

# A Review on Some Ecological Aspects of Invasive Flora Based on Comparative Analysis of “Tehri” and “Pauri” Garhwal, Uttarakhand, India

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## ABSTRACT

The establishment of invasive plants in a particular area leads to significant ecological changes on the native species of that area, alters ecosystem services and is one of the major drivers of biodiversity loss. In recent years, invasion by alien plants in the hilly regions has posed a severe threat to the ecosystem of these areas. A review was made in this context to study the Invasive Alien Plant Species (IAPS) of “Tehri” and “Pauri” districts. Large number of invasive alien plants was identified under different genera and families from both the study areas. Based on the growth form of invasive plants, herbs contributed the maximum percentage. Asteraceae was found to be dominating over other families followed by Solanaceae. The native range indicated differences in nativity of invasive flora found in Tehri and Pauri with a large percentage of invasive plants coming from Asia (23%) and Tropical America (26%) and respectively. It was observed that invasive plants are invading higher elevation zones which parallels with the directional filtering theory. Due to higher proliferation rates outside their native range and absence of natural predators, it is quite difficult to control this increasing expansion of invasive plants which is a call for concern and needs immediate attention.

**Keywords:** Invasive alien plant species (IAPS), Ecosystem services, Native species, Biodiversity, Directional filtering

## INTRODUCTION

India is known as one of the mega-diversity countries in the world. Scientists from India and other countries have come up with an inventory of alien plants which were introduced in South Asian countries and have over the years become invasive. About 40% of Indian flora is alien, out of which 25% are Invasive Alien Species (IAS) <sup>[1]</sup>.

Invasive plants are those species that occur outside their natural adapted ranges and threaten areas where they are introduced intentionally or unintentionally. These are the agents that lead to changes in the biological diversity. They express the capability to invade and out-compete the native species. They cause loss of biodiversity including species extinctions, changes in ecosystem functions and act as serious hindrance in biodiversity conservation. Generally invasive alien plants proliferate along way sides or open forest cover areas or boundaries in the Indian Himalayan Region.

Alien plants that become invasive possess certain characteristics that favours them to get advantage over the native biota. They survive in a wide range of ecological requirements often covering large geographical range <sup>[2]</sup>. Studies from the past

introductions demonstrate that the effects of invasive plant species are complex and can permanently alter the structure of communities [3].

The invasive alien plant species (IAPS) have posed severe threats to the local biodiversity, human health, environmental quality and ecosystem services [4]. Their effect on native plants is mostly negative resulting in loss of native plant diversity. They act as weeds resulting in a decrease of agricultural productivity, loss of nutrients and also hamper the forests diversity. Following invasions agriculture, water sanitation, human-health and food security are all adversely affected.

Studies have shown that due to the growth and development of invasive plants, genetic variation occurs in regional populations and obstructions have been observed in plant pollination interaction [5].

Invasive plants have faster growth rates, short life cycles, higher reproductive potential, high competitive abilities and allelopathy which make them successful invaders of native habit [6]. Many invasive species once they become dominant in the area become essential to the ecosystem of that area. Although generally invasive species are harmful but sometimes they are beneficial too. They provide a suitable habitat or food source for other organisms. They may be beneficial from medicinal point of view. The areas where native species has become extinct, invasive species fill their role to increase the biodiversity in an ecosystem. Many invasive species also support forestry and farming.

The first ever inventory on invasive alien plant species of India was compiled of which total 173 invasive alien plants species belonging to 117 genera under 44 families were documented. The IAS flora of India has recorded the highest number of species from family Asteraceae [7].

A total of 163 invasive alien species under 105 genera, belonging to 46 families have been recorded in Uttarakhand based on field observations, herbarium and literature consultations. Distributions based on habitat

have shown that maximum numbers of species are found in wastelands, followed by cultivated fields, along road sides and forests [8].

The Uttarakhand state is divided into two divisions, Garhwal and Kumaun, with a total of 13 districts. Kumaun Himalayan region of Uttarakhand revealed the presence of 48 invasive plants species belonging to 25 families which were used by locals for curing various kinds of ailments [9].

