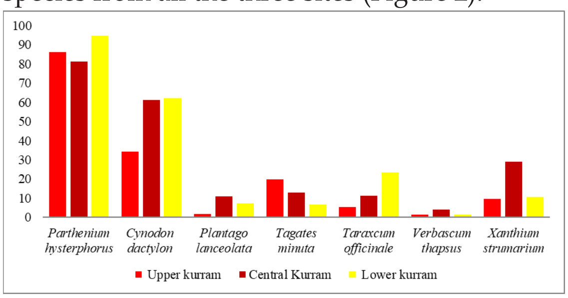

Figure 2: Importance value of weed species across three the sites: Upper, Lower, and Central Kurram

Table 1: Different plant species associated with *Parthenium* communities in District Kurram

S. No	Family Names	**Botanical Names**	Local Names	Life Cycle
Angiosperm Monocot				
1	Areaceae	*Nannorrhops ritchiana* (Griff.) Aitch.	Mazari	P
2	Asparagaceae	*Asparagus adscendens* Roxb	Lahty	P
3		*Dichanthium annulatum* (Forssk.) Stapf)	Marval waha	P
4		*Cynodon dactylon* (L) Pers.	Kabal	P
5		*Aristida cyanantha* Steud.	Sargary	P
6		*Dichanthium caricosum* (L).	Shana waha	P
7		*Saccharum spontaneum* L.	Ghorga	P
8	Poaceae	*Hyparrhenia hirta* (L.) P. Beauv.ex Roem. & Schult L		P
9		*Heteropogon contortus* (L.) P.Beauv. ex Roem. & Schult		P
10		*Poa annua* L.		A
11		*Eleusine indica* L.		A
12		*Themeda anathera* (Nees ex Steud). Hack		P
Dicot				
13		*Amaranthus viridis* L.	Rinzaka	P
14		*Chenopodium ovate* L.		A
15	Amaranthaceae	*Amaranthus spinosus* L.		A
16		*Chenopodium album* L.	Naray Rinzaka	A
17	Apiaceae	*Eryngium corallinum* Mathias & Constance		P
18		*Parthenium hysterophorus* L.	Mardar boti	A
19		*Tagetes minuta* L.	Bianak boti	A
20		*Artemisia scoparia* Waldst.&Kitam	Shna Tarkha	P
21		*Artemisia vulgaris* L.	Darlong	P
22		*Xanthium strumarium* L.	Khara Datura	A
23		*Cichorium intybus* L.	Shingul	P
24	Asteraceae	*Trifolium repens* L.	Shaftale	P
25		*Dittrichia viscosa* L.		P
26		*Taraxacum officinale* Webb	Zairgulae	P
27		*Sonchus asper* (L.) Hill	Tareza	A
28		*Seriphidiumkurramense* (Qazib.) Y. R Ling	Tarha	P
29		*Xanthium spinosum* L.	Tera azghaya	A
30		*Lactuca sativa* L.	Shudoo wala	A
31		*Onopordum achanthium* L.		B
32		*Anthemis cotula* L.		A
33		*Onosma dichroantha* Bioss		P
34	Boraginaceae	*Trichodesma indicum* (L.) Lehm		A
35	Cannabaceae	*Cannabis sativa* L.	Bhang	A
36	Caprifoliaceae	*Morina persica* L.		P
37	Caryophyllaceae	*Silene conoidea* L.	Kuzo Saba	B
38	Convolvulaceae	*Convolvulus Arvenis*.L	Parvaty	P
39	Euphorbiaceae	*Euphorbia heloscopia* L.	Peshkhwatay	A
40		*Lespedeza junicea* (L.f.) Pers.		P
41	Fabaceae	*Astragalus umbellatus* Bunge	Shasha	P
42		*Prosopis juliflora* (Sw.) DC.	Kikar	P
43		*Scutellaria Linearis* Benth		P
44		*Thymus vulgaris* L.		P
45	Lamiaceae	*Salvia reflexa* Hornem.	Shugar Boti	P
46		*Teucrium stocksianum* Boiss	Khar Boti	P
47		*Malva neglecta Wallr.*	Tikalay	P
48	Malvaceae	*Malvastrum coromandelianum* (L)Garcke		A
49	Oxalidaceae	*Oxalis corniculata* L.	Bibimalga	P
50	Plantaginaceae	*Plantago lanceolata* L.	Ghwajabi	P
51	Polygonaceae	*Rumex pulcher* L.	fiddle dock	P
52	Scrophulariaceae	*Verbascum Thapsus* L.	Spairay Ponri	B
53		*Datura stramonium* L.	Shna Datura	A
54	Solanaceae	*Solanum surattense* Burm.f.	Marghony	A
55		*Solanum elaegnifolium* L.		P
56	Thymeleace	*Dephne oleoides* Schreb	Laghuny	P

Key: A-Annual, B-Biennial and P-Perennial

A total of 35 species were documented from Upper Kurram, 21species were recorded in central Kurram while, 27 plant species recorded in Lower Kurram. The method of categorizing vegetation into 3 distinct communities are consistent with the research conducted by (Ali *et al*., 2018; Ilyas *et al*., 2018); Hussain *et al*., 2019; Haq and Badshsh, 2021). Fifty-six species (56 species) were identified across the sampling units, with one specie (*ProsopIs juliflora* (SW.)

