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# Diversity and distribution of invasive alien plants along the altitudinal gradient in Darjiling Himalaya, India

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**Abstract**

A study was carried out to assess the phytosociology of the invasive alien plants along the altitudinal gradient in Darjiling Himalaya with information on family, growth form and nativity. A total of 66 invasive alien species belonging to 26 families have been recorded. The analysis revealed that most of the species were reported from American sub-continent. Majority of the species were found to be introduced unintentionally and the distribution was maximum towards the temperate zone. Proper management strategies are required to understand the invasion and colonization of these alien species in this region.

***Key words:*** Alien plants, Darjiling, Phytosociology, Impact

## INTRODUCTION

According to the International Union for Conservation of Nature and Natural Resources (IUCN), the invasive alien species (IAS) are the species which becomes established in natural or semi-natural ecosystems or habitat, an agent of change, and threatens to native biological diversity (IUCN 2000). These alien species are widely distributed among all categories of living organisms as well as all kind of ecosystems throughout the world. Alien species are exotic organisms those occur outside their natural adapted ranges and with high dispersal potential (Raghubanshi *et al* 2005). They are introduced species with high reproductive rates and have the potential to spread rapidly over large areas (Pysek *et al* 2004). The alien species becomes invasive when they are intentionally or unintentionally introduced outside from their natural habitats into new areas where they express their capability to establish, invade and out-compete native species (Sujay *et al* 2010; Pant & Sharma 2010). Some alien species may be beneficial to the local communities and are often cultivated but others have negative impacts on agriculture, human health or ecosystems (Pimental *et al* 2000; Sharma *et al* 2005; Kohli *et al* 2006). Invasive alien species have rapidly increased throughout the world and have become a substantial threat to the biodiversity and ecological integrity of native habitats and ecosystems (Booth *et al* 2003; Hulme 2003). The magnitude of this threat is increasing globally (Hulme 2009). Invasive alien species alters the processes of the ecosystem (Raizada *et al* 2008). It decreases the species richness and abundance via competition, predation, hybridization and indirect effects (Blackburn *et al* 2004; Gaertner *et al* 2009). The effects of invasive species are complex and they can permanently alter the community structure (Holway *et al* 2002; Carlton 2003) and also the genetic diversity (Ellstrand & Schierenbeck 2000).

The Himalayan regions have always been intruded by invasive alien plants (Khuroo *et al* 2007, 2012). The Darjiling Himalaya is the part of 'Himalaya Hotspot for Conservation' established by IUCN in 2004. Due to great variation in altitude in this region, wide arrays of climatic zones are available, which favoured the luxuriant growth of diversified and rich vegetation (Das 2004). However, there have only been few studies on the diversity and distribution of invasive alien plants in this region. However, Das & Chanda (1986) and Das (2002) recorded the occurrence of 114 species of naturalized or semi-naturalized exotic angiosperms in Darjiling hills. Even then, a comprehensive study on the invasion of alien species is still missing. Therefore, the present work has been selected to understand the diversity and distribution of invasive alien plants in the Darjiling Himalaya for understanding their impact and thereby developing management strategies to control their aggression.

## STUDY AREA

The Darjiling Himalaya (26° 27' 05" & 27° 13' 10" N latitude and 87° 59' 30" & 88° 53' E longitude) is the part of Singalila range of the Eastern Himalaya located on the eastern region of India covering an area of around 3149 sq km. Darjiling is exclusively mountainous with the altitudinal range varying between ca. 132 m to 3660 m. The neighbouring countries of Darjiling Himalaya are the Nepal, Bhutan, Bangladesh and China. There are normally 5 seasons of the year in Darjiling. Spring, which is short lived from March to April, the summer starts from May and continued to June, by June the monsoon starts and usually lasts through August, the pleasant autumn starts from September up to November, the winter begins from December until February. The average annual rainfall for the place ranges from 200 – 300 cm. The economy of Darjiling is purely dependent upon tourism and tea which is the geographical indicator for the region.

With great altitudinal variation and extremely wet condition in this region, major vegetation types find its representation from tropical (below 800 m), subtropical (800 – 1600 m), temperate (1600 – 2400 m), cold-temperate (2400 – 3200 m) and sub-alpine (3200 – 4000 m) zones (Das & Chanda 1987; Bhujel 1996). The main road for entering the hill is the National Highway 55 that covers different zones of Darjiling from tropical to cold–temperate and also some state highways and jeep able roads at higher altitudes (Fig. 1).