#### **DATA SOURCES**

A number of literatures available on the diversity of invasive alien plant species were studied and relevant data was thereof compiled. During the review of literature, it was felt that since alien plants are becoming more and more invasive and have even acquired the hilly regions, there is a need to tackle this ongoing problem of biological invasion before it becomes a serious concern for not only the native plants but also the biodiversity as a whole.

In present context a review on the diversity of alien invasive plants was felt that could add more knowledge base to this area of research along with other objectives such as the expansion of invasive plants to higher elevation zones.

Keeping in mind the above perspectives, the studies in Tehri and Pauri have been reviewed by many authors [10, 11] on the following aspects:

- Invasive alien plants distribution in Tehri and Pauri Garhwal districts of Uttarakhand Himalaya
- Studying growth form and families of invasive flora
- Native range studies of alien plants
- Studying diversity patterns
- Identifying factors that lead to variation among invasive flora diversification in both districts

#### **RESULT AND DISCUSSION**

Invasive plant species are a major threat to native plants affecting their growth and depriving them of essential nutrients. Due to their high seed production capacity,

adaptations to wide variety of climates and absence of natural predator, the control of alien plant species has always been challenging. In this review, an analysis of some ecological aspects of invasive alien plant species was done taking references from studies conducted in Tehri and Pauri districts of Uttarakhand, India.

### IAPS Distribution

A total of 75 Forest Invasive Species (FIS) from Tehri District of Garhwal Himalaya, Uttarakhand were identified as invasive through extensive field survey and Quadrat method <sup>[10]</sup>. Among the 75 species, 12 invasive plant species belonging to family Asteraceae, 7 from Poaceae and Solanaceae each, 5 of Lamiaceae, followed by 4 species each of Ranunculaceae and Polygonaceae while the other belonging to Papilionaceae, Cyperaceae, Euphorbiaceae and various other angiospermic families were recorded.

A total of 82 plant species under 72 genera, belonging to 39 families are identified as alien plant species from Pauri Garhwal district of Uttarakhand <sup>[11]</sup>. The dicots and monocots were represented by 37 families and 2 families respectively. Maximum genera in the study area belongs to family Asteraceae (18 genera), Fabaceae and Rosaceae (4 invasive genera) while Amaranthaceae, Euphorbiaceae, Lamiaceae and Solanaceae each with 3 invasive genera, family Cannabaceae, Lauraceae and Mimosaceae comprised 2 genera each and 29 genera with single exotic species.

**Table 1: Invasive alien plants distribution study from Tehri and Pauri districts**

Distribution areas	Total number of IAPS identified
Tehri district	75
Pauri district	82
<b>Total</b>	<b>157</b>

Invasive plants propagate in a variety of ways and their dispersal mechanism is also vast. In the last few years alien plants have managed to acquire hilly areas leading to severe economic losses posing a threat to the ecosystem of these areas. These species

have managed to gain entry in higher elevation zones with a continuous outspread to newer areas. Their accelerated growth in higher altitudes results in the displacement of the native plants of those areas simultaneously affecting soil quality and climate change. Mountainous regions such as Tehri and Pauri Garhwal have also seen this aggressive growth of IAPS.

Invasive plants are generalists that can thrive well in wide range of environmental conditions. It is generally accepted that diversity patterns have been associated with ecological processes, evolutionary history and environmental factors <sup>[12]</sup>. At regional or local scales, climate, soil type and topography play more important roles in diversity distributions compared to other environmental factors <sup>[13]</sup>.

A total of 157 invasive alien plants from Tehri and Pauri were identified which is a huge number and proves how a large number of alien plants have invaded hilly areas in recent years. Number of invasive species found in Tehri and Pauri are more or less similar (75 and 82 respectively) which proves that the environmental conditions for introduction of invasive alien plants are equally same for both the districts.

Directional Ecological Filtering Hypothesis (DEFH) suggests that only species with broad environmental tolerances will successfully spread from lowlands (where most introductions occur) to high elevations <sup>[14]</sup>. The Directional Ecological Filtering Hypothesis proposes that alien species richness patterns along abiotic gradients are a result of the sequential filtering of species with progressively broader climatic niches along a gradient of increasing environmental severity.