DC.) represented among trees (in a shrubby state), two species among shrubs (*Dephine oleoides, Nannorrhops ritchiana*), and a substantial 53 species among herbs (Table 1). Utilizing the Importance Value (IV) criterion, three distinct communities were established across three monitoring sites. Based on family importance value Asteraceae was the leading family with an FIV of 478.16 followed by Poaceae (260.99), Fabaceae (24.8), Amaranthaceae (22.22), Plantaginaceae (19.64), Solanaceae (12.51), Lamiaceae (11.54), Euphorbiaceae (9.83), Oxalidaceae (9.26) and Malvaceae with (8.06). Scrophulariaceae, Areaceae, had importance values ranging from 7.24 to 7.16. Boraginaceae (5.9), Thymeleace (4.11), Caprifoliaceae, Caryophyllaceae and Cannabaceae have same FIV of 3.32. Convolvulaceae (1.81), Asparagaceae and Apiaceae also have same FIV of (1.55). Polygonaceae have (1.48) respectively.

Classification of Community

The communities were categorized according to their species' Importance Value. The first community was recorded vs; *Parthenium-Dichanthum-Cynodon*, second community vs; *Parthenium-Cynodon-Xanthium* and third community i.e *Parthenium-Cynodon-Taraxacum.*

Site No: 1 Upper Kurram

The soil texture was identified as sandy loam, comprising 53% sand, 38% silt, and 9% clay (Table 2). The soil analysis detected nitrogen at 0.16%, phosphorus at 7.50mg/kg, potassium at 105mg/kg, zinc at 9.83mg/kg, copper at 6.05mg/kg, iron at 39.13mg/kg, and manganese at 6.80mg/kg. The pH recorded at this monitoring site was 7.10, accompanied by an organic matter content of 2.62%. The electrical conductivity (EC) measured 0.25dSm-1. as shown in (Table 3 and 4).

***Parthenium-Dichanthum-Cynodon* community (PDC)**

The plant community in the Upper Kurram region was documented, with *Parthenium hysterophorus* emerging as the dominant species, exhibiting an importance value (IV) of 86.33. It was followed by *Dichanthium annulatum* with an IV of 44.54, and *Cynodon dactylon* with an IV of 34.25. Other species found in this community included *Tagetes minuta* (IV 19.71), *Seriphidium kurramense* (IV 14.23), *Xanthium strumarium* (IV 9.49), *Oxalis corniculata* (IV 9.26), *Amaranthus viridis* (IV 5.71), *Xanthium spinosum* (IV 5.38), *Taraxacum officinale* (IV 5.25), *Chenopodium ovate* (IV 5.60), *Euphorbia helioscopia* (IV 4.93), *Solanum surattense* (IV 4.83), *Onosma dichroantha* (IV 4.35), *Tripolium repens* (IV 3.73), *Aristida cyanantha* (IV 3.64), *Amaranthus spinosus* (IV 3.08), *Artemisia vulgaris* (IV 3.02), *Scutellaria linearifolia* and *Eleusine indica* (both with IV 2.87), *Dichanthium caricosum* (IV 2.38), *Sonchus asper* and *Convolvulus arvensis* (both with IV 1.81), *Datura stramonium* (IV 1.71), and *Lespedeza juncea*, *Dittrichia viscosa*, *Artemisia scoparia*, *Saccharum spontaneum*, *Plantago lanceolata*, and *Astragalus umbellatus* (all with IV 1.59). *Verbascum thapsus*, *Themeda anthemoides*, and *Rumex pulcher* had IVs of 1.48, while Cichorium intybus had an IV of 1.38 (Table 4).

Table 2: Texture and physicochemical characteristics of soils samples from the Upper, Lower, and Central Kurram.

S. No	Locality		Clay %	Silt	Sand	Ph	EC Ds/m	SOM %
Site1	Upper Kurram	Sandy loam	9	38	53	7.10	0.25	2.62
Site 2	Central Kurram	Silty loam	9	66	25	7.15	0.34	3.17
Site 3	Lower Kurram	Silty loam	11	74	15	7.13	0.34	1.93

Table 3: Soil macro and micronutrients across Upper, Lower, and Central Kurram.

S. No	Locality	N	P	K	Zn	Cu	Fe	Mn
		%	………mg kg^{-1}………					
Site 1	Upper Kurram	0.16	7.50	105	9.83	6.05	39.13	6.80
Site 2	Central Kurram	0.15	4.72	131	1.87	5.68	20.56	4.39
Site 3	Lower Kurram	0.21	1.99	107	1.11	5.64	31.03	5.35

Site No :2 Central Kurram

The soil in the area was classified as silty loam, consisting of 66% silt, 25% sand, and 9% clay (Table.2). Soil analysis revealed the following nutrient levels: nitrogen at 0.15%, phosphorus at 4.72 mg/kg, potassium at 131 mg/kg, zinc at 1.87 mg/kg, copper at 5.68 mg/kg, iron at 20.56 mg/kg, and manganese at 4.39 mg/kg. The soil's pH was 7.15, and it contained 3.17% organic matter. The electrical conductivity (EC) of the soil was recorded at 0.34 dSm^{-1}, as shown in (Tables 3 and 4).

Parthenium-Cynodon-Xanthium community (PCX)

This plant community was reported from Central Kurram. This community consists of 21 species led by *Parthenium hysterophorus* with an IV of 81.24, followed by *Cynodon dactylon* with a 61.3 and *Xanthium strumarium* 29.03. Other associated members of this community were *Dichanthium annulatum* (23.56), *Xanthium spinosum* and *Tagates minuta* have same (12.89), *Artemisia scoparia* (11.64), *Taraxacum officinale* (11.4), *Plantago lanceolata* (10.8), *Amaranthus viridis* (5.39), *Lactuca sativa* (5.24), *Euphorbia heloscopia* (4.89), *Verbascum thapsus* (4.21), *Solinum elaeagnifalium* (3.65), *ProsopIs juliflora, Onopordum acanthium, Cannabis sativa, Morina persica* and *Silene conoidea*, these species have same (3.32), *Anthemis cotula* have 1.55 (Table 4).