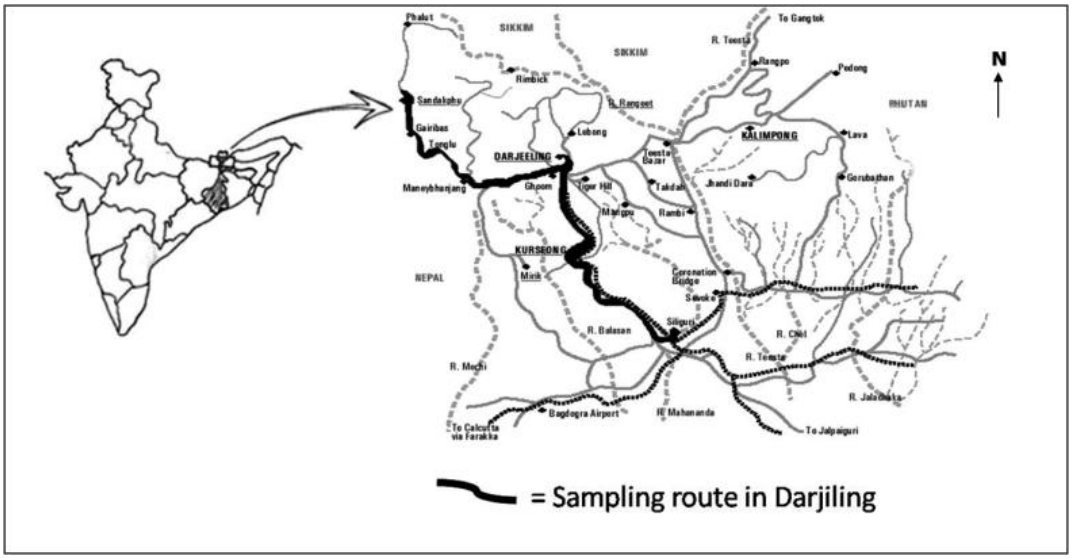


**Fig. 1:** Location map of the study area [*not to scale*]

## MATERIALS AND METHODS

Field studies were conducted along the altitude gradient to record the distribution of invasive alien species. The main road (NH 55) covering 77 km from Terai with altitude of about 130 m upto an altitude of 2250 m in the hills and jeepable road of 40 km covering higher altitude upto 3600 m were taken as the transect. Nested quadrates alongside and parallel to the roads were placed to investigate the distribution of alien plants and also to understand their phytosociological status. The quadrate size of 20 m x 20 m was laid along the road-side keeping a distance of 100 from the road. Then, five quadrates of 1 m x 1 m size were placed within the larger sample area (Mishra 1966; Malhotra 1973; Das & Lahiri 1997; Rai *et al* 2011). A total of 92 roadside plots (20 m x 20 m) were selected along these routes. The location and altitude of the plots were recorded by global positioning system (GPS; Garmin eTrex H). The phytosociological data of the recorded species were analyzed using the formula as suggested by Mishra (1966), Phillips (1959), Das & Lahiri (1997) and Ghosh (2006). The species diversity was determined using Shannon-Weiner's Index (1963) and species richness by using Menhinick's Index (1964). The concentration of dominance (CD) was computed by Simpson's Index (1949). The Dominance-diversity curve for species was drawn on the basis of IVI scores. The vouchers specimens were processed with conventional methodology (Jain & Rao 1977), identified in the Taxonomy & Environmental Biology Laboratory, Department of Botany, North Bengal University using local floras including Hooker (1872 – 1897); Grierson & Long (1983-1987,1991,1999, 2001); Noltie (1994, 2000); Hara (1966, 1971) and Ohashi (1975) and then verified by matching at CAL and NBU. All the voucher specimens will be deposited at NBU and at CAL after finalization of the projected works.

## RESULTS AND DISCUSSION

The pristine beauty and the natural richness of the Darjiling Himalaya have always attracted numerous kinds of people from all corners of the world at least for the last three centuries (Das & Chanda 1986; Das 1995, 2004). The cultivation of tea in the area is the primary