A study conducted around Pantnagar in 2015 revealed the presence of 94 invasive alien species under 72 genera, belonging to 33 families <sup>[15]</sup>. Pantnagar, Uttarakhand located at a lower altitude has more number of invasive plants as compared to higher altitudinal zones such as Tehri and Pauri. This comparison is in accordance with the Directional Ecological Filtering Hypothesis

and shows invasive plants are generalist which can thrive well in a wide range of environmental conditions.

### IAPS Habit (Growth forms)

Habit analysis of Tehri district showed that highest percentage of invasive plant diversity was of herbs (81.33%), shrubs (17.33 %) and tree species (1.34%). Herbs has shorter life cycle which makes their proliferation easier as compared to shrubs

and trees which is one of the reasons for their large percentage cover as invasive plants in both the districts.

Herbs, shrubs and trees may have equal chances of dispersal to non-native lands but since herbs have shortest life cycle their further proliferation in non-native lands is easier<sup>[15]</sup>. This is one of the reasons for their large percentage as invasive species in both Tehri and Pauri district.

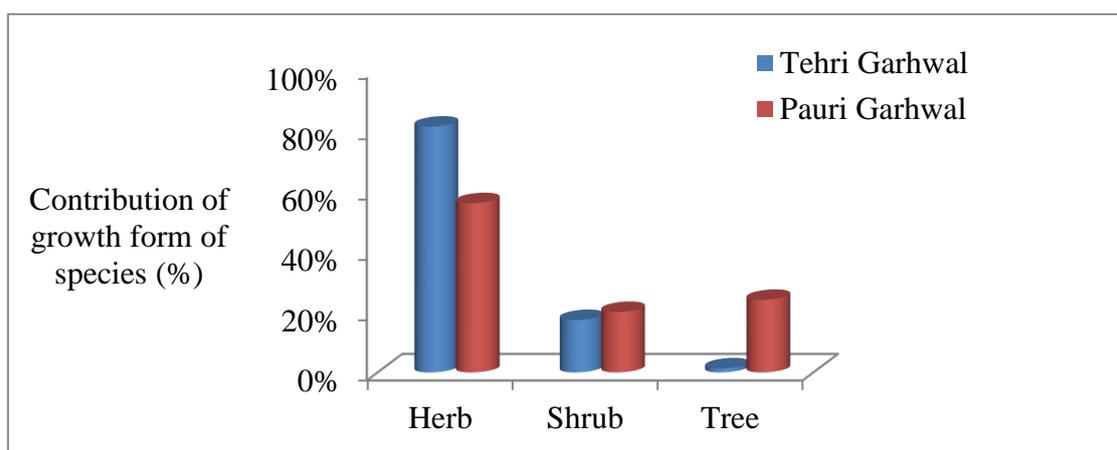


Figure 1: Comparative analysis of habit of IAPS found in "Tehri" and "Pauri" Garhwal districts.

The study from the Pauri region revealed that maximum number of exotic species contribution comes from herbs (56%), followed by shrubs (20%) and trees (24%). But the shrub and tree percentage is contradictory for both regions. In Tehri, shrubs are more than trees vice versa in Pauri. The reason for this difference could be attributed to the variability in environmental factors such as precipitation, humidity, wind velocity and soil. Tehri receives about 155.42 mm of precipitation that is lower than Pauri district (172.88 mm). In addition to this, Tehri has a comparatively drier climate while Pauri is humid. Loamy soil found in Pauri district might also contribute for its successful invasive tree species count.

### IAPS Families

The study in 2017 from Tehri Garhwal revealed among the 75 FIS reported 12 species belong to family Asteraceae (16 %) ranking it as the dominant family followed

by Poaceae and Solanaceae (7 species each) (9 % each), Lamiaceae (5 species) (7%), Polygonaceae and Ranunculaceae (4 species each) (5% each), Cyperaceae, Euphorbiaceae, Fabaceae and Rosaceae with 3 species each, Amaranthaceae, Apiaceae, Malvaceae, Oxalidaceae, Rubiaceae with 2 species each and rest 14 families with 1 species each<sup>[10]</sup>.

The study conducted in 2022 from Pauri Garhwal revealed the dominance of family Asteraceae (19 species; 23%, followed by Solanaceae (7 species; 8%), Rosaceae (5 species; 6%), Euphorbiaceae, Amaranthaceae, Fabaceae, Lamiaceae (4 species; each 5%), Cannabaceae and Lauraceae (2 species; each 2%). Rest of the 29 families is represented by only single exotic species (1% each)<sup>[11]</sup>.