Site No:3 Lower Kurram

The soil at the monitoring site was classified as silty loam, consisting of 74% silt, 15% sand, and 11% clay (Table 2). Soil analysis revealed nitrogen content of 0.21%, phosphorus at 1.99 mg/kg, potassium at 107 mg/kg, zinc at 1.11

mg/kg, copper at 5.64 mg/kg, iron at 31.03 mg/kg, and manganese at 5.35 mg/kg. The soil pH was recorded at 7.13, with an organic matter content of 1.93%. The electrical conductivity (EC) was measured at 0.34 dSm-1, as shown in (Tables 3 and 4).

Parthenium-Cynodon-Taraxacum community (PCT)

The plant community documented in Lower Kurram comprises 27 species, dominated by *Parthenium hysterophorus* with an IV of 94.75, followed by *Cynodon dactylon* with a 62.35 and *Taraxacum officinale* 23.47. Other prominent member of this community were *Prosopis juliflora* (18.3), *Tripolium repens* (15.33), *Xanthium strumarium* (10.72), *Eleusine indica* (8.31), *Plantago lanceolata* (7.25), *Nannorrhops ritchiana* (7.16), *Tagates minuta* (6.77), *Malvastrum coromandelianum* (6.17), *Aristida cyanantha* (4.59), *Dephine oleoides* (4.11), *Hyparrhenia hirta* (4.2), *Scutellaria lineraris* (3.15), *Hetropogan contortus* (2.66), *Teucrium stocksianum* and *Sonchus asper* both have same (2.47), *Datura stramonium* (2.32), *Malva neglecta* (1.89), *Themedia anther* and *Chenopodium album* have same 1.72. *Salvia reflexa*, *Asparagus adscendens*, *Poa annua*, *Eryngium corallinum* and *Verbascum thapsus* these species have same IV 1.55 (Table 4).

Table 4: Showing the Importance Value of Vegetation in Upper, Central and lower Kurram.

S. No	Name of Species	Site 1	Site 2	Site 3
Herb				
1	*Amaranthus spinosus*	3.08	0	0
2	*Amaranthus viridis*	5.71	5.39	0
3	*Anthemis cotula*		4.47	
4	*Aristida cyanantha*	3.64	0	4.59
5	*Artemisia scoparia*	1.59	11.64	0
6	*Artemisia vulgaris*	3.02	0	0
7	*Asparagus adscendens*	0	0	1.55
8	*Astragalus umbellatus*	1.59	0	0
9	*Cannabis sativa*		3.32	
10	*Chenopodium album*	0	0	1.72
11	*Chenopodium ovate*	5.6	0	0
12	*Cichorium intybus*	1.38	0	0
13	*Convolvulus Arvenis*	1.81	0	0
14	*Cynodon dactylon*	34.25	61.3	62.35
15	*Datura stramonium*	1.71	0	2.32
16	*Dichanthium annulatum*	44.54	23.56	0
17	*Dichanthium caricosum*	2.38	0	0
18	*Dittrichia viscosa*	1.59	0	0
19	*Eleusine indica*	2.87	0	8.31
20	*Eryngium corallinum*	0	0	1.55
21	*Euphorbia heloscopia*	4.93	4.89	0
22	*Hetropogan contortus*	0	0	2.66
23	*Hyparrhenia hirta*	0	0	4.2
24	*Lactuca sativa*		5.24	
25	*Lespedeza juncea*	1.59	0	0
26	*Malva neglecta*	0	0	1.89
27	*Malvastrum coromandelianum*	0	0	6.17
28	*Morina persica*		3.32	
29	*Onopordum acanthium*		3.32	
30	*Onosma dichroantha*	4.35	0	0
31	*Oxalis corniculate*	9.26	0	0
32	*Parthenium hysterophorus*	86.33	81.24	94.75
33	*Plantago lanceolata*	1.59	10.8	7.25
34	*Poa annua*	0	0	1.55
35	*Rumex pulcher*	1.48	0	0
36	*Saccharum spontaneum*	1.59	0	0
37	*Salvia reflexa*	0	0	1.55
38	*Scuttlerria lineris*	2.87	0	3.15
39	*Seriphidium kurramense*	14.23	0	0
40	*Silene conoidea*		3.32	

41	*Solanum elaeagnifolium*		3.65	
42	*Sollanium surritanse*	4.83	0	0
43	*Sonchus asper*	1.81	0	2.49
44	*Tagates minuta*	19.71	12.89	6.77
45	*Taraxcum officinale*	5.25	11.4	23.47
46	*Teucrium stocksianum*	0	0	2.49
47	*Themedia anther*	1.48	0	1.72
48	*Thymus vulgaris*	1.48	0	0
49	*Trichodesma indicum*		1.55	
50	*Tripolium repens*	3.73	0	15.33
51	*Verbascum Thapsus*	1.48	4.21	1.55
52	*Xanthium spinosum*	5.38	12.89	0
53	*Xanthium strumarium*	9.49	29.03	10.72
Shrub				
54	*Dephine oleoides*	0	0	4.11
55	*Nannorrhops ritchiana*	0	0	7.16
Tree				
56	*Prosopis juliflora*	0	3.32	18.3

Site-1 (Upper Kurram), Site-2 (Central Kurram), Site-3 (Lower Kurram)

Cluster Analysis

Cluster analysis technique was used to identify patterns and similarities.