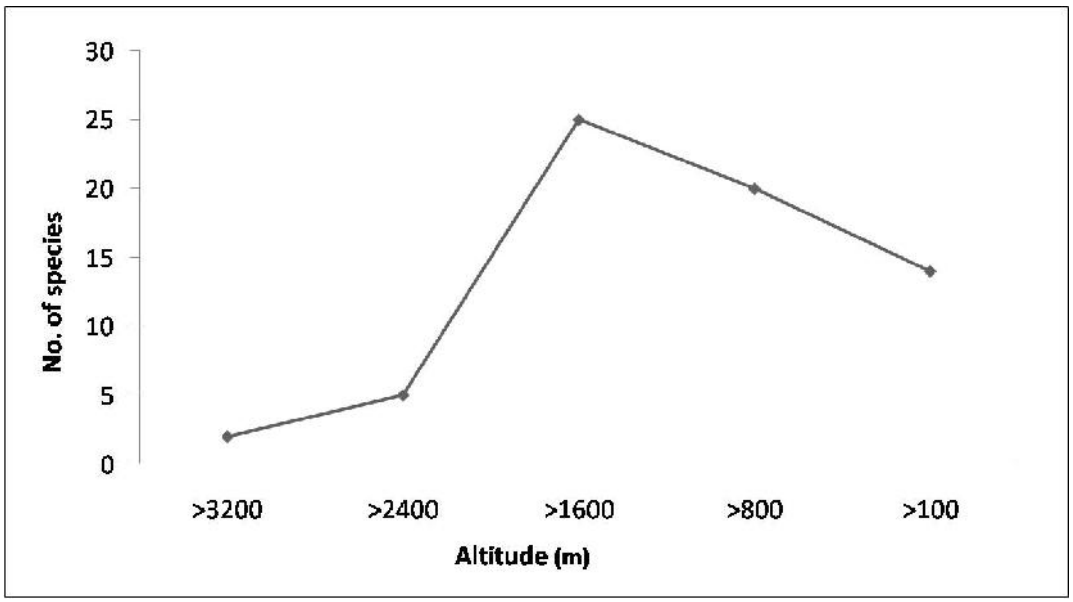


**Fig. 2:** Number of species at different altitude of Darjiling Himalaya

cause for the migration of tourists which led to the increase in the number of invasive alien plants (Das 2002). Some alien plants were introduced into Himalayan regions by historical trading (Khuroo *et al* 2007, 2012). The composition of the alien species varied along the altitude of the Darjiling Himalaya.

During the present investigation a total of 66 species of invasive alien plants belonging to 26 families were recorded from the study area. The most dominant family was Asteraceae (21 species) and Solanaceae (7 species) was the co-dominant. Most of the invasive alien species in the Darjiling Himalaya originated from the American sub-continent (68 %), followed by Asian region (15 %), European region (9 %) and African sub-continent (8 %). The plant were introduced through different purposes, 40 species were introduced unintentionally, 13 species as ornamental, 9 species as weeds, 3 as fodder and 1 species as narcotic. Majority of the species were distributed in the temperate zone (38 %), followed by 30 % species at the sub-tropical zone, 14 species (21 %) were recorded from the tropical region, 5 species (8%) from the cold-temperate and only 2 species (3%) from the sub-alpine zone (Fig. 2).

The phytosociological studies of the distributed species along the altitude revealed that the most dominant species among all the invasive plants was *Eupatorium adenophorum* having IVI score of 16.10, whereas the co-dominant species was *Ageratum houstonianum* with IVI score 13.69. The least dominating species were *Elephantopus scaber* with an IVI score of 1.65. The determined abundance to frequency ratio of the species was highest for *Peperomia pellucida*, *Anaphalis margaritacea* and *Galinsoga parviflora* and least for the species like *Tithonia diversifolia* and *Lantana camara* (Table-1). The species diversity was found to be 3.876 and the species richness was 1.739. The concentration of dominance was estimated to be 0.970. The dominance-diversity curve was drawn on the basis of IVI scores (Fig. 3).