From the above description of IAPS distribution, it is evident that in both districts, family Asteraceae dominates over other family which is followed by

Solanaceae. Rest all other families have different percent of dominance and no specific pattern is visualized for the two districts as Lamiaceae is the third highest in

the Tehri region (7%) whereas Rosaceae takes the spot in Pauri district with 6% abundance.

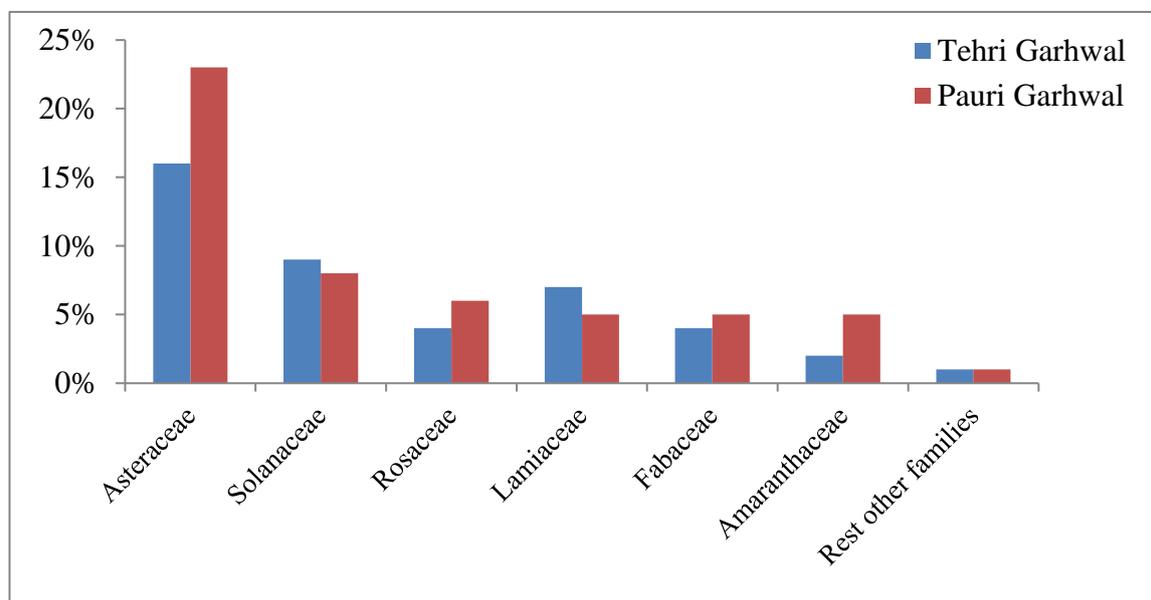


Figure 2: Figure shows comparative analysis of IAPS families found in "Tehri" and "Pauri" Garhwal districts.

Asteraceae is the largest family under Angiosperms which in itself proves as to why they are the foremost invasive family and have surpassed other invasive families in these areas.

The dominance of family Asteraceae in both districts may be attributed to its prolific seed production and efficient seed dispersal mechanism [15]. Invasive plants belonging to family Asteraceae thrive well in disturbed habitats. Their ability to survive in a wide range of conditions gives them the opportunity to quickly invade and displace native species which makes them one of the paramount invasive families.

The predominance of Asteraceae species in invasive category shows the high impact of Neotropical flora on Indian region [7] as for instance, species of *Ageratina* are found to occur in both the districts which is of Neotropical origin.

Following Asteraceae, Solanaceae is the second largest invasive family common to both districts. Members of family

Solanaceae are widely distributed to tropical region which is one of the most common native ranges of alien plants as invasive plants from Tropical America are found in both Tehri (9%) and Pauri (26%) districts.

Due to a great diversity in habitat and ecology, both Asteraceae and Solanaceae are capable of invading non-native regions which provides a substantial basis of evidence for their invasions in Tehri and Pauri Garhwal compared to other invasive families.

#### Native range

Our studies from both these data's concluded that due to a large number of invasive plants being different to both districts, the native range of invasive plants varied a lot in general.