Cluster I. Cluster I comprise these species with IV values *Cynodon dactylon* (combined IV value 157.9) and *Parthenium hysterophorus* (combined IV value 262.32) species.

Cluster II. Cluster II contains species like *Amaranthus spinosus with IV (*3.08) followed by *Amaranthus viridis (*11.1), *Anthemis cotula (*4.47), *Aristida cyanantha (*8.23), *Asparagus adscendens (*1.55), *Astragalus umbellatus (*1.59), *Cannabis sativa (*3.32), *Chenopodium album (*1.72), *Chenopodium ovata (*5.6), *Cichorium intybus* (1.38), *Convolvulus arvenis (*1.81), *Datura stramonium* (4.03), *Dichanthium annulatum (*68.1), *Dichanthium caricosum (*2.38), *Dittrichia viscosa (*1.59), *Eleusine indica (*11.18), *Eryngium corallinum (*1.55), *Euphorbia heloscopia (*9.82), *Hetropogan contortus (*2.66), *Hyparrhenia hirta (*4.2), *Lactuca sativa (*5.24), *Lespedeza juncea (*1.59), *Malva neglecta (*1.89), *Malvastrum coromandelianum (*6.17), *Morina persica (*3.32), *Onopordum acanthium (*3.32), *Onosma dichroantha (*4.35), *Oxalis corniculate (*9.26), *Plantago lanceolate (*19.64), *Poa annua (*1.55), *Rumex pulcher* (1.48), *Saccharum spontaneum (*1.59), *Salvia reflexa (*1.55), *Scuttlerria lineris (*6.02), *Seriphidium kurramense (*14.23), *Silene conoidea (*3.32), *Solanum elaeagnifolium* (3.65), *Sollanium surritanse* (4.83), *Sonchus asper* (4.3), *Teucrium stocksianum (*2.49), *Themeda anathera (*3.2), *Thymus vulgaris (*1.48), *Trichodesma indicum (*1.55), *Verbascum Thapsus (*7.24), *Xanthium spinosum (*18.27), *Dephine oleoides* (4.11), *Nannorrhops ritchiana* (7.16).

Cluster III. Cluster III consist of the species *Tripolium repenswith IV (*19.06) *followed by Xanthium strumarium (*49.24), *Prosopis juliflora (*21.62), *Tagetes minuta (*39.37), *and Taraxcum officinale (*40.12) (Figure 3).

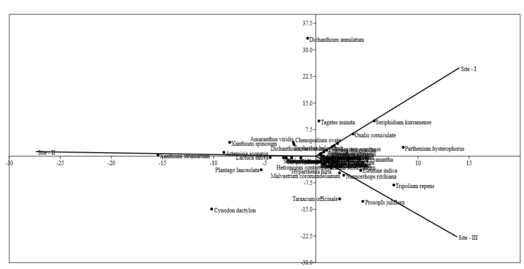

Figure 3: Cluster analysis reveals the association of species based on their Importance Value (IV) across three sites

Principal Component Analysis

Principal Component Analysis (PCA) is a widely used method in ecology, first introduced by Pearson, to study vegetation and its relationship with soil properties. In PCA plot 1, *Cynodon dactylon* and *Parthenium hysterophorus* show a positive correlation. In PCA plot 2, several species, including *Amaranthus spinosus*, *Amaranthus viridis*, *Anthemis cotula*, *Aristida cyanantha*, *Asparagus adscendens*, *Astragalus umbellatus*, *Cannabis sativa*, *Chenopodium album*, *Chenopodium ovate*, *Cichorium intybus*, *Convolvulus arvenis*, *Datura stramonium*, *Dichanthium annulatum*, *Dichanthium caricosum*, *Dittrichia viscosa*, *Eleusine indica*, *Onosma dichroantha*, *Oxalis corniculate*, *Plantago lanceolate*, *Poa annua*, *Rumex pulcher*, *Saccharum spontaneum*, *Salvia reflexa*, *Scutellaria linearifolia*, *Seriphidium kurramense*, *Silene conoidea*, and *Solanum elaeagnifolium* exhibit a weak positive correlation and a scattered distribution. In PCA plot 3, species like *Tripolium repens* (19.06), *Xanthium spinosum* (18.27), *Xanthium strumarium* (49.24), *Prosopis juliflora* (21.62), *Tagetes minuta* (39.37), and *Taraxacum officinale* (40.12) form an isolated community (Figure 4).

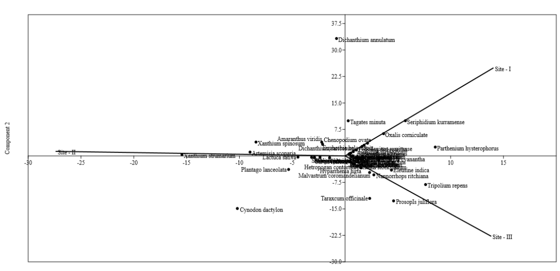

Figure 4: The PCA biplot illustrates the association of species based on their Importance Value (IV) across three sites.

Parthenium weed management strategies

The data analysis revealed that all six weed management methods effectively controlled *Parthenium* populations. Particularly, the salt and urea treatments were successful in completely eradicating the weed at the end of the experiment.

Chemical control strategies

In this study, the herbicide application was less effective in controlling *Parthenium* compared to other methods, although a noticeable reduction in weed populations was observed, potentially due to Glyphosate resistance. Herbicides showed the best results when applied to young plants. On the other hand, urea proved highly effective, successfully eliminating *Parthenium* when applied during the early flowering stage. Likewise, a salt solution led to the complete wilting and death of young plants before they could flower.