Pauri Garhwal has a sub-tropical to temperate climate which favors the growth of tropical American invasive plants as these plants have found climatic conditions similar to their native habitats [15].

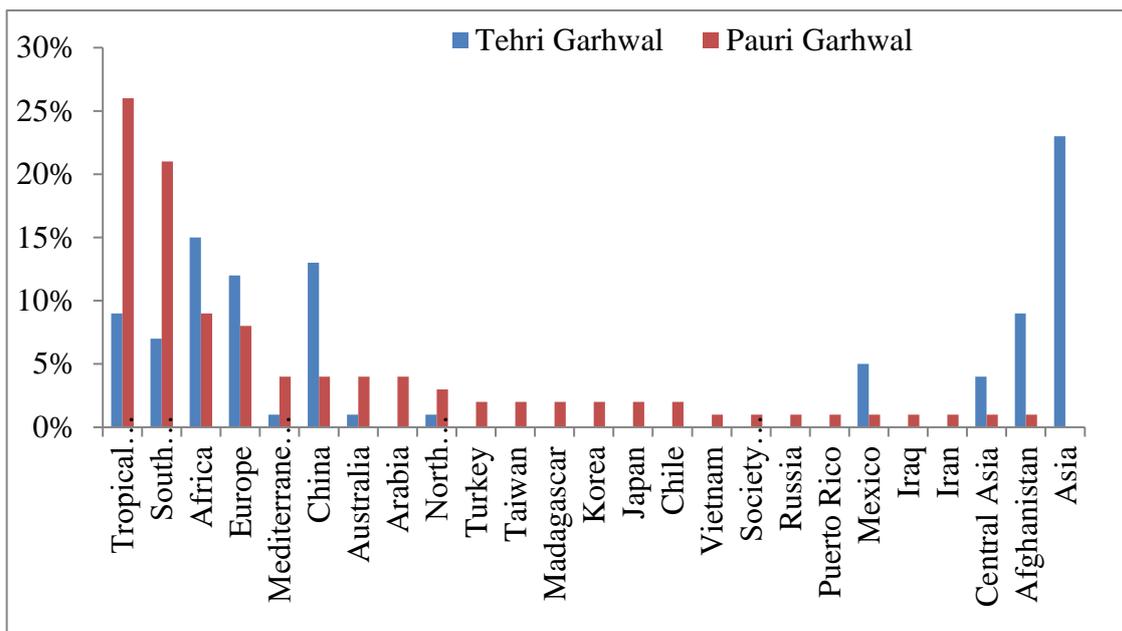


Figure 3: Figure shows the comparative analysis of native range of IAPS found in “Tehri” and “Pauri” Garhwal districts.

Disturbed and unfit ecosystems are prone to biological invasions. Disturbances caused by human activities in mountainous regions gives access to invasive alien plant species which have now occupied the roadside habitat and in near future might invade forested regions. This is one of the reasons as to why these plants have spread so easily across Tehri and Pauri districts.

Invasive alien plants such as *Bidens pilosa* and *Parthenium hysterophorus* have been found to be rapidly invading hilly areas especially along roadsides. *Ageratina adenophora* and *Lantana camara* have already invaded some forests of Uttarakhand. These plants can tolerate a wide range of environmental condition which helps them to proliferate outside their adapted native range easily as seen in Tehri and Pauri districts where the native range of maximum invasive plants comes from Asia (23%) and Tropical America (26%) respectively.

Invasive alien plants such as *Argemone mexicana* and *Nicotiana plumbaginifolia* found in Tehri, and *Peperomia schizandra*, *Stachys melissifolia* and *Stachys sericea* found in Pauri belong to neotropics which

testifies for Neotropical invasions in these regions.

There are various pathways through which invasive alien plants get introduced to new habitats. Both natural dispersal and anthropogenic assistance helps in their introductions after which they get established in newer habitat often displacing the native species and acting as a menace to the ecosystem.

Invasive plants generally align with the fast side of the plant’s trait economic spectrum, characterized by fast nutrient acquisition, growth and reproduction [16]. These plants grow rapidly which is why the current control measures are not enough to cease their increasing expansion to higher altitudinal regions. In recent years, hilly areas have been prone to human disturbances which give alien plants a means of entry in these ecosystems.

Rising temperature is the primary element driving the distribution limit of invasive alien species into higher latitudes, as well as greater altitudes [17]. The spatial scale projected by a model developed in 2011 showed that *Parthenium* weed still has the potential to expand its invasion territory [18]. Under future climate, more temperate and

higher elevation regions may come under substantial threat from *Parthenium* weed establishment [19]. This shows how invasive plants are expanding their geographic native range which is leading to their invasions in higher elevation zones.

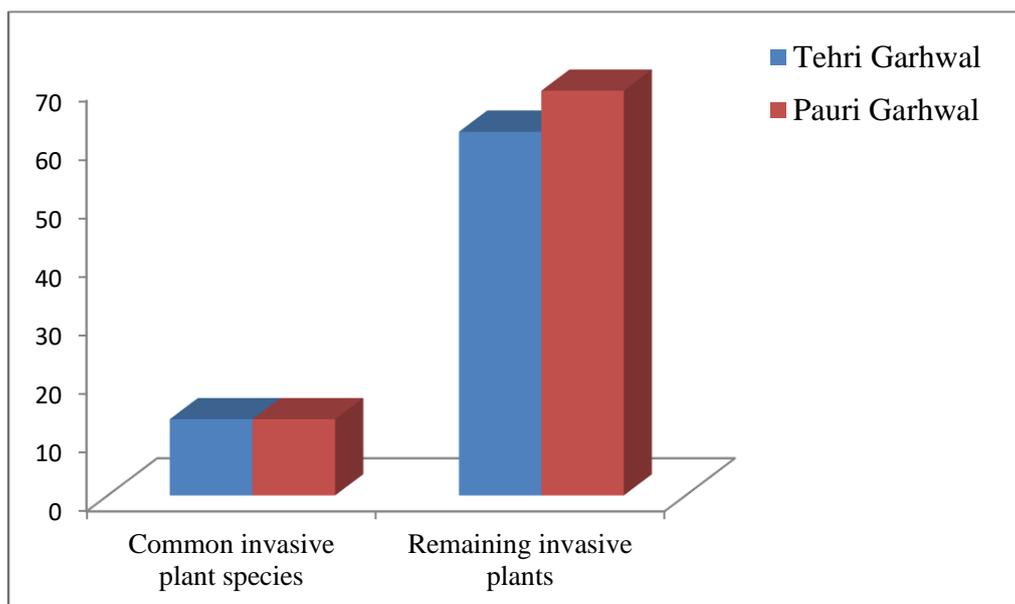
### IAPS Diversity

The study from Tehri Garhwal in 2017 and from Pauri Garhwal in 2022 reported the presence of 75 and 82 invasive plants respectively. It may be due to Tehri Garhwal region which extends from 30°55′ to 31°18′ North latitude and 78° to 79°25′ East longitude in Western Himalaya is highly mountainous, ranging in altitude

from 300 masl to 7000 masl. It has a humid subtropical, dry winter climate with the yearly average temperature being 19.96° C. While Pauri Garhwal district lies in the subtropical to temperate zone between the altitudes 800 masl to 3100 masl that extends between 29°45′ to 30° North latitude and 78°24′ to 79°23′ East longitude [10, 11]. This shows both districts have almost similar latitudinal and longitudinal ranges, more or less similar climatic conditions so the vegetation pattern and distribution of species could be the same as seen in the case of 13 invasive floras which are common to both districts.

**Table 2: Common IAPS found in “Tehri” and “Pauri” Garhwal mentioned along with their growth form and family.**

S.No.	Botanical Name	Growth form	Family
1.	<i>Ageratum conyzoides</i> L.	Herb	Asteraceae
2.	<i>Amaranthus spinosus</i> L.	Herb	Amaranthaceae
3.	<i>Cannabis sativa</i> L.	Shrub	Cannabinaceae
4.	<i>Datura metel</i> L.	Shrub	Solanaceae
5.	<i>Desmodium triflorum</i> L.	Shrub	Fabaceae
6.	<i>Euphorbia hirta</i> L.	Herb	Euphorbiaceae
7.	<i>Lantana camara</i> L.	Shrub	Verbenaceae
8.	<i>Parthenium hysterophorus</i> L.	Herb	Asteraceae
9.	<i>Physalis peruviana</i> L.	Herb	Solanaceae
10.	<i>Sonchus oleraceus</i> L.	Herb	Asteraceae
11.	<i>Tridax procumbens</i> L.	Herb	Asteraceae
12.	<i>Urena lobata</i> L.	Shrub	Malvaceae
13.	<i>Xanthium strumarium</i> L.	Herb	Asteraceae



**Figure 4:** Figure shows common IAPS found in “Tehri” and “Pauri” Garhwal and the number of invasive plants that differ in both districts.