Physical control strategies

In this study, manual uprooting was found to be highly effective in controlling Parthenium weed, especially when done before flowering and seed setting. This method is widely adopted by farmers for managing the weed. However, slashing alone proved ineffective, as the remaining roots allowed the plants to regrow, reducing its overall success. Repeated burning helped lower Parthenium populations by killing plants and seeds near the soil surface, though buried seeds may still survive.

DISCUSSION

The study on *Parthenium hysterophorus* in District Kurram, Khyber Pakhtunkhwa (KPK), Pakistan, is the first of its kind. It reveals that much of the district is invaded by this weed, first documented by (Hussain *et al.*, 2019). *Parthenium* is an invasive species that was accidentally introduced to Pakistan and is now a major environmental threat. It is spreading rapidly across regions such as Islamabad, KPK, Punjab, Balochistan, Gilgit-Baltistan, and Kashmir, where it is outcompeting native plants due to the absence of natural predators. The weed negatively impacts agriculture, reduces crop yields, harms biodiversity, and poses health risks to livestock. If uncontrolled, it could further spread across Khyber Pakhtunkhwa. Our research shows that *Parthenium* weed is rapidly spreading in District Kurram, KPK, Pakistan, becoming a major threat to local plants. Water, wind, vehicles, and farming tools are facilitating its spread. The weed's allelopathic nature, which releases chemicals like phenolics and sesquiterpene lactones (including parthenin and coronopilin), inhibits the growth and germination of nearby plants, further aiding its rapid colonization. Raiz and Javid,2012 reported that *Parthenium* has a natural ability to suppress the growth of nearby plants by releasing chemicals such as phenolics and sesquiterpene lactones, including parthenin and coronopilin. This allelopathic effect is a key factor in its rapid spread. The findings show that *Parthenium hysterophorus* has become a significant weed problem in areas like vacant lands, roadsides, orchards, lawns near water, and towns in District Kurram. Masum *et al*.,2022 noted that in grazing fields and along roadsides, *Parthenium* significantly impacts the growth of other plants, often out competing them. Khan *et al*.,2014 also highlighted that the rapid spread of *Parthenium* has made it one of the most troublesome weeds in KPK. In the current study, we documented 56 plant species across 21 families, including Asteraceae, Poaceae, Amaranthaceae, and Lamiaceae. Out of the 45 quadrats sampled for the presence of *Parthenium* weed, we found it in all of them, meaning it was present in 100% of the quadrats (Mutua *et al.,* 2022; Khan *et al.,* 2023). In this study, the distribution of *Parthenium hysterophorus* and other plants was assessed in quadrats and categorized into three communities based on Important Value (IV). At Site-1 in Upper Kurram, the *Parthenium-Dichanthum-Cynodon* (PDC) community was identified. Lower altitudes, with warmer temperatures, higher moisture, and more fertile soil, provide favorable conditions for *Parthenium* growth. Human activities like agriculture further disturb the soil, aiding its spread. In contrast, higher altitudes face more competition from other plants, and *Parthenium* struggles due to cooler temperatures, harsher conditions, and potential genetic limitations. Additionally, rainwater can transport *Parthenium* seeds from higher to lower elevations.

The main road connecting District Kurram to Peshawar plays a crucial role in the spread of *Parthenium hysterophorus* seeds to Upper Kurram. The road between Upper and Lower Kurram is heavily infested with this weed, suggesting that the Lower Kurram Road is the likely starting point for *Parthenium* invasion along the Upper Kurram Road. Previous studies have shown that roadsides serve as key pathways for the spread of *Parthenium* and other invasive species (Thapa *et al.,* 2018; Ojija and Manyanza, 2021). Our study found that *Xanthium strumarium* and *Tagetes minuta* were common in several areas, particularly along roadsides, wastelands, and agricultural fields in Upper Kurram. These plants produce light seeds easily dispersed by the wind and have thorny parts that cling to clothes and animal fur, further aiding their spread. Similar to our findings, Murona *et al.* (2018) reported that *Xanthium strumarium* and *Tagetes minuta* were dominant herbaceous species in many sampling sites, likely due to their competitive nature and effective seed dispersal mechanisms. At Site II in Central Kurram, we identified the *Parthenium-Cynodon-Xanthium* (PCX) community to track the spread of *Parthenium hysterophorus*. Our observations show that *Parthenium* is primarily invading roadsides and wastelands, with higher concentrations at lower elevations despite the region’s overall higher altitude. The weed's prevalence decreases as altitude increases, a trend also observed by (Lazaro and& Ervin,2019 and Kumar et al.,2022) who found *Parthenium* predominantly in lower-altitude areas. Similarly, at Site III in Lower

Kurram, a *Parthenium-Cynodon-Taraxacum* (PCT) community was documented, where *Parthenium* is more widespread. Originating in Lower Kurram, it has spread to croplands, roads, residential areas, and riverbanks, negatively affecting crops and contributing to skin diseases in the local population (Lalita and Kumar, 2018). Sharma and Kumawat, (2023) highlighted the harmful allelopathic effects of *Parthenium* chemicals like hysterin and hymenin. In Shurku Valley, *Parthenium* is suppressed by *Heteropogon contortus*, while *Prosopis juliflora* helps control its spread along Lower Kurram's main road.

In our study area, the soil was mainly sandy loam and silty loam with a pH of 7.10 to 7.15. Organic matter ranged from 1.93 to 3.17%, while electrical conductivity (EC) was between 0.25 and 0.34 dSm-1. Nitrogen levels varied from 0.15 to 0.21%, phosphorus from 1.99 to 7.50 mg/kg, and potassium from 105 to 131 mg/kg. Zinc ranged from 1.11 to 9.83 mg/kg, copper from 5.64 to 6.05 mg/kg, iron from 20.56 to 39.13 mg/kg, and manganese from 4.39 to 6.80 mg/kg. Our findings suggest that *Parthenium* weed may be associated with specific soil properties such as pH, EC, nitrogen, phosphorus, potassium, zinc, iron, copper, organic matter, and manganese, consistent with earlier studies (Etana *et al.,* 2015; Osunkoya *et al.,* 2017). Similar results were noted by (Lalita and Kumar,2018) who reported *Parthenium* favoring sandy loam soils with pH between 5.4 and 7.4, and high organic matter and nutrient content. (Bashar et al.,2021) found higher nutrient levels in invaded soils, although zinc levels were lower.

The spread of *Parthenium hysterophorus* has been driven by a lack of public awareness, and without prompt action, it could spread further. (Bajwa *et al.*,2019) highlighted the importance of public awareness for managing invasive species. To address this, we organized a seminar in District Kurram, KPK, Pakistan, to raise awareness about the weed's impact on plants, animals, and human health. We also held community sessions to educate locals on the dangers of *Parthenium* and its environmental effects.

For controlling its spread in District Kurram, we applied various management strategies. Our findings indicated that while herbicide use had little effect on *Parthenium* populations, a declining trend suggested possible glyphosate resistance. Similar studies Odero 2012 reported glyphosate resistance, while other herbicides such as atrazine, metribuzin, bromoxynil, and Gramaxone proved effective (Natukunda *et al.,* 2020; Dukpa *et al.,* 2020). Khan *et al.*,2012 emphasized the importance of applying herbicides at the right growth stage, especially during the rosette stage.

Additionally, the high cost of glyphosate poses challenges for local farmers. In contrast, the use of urea fertilizer was highly effective; applying a urea solution during the early flowering stage caused complete wilting and death of the plants. (Million *et al.*,2021) found that combining glyphosate with urea and salt solutions also controlled Parthenium at the 4–6 leaf stage in non-cropped areas. Salt solutions have shown efficacy as well, but they can harm neighboring plants. Therefore, while urea offers a more favorable alternative, educating local residents on its balanced application is crucial for effective weed control and protecting surrounding vegetation.

Effective removal of *Parthenium* requires uprooting the plants during the early rosette stage, preferably when the soil is wet, to reduce health risks. Protective gear should be worn to avoid allergic reactions. However, hand-pulling can be ineffective if the soil is dry, as the root system may remain, leading to regrowth. Studies by (Natukunda *et al.*,2020) suggest uprooting before flowering to prevent new shoots, though this increases the risk of dermatitis. Slashing can help control *Parthenium* by preventing seed production and weakening roots, but it may not stop regrowth as remaining roots can survive. Burning, although sometimes used, is not effective for *Parthenium*. It requires significant fuel, can damage surrounding plants, and may harm soil and air quality (Sharma and Kumawat, 2023).

CONCLUSION AND RECOMMENDATION

Parthenium hysterophorus is rapidly spreading in District Kurram, especially in Lower Kurram, where it invades roadsides, wastelands, and agricultural fields. This invasive weed poses a serious threat to ecosystems, reduces crop yields, limits fodder availability, harms biodiversity, and causes health issues for both humans and animals. Its ability to rapidly produce seeds and adapt to various conditions makes it difficult to control, with roads and disturbed soils aiding its spread. Immediate action is required to manage its growth, particularly along key routes, to safeguard native plants and agricultural productivity. Raising public awareness and fostering collaboration between policymakers and researchers are essential for effective control.

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REFERENCES

Abbas, W., W. Hussain, L. Badshah, K. Hussain and A. Pieroni(2020). Traditional wild vegetables gathered by four religious groups in Kurram District, Khyber Pakhtunkhwa, North-West Pakistan. *Genetic Resources and Crop Evolution.* 67:1521-36.

Adhikari, P., Y.H. Lee, A. Poudel, G. Lee, S.H. Hong and Y.S. Park (2023). Predicting the Impact of Climate Change on the Habitat Distribution of *Parthenium hysterophorus* around the World and in South Korea. Biology. 12(1): 84-95.

Adnan, M., M.S. Hayyat, Q. Mumtaz, M.E. Safdar, F. Rehman, H. Ilahi and K. Tampubolon(2021). Improving the management of *Parthenium hysterophorus* to enhance okra production through the application of chemicals, adjuvants and plant extract blends in Pakistan. *Journal of Sustainable Agriculture.* 36(1): 165-174.

Afzal, I., M. Akram, T. Javed, F. Ali, H.M. Kalaji, J. Wróbel and M.A. Ahmed(2022). Quantifying the germination response of *Parthenium hysterop horus* at various temperatures and water potentials by using population-based threshold model. *Frontiers in Plant Science.* 13: 1-10.

Ali, M., Z. Huang, Y. Bai, D.Y.P. Tng, F. Qin and Z. Fang(2024). A multifaceted approach to expanding conservation efforts in the Pan-Himalayan landscape. *Journal of Cleaner Production*.476: https://doi.org/10.1016/j.jclepro.2024.143783.

Ali, M., P. Yar, S. Khan, S. Muhammad, W. Hussain, K. Hussain and R.W. Bussmann(2022). Land use and land cover modification and its impact on biodiversity and the ecosystem services in District Kurram, Pakistan. *Boletín Latinoamericano y del Caribe de Plantas Medicinales y Aromáticas.* 21: 365-388.