The soil of Tehri has a widely variable pH from acidic to slightly alkaline [20]. Soil of Pauri is slightly acidic, medium to high in organic carbon content with alluvial or sandy loamy soil being the most common.

Invasive alien plants such as *Ageratum conyzoides* L., *Desmodium triflorum* L., *Lantana camara* L., *Parthenium hysterophorus* L., *Physalis peruviana* L., and *Xanthium strumarium* L. can grow in a wide range of soil types such as acidic, alkaline, alluvial and sandy loam soil. This could be the rationale as to why these invasive plants are commonly found in both the districts.

Over the years, several studies have been performed in Uttarakhand which have addressed a notable rise in temperature due to climate changes in mountainous regions. Due to this, there has been an increase in temperature with an elevation in carbon dioxide levels which enhances plant growth. Both of these factors interact with water availability, increasing water use efficiency and shortening life cycle. The overall effect is an enhanced plant survival as seen in the case of *Parthenium* which is a potential invasive plant and is found to occur in both Tehri and Pauri Garhwal [21].

Tehri and Pauri both have sub-tropical climate which is suitable for the growth of *Lantana camara* and this aligns with its occurrence to both the districts. *Lantana camara* has flourished across these regions because of its wide dispersal range. Production of toxic chemicals by *Lantana* which inhibits the growth of native plant species, tolerance of a wide range of environmental conditions and an extremely high seed production capacity makes it a successful invasive alien plant. But a majority of invasive plants found in Tehri and Pauri Garhwal are distinct to both districts. Ecotypic differentiation which can occur over short distances such as along topographic or elevation gradients could be the reason for such large difference in alien plants distinction to Tehri and Pauri [22].

A major part of Tehri is covered by soils of Lesser Himalaya which is moderately

shallow, slightly stony, excessively drained and moderately eroded loamy soil whereas the soil type of Pauri is clayey loam in nature. Due to this variation in soil type, both districts have a marked majority of difference in invasive plant species composition [23].

## CONCLUSION

Increasing expansion of invasive flora to higher elevation gradients in recent years is becoming a serious concern and is altering the biodiversity of these regions. From the study it is evident that more number of invasive plants is reported from Pauri as compared to Tehri district which shows the gradual movement and an increase in number of invasive to higher altitudinal zones. Invasive flora such as *Ageratum conyzoides* L., *Amaranthus spinosus* L., *Cannabis sativa* L., *Datura metel* L., *Desmodium triflorum* L., *Euphorbia hirta* L., *Lantana camara* L., *Parthenium hysterophorus* L., *Physalis peruviana* L., *Sonchus oleraceus* L., *Tridax procumbens* L., *Urena lobata* L. and *Xanthium strumarium* L. have higher adaptation and resilience capacity than other invasive due to which they are common in both the districts. This aligns with the Directional Ecological Filtering Hypothesis which states the movement of invasive plants with wide environmental endurances to higher elevation zones. There is a need to identify those favorable conditions or factors which are leading to this shift. Although 13 IAPS are common to both study areas, a significant number of plant species are different despite the fact that both districts have almost similar climatic conditions. This variability could be attributed either to some ecological factors or probably due to the un-exploration of invasive plants during the study. This can be taken into consideration and further exploration of invasive alien plants species could be performed. Asteraceae has clearly established itself as the most successful invasive family. *Ageratina adenophora* has already invaded Pine and Oak forests along

with *Parthenium hysterophorus* acquiring the roadside areas. This indicates how this particular family has acclimatized itself in non-native ecosystems. In-depth studies could be performed for identifying those factors which are leading to their successful invasion so that control measures can be taken up to lower their expansion range.

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