Ali, A., L. Badshah and F. Hussain(2018). Vegetation structure and threats to montane temperate ecosystems in Hindukush range, Swat, Pakistan. *Applied Ecology & Environmental Research.* 16(4): 4789-4811.

Ali, S. and I.A. Khan(2017). Distribution of *Parthenium hysterophorus* (L.) in the Swabi

District of Khyber Pakhtunkhwa. *Sarhad Journal of Agriculture*. 33(2): 269-275.

Bajwa, A.A., M. Farooq, A. Nawaz, L. Yadav, B.S. Chauhan and S. Adkins(2019). Impact of invasive plant species on the livelihoods of farming households: evidence from *Parthenium hysterophorus* invasion in rural Punjab, Pakistan. *Biological Invasions* 21: 3285-3304.

Bashar, H.M.K., A.S. Juraimi, M. S. Ahmad-Hamdani, M. K. Uddin, N. Asib, M.P. Anwar and A. Hussain(2023). Evaluation of allelopathic effects of *Parthenium hysterophorus* L. Methanolic extracts on some selected plants and weeds. *Plos one*. 18: 0280159.

Bashar, H.M.K., A.S. Juraimi, M.S. Ahmad-Hamdani, M.K. Uddin,N. Asib, M.P. Anwar and F. Rahaman(2021). A Mystic Weed, *Parthenium hysterophorus L*: Threats, Potentials and Management. *Agronomy*. 11(8): 2-21.

Boja, M., Z. Girma and G. Dalle(2022). Impacts of *Parthenium hysterophorus* L. On Plant Species Diversity in Ginir District, Southeastern Ethiopia. *Diversity*. 14(8): 2-21.

Costello, B., O.O. Osunkoya, J. Sandino, W. Marinic, P. Trotter, B. Shi and K. Dhileepan(2022). Detection of *Parthenium* Weed (*Parthenium hysterophorus* L.) And Its Growth Stages Using Artificial Intelligence. *Agriculture*. 12: 11-38.

Dukpa, R., A. Tiwari and D. Kapoor(2020). Biological management of allelopathic plant *Parthenium* sp. *Open Agriculture*. 5: 252-261.

Etana, A., E. Kelbessa and T. Soromessa(2015). Impact of *Parthenium hysterophorus* L. (Asteraceae) on soil chemical properties and its distribution in a reserve area: A case study in Awash National Park (ANP), *Ethiopia. Journal of Soil Science and Environmental Management*. 6(5): 116-124.

Haq, A. and L. Badshah(2021). The structure of threatened vegetation in the montane temperate ecosystem of Pashat Valley, Pak-Afghan Border, Hindukush Range, Bajaur, Pakistan. *Applied Ecology and Environmental Research*. 19(5): 3579-3600.

Hussain, W., L. Badshah, M. Ullah, M. Ali, A. Ali and F. Hussain(2018). Quantitative study of medicinal plants used by the communities residing in Koh-e-Safaid Range, northern Pakistani-Afghan borders. *Journal of Ethnobiology and Ethnomedicine*. 14: 1-18.

Hussain, W., J. Hussain, R. Ali, I. Khan, Z.K. Shinwari and I.A. Nascimento(2012). Tradable and conservation status of medicinal plants of Kurram Valley. Parachinar, Pakistan. *Journal of Applied Pharmacological Science*. 2(10): 66-70.

Hussain, S.T., S. Muhammad, S. Khan, W. Hussain and A. Pieroni(2023). Ethnobotany for food security and ecological transition: wild food plant gathering and consumption among four cultural groups in Kurram District, NW Pakistan. *Journal of Ethnobiology and Ethnomedicine*. 19: 1-15.

Hussain, S., W. Hussain, A. Nawaz, L. Badshah, A. Ali, S. Ullah and R.W. Bussmann(2022). Quantitative ethnomedicinal study of indigenous knowledge on medicinal plants used by the tribal communities of Central Kurram, Khyber Pakhtunkhwa, Pakistan. *Ethnobotany Research and Applications*. 23: 1-31.

Hussain, W., W. Abbas and A. Pieroni(2023). Exercising ethnobiological resilience in turbulent times and places: in memoriam Sayed Hussain. *Journal of Ethnobiology and Ethnomedicine*. 19: 1- 23.

Hussain, W., L. Badshah, A. Ali and F. Hussain(2019). Quantitative aspects of the Koh-e-Safaid Range vegatation across the altitudinal gradient in Upper Kurram

Valley, Pakistan. *Applied Ecology and Environmental Research***.** 17: 9905-9924.

Ilyas, M., R. Qureshi, N. Akhtar, M.K.A Ziaul-Haq and A.M. Khan(2018). Floristic diversity and vegetation structure of the remnant subtropical broad leaved forests from Kabal valley, Swat, Pakistan. *Pakistan Journal Botany*. 50(1): 217-230.

Iqbal, J., A.A. Khan, T. Aziz, W. Ali, S. Ahmad, S.U. Rahman and M. Alhomrani(2022). Phytochemical investigation, antioxidant properties and in vivo evaluation of the toxic effects of *Parthenium hysterophorus*. *Molecules*. 27(13): 1-12.

Jaiswal, J., P.K. Doharey, R. Singh, P. Tiwari, N. Singh, A. Kumar and B. Sharma(2022). Biochemical characterization of different chemical components of Parthenium hysterophorus and their therapeutic potential against HIV-1 RT and microbial growth. *Biomed Research International*. 28: 1-21.

Khan, H., K.B. Marwat, G. Hassan and M.A. Khan(2012). Chemical control of *Parthenium hysterophorus* L. at different growth stages in non-cropped area. *Pakistan Journal of Botany.* 44(5): 1721-1726.

Khan, N., K. Bibi and R. Ullah(2020). Distribution pattern and ecological determinants of an invasive plant *Parthenium hysteroph*orus L., in Malakand division of Pakistan. *Journal of Mountain Science***.** 17: 1670-1683.

Khan, N., A. D. Shabbir, D. George, G. Hassan and S.W. Adkins(2014). Suppressive fodder plants as part of an integrated management program for *Parthenium hysterophorus* L. Field Crops Research 156: 172-179.

Khan, N., R. Ullah, M.K. Okla, M.A. Abdel-Maksoud, I.A. Saleh, H.A. Abu-Harirah and H. abdelgawad(2023). Spatial distribution of the four invasive plants and their impact on natural communities' dynamics across the arid and semi-arid environments in northwest Pakistan. *Frontiers in Plant Scienc.e* 14: 1-17.

Khan, W.A. and O.P. Gurjar(2023). *Parthenium hysterophorus* (Congress grass) a unwanted plant and its uses. *South Asian Journal of Agricultural Science*. 3(1)**:** 01-07

Kumar, V., B.S. Bisht, R. Ballabha, P. Bachhwan and A. Rani(2022). Infestation of Weed Vegetation *Parthenium hysterophorus* L. In Tehri Garhwal Himalaya, Uttarakhand, India. *Journal of Mountain Research*. 17(1): 105-117.

Kumawat, A(2023). Health hazards of *Parthenium hysterophorus* l. And its managements. *Life sciences leaflets*. 157: 20-30.

Lalita, A. and P. Kumar. (2018). Review on a weed *Parthenium Hysterophorus* (L.).International *Journal of Cureent Reseach Review*.10: 2231-2196.

Lázaro-Lobo, A. and G.N. Ervin. (2019). A global examination on the differential impacts of roadsides on native vs. Exotic and weedy plant species. *Global Ecology and Conservation.* 17: 1-13.

Masum, S.M., A. Halim, M.S.H. Mandal, M. Asaduzzaman and S. Adkins(2022). Predicting Current and Future Potential Distributions of *Parthenium hysterophorus* in Bangladesh Using Maximum Entropy Ecological Niche Modelling. *Agronomy*. 12(7): 1-19.

Million, D., L. Nigatu, Z. Bekeko and H. Legesse(2021). Integrated management of *Parthenium* (*Parthenium hysterophorus* L.) And its effect on yield components and yield of maize (*Zea mays* L.) In West Gojjam Zone, Amhara National Regional State, Ethiopia. *Weed Biology and Management.* 21: 100-112.

Murono, D.A., E. Wabuyele, P.K. Muoria and J.O. Abuto(2018). Distribution of *Parthenium* *hysterophorus* L. In and its Impacts on Biodiversity in Nyando Sub-County, Kisumu County, Kenya. *European Academic Research.* 6(4): 1599-1621.

Mutua, B.M., W. Chiuri, V. Ngure and V. Kimani(2022). Distribution of *parthenium* weed (*Parthenium hysterophorus* L.) in Nakuru County, Kenya. *Journal of Environmental Sciences and Technology*. 1: 48-57.

Natukunda, M.I., K. Natukunda, G. Kyeyune, S.M. Tusiime, I. Agbemafle and J. Bisikwa(2020). Management strategies for the noxious invasive *Parthenium* weed (*Parthenium hysterophorus* L.) In Uganda. *African Journal of Agricultural Research*. 15(1): 1-9.

Oduor, A.M. (2021). Native plant species show evolutionary responses to invasion by *Parthenium hysterophorus* L. in an African savanna. *New Phytologist. 2*: 983-994.

Osunkoya, O.O., O.A. Akinsanmi, L.S. Lim, C. Perrett, J. Callander and K. Dhileepan(2017). *Parthenium hysterophorus* L. (Asteraceae) invasion had limited impact on major soil nutrients and enzyme activity: Is the null effect real or reflects data insensitivity? *Plant and soil* .420: 177-194.

Qureshi, H., M. Arshad, Y. Bibi, O.O. Olukoya and S.W. Adkins(2018). Multivariate impact analysis of *Parthenium hysterophorus* L. Invasion on above-ground plant diversity of Pothwar region of Pakistan. *Applied Ecology and Environmental Research*. 16(5): 5799-5813.

Riaz, T. and A. Javaid(2012). Invasion of *Parthenium hysterophorus* L. In district Nankana Sahib, Pakistan. *Pakistan Journal of Science*. 64: 80-94.

Shah, S. M., W. Hussain, I. Hussain, A. Ali, N. Ali, F. Ali, A. U. Haq and R..W. Bussmann(2025). Phytoecological study of threatened plant communities along the durand line at Shurku valley, district lower Kurram, Khyber Pakhtunkhwa, Pakistan. *Frostiest* .04: 1-13.

Sharma, S. K., S. Dash, P. Shukla, R. Gupta, U. Sami, S. Sharma and S. Dash(2023). A Survey-Based Assessment of Awareness Regarding Parthenium hysterophorus in a Rural Population of North India. *Cureus*. 15(7): 1-7

Thapa, S., V. Chitale, S.J. Rijal, N. Bisht and B.B. Shrestha(2018). Understanding the dynamics in distribution of invasive alien plant species under predicted climate change in Western Himalaya. *Plos one*. 13: 10-37.

Zareen, S., N.M. Khan and S. Rahman(2021). Distributions of invasive weed *Parthenium* (*Parthenium hysterophorus* L.) In the University campus Peshawar KPK.. *Acta Ecologica Sinica*. 41: 10-17.