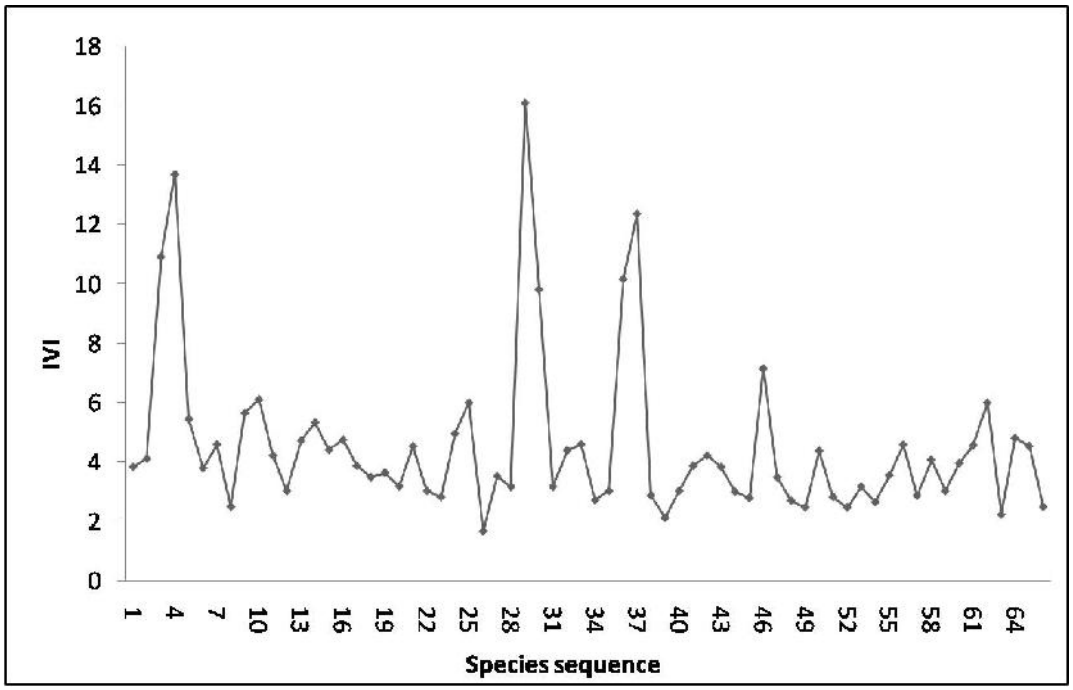


**Fig. 3:** Dominance-diversity curve for the alien species

**Table 1:** Summary of the Invasive alien plants in Darjiling Himalaya [*Abbreviations used*: Growth form: AG – Annual Grass; AH – Annual Herb; C – Shrubby Climber; CH – Climbing Herb; F – Fern; PG – Perennial Grass; PH – Perennial Herb; S – Shrub; SH – Succulent Herb; US – Under shrub; Mode of Introduction: Fd – Fodder; N – Narcotic; O – Ornamental; Ui – Unintentional; W – Weed; A/F – Abundance/Frequency; IVI – Importance Value Index]

| Plant name [Family]; Voucher specimen | Nativity | Growth form | Mode of Introduc-tion | Altitude (m) | | A/F ratio | IVI |
|---|---|---|---|---|---|---|---|
| | | | | Min | Max | | |
| ***Adenostemma lavenia*** (Linnaeus) Kuntze [Asteraceae]; *S. Moktan & AP Das 0070* | S. America | AH | Ui | 500 | 1800 | 2.04 | 3.82 |
| ***Adiantum philippense*** Linnaeus [Adiantaceae]; *S. Moktan & AP Das 0206* | C. Asia | F | Ui | 500 | 1600 | 2.30 | 4.10 |
| ***Ageratum conyzoides*** Linnaeus [Asteraceae]; *S. Moktan & AP Das 0132* | C. America | AH | O | 200 | 1900 | 5.18 | 10.91 |
| ***Ageratum houstonianum*** Miller [Asteraceae]; *S. Moktan & AP Das 0093* | Cent. America | AH | Ui | 250 | 1300 | 4.55 | 13.69 |
| ***Alternanthera sessilis*** (Linnaeus) DC. [Amaranthaceae]; *S. Moktan & AP Das 0146* | Trop. America | AH | Ui | 200 | 1500 | 7.19 | 5.43 |
| ***Anaphalis contorta*** (D. Don) Hooker *f.* [Asteraceae]; *S. Moktan & AP Das 0698* | C. Asia | PH | Ui | 2100 | 3500 | 2.94 | 3.78 |
| ***Anaphalis margaritacea*** (Linnaeus) Bentham & Hooker f. [Asteraceae]; *S. Moktan & AP Das 0561* | N. America | PH | Ui | 900 | 4000 | 9.20 | 4.58 |
| ***Argemone mexicana*** Linnaeus [Papaveraceae]; *S. Moktan & AP Das 0159* | S. America | AH | Ui | 300 | 400 | 4.09 | 2.47 |
| ***Arundo donax*** Linnaeus [Poaceae]; *S. Moktan & AP Das 0073* | S. America | PG | Ui | 1220 | 2000 | 3.71 | 5.64 |
| ***Axonopus compressus*** (Swartz) P. Beauvois [Poaceae]; *S. Moktan & AP Das 0084* | S. America | PG | Fd | 130 | 1600 | 5.70 | 6.09 |
| ***Bidens pilosa*** Linnaeus [Asteraceae]; *S. Moktan & AP Das 0140* | Trop. America | AH | Ui | 150 | 2400 | 5.18 | 4.20 |
| ***Brugmansia suaveolens*** (Willdenow) Berchtold & Presl [Solanaceae]; *S. Moktan & AP Das 0015* | SE Brazil | S | Ui | 600 | 1800 | 2.02 | 3.01 |
| ***Calceolaria tripartita*** Ruiz & Pavon [Scrophulariaceae]; *S. Moktan & AP Das 0103* | C. America | AH | O | 1900 | 2400 | 4.05 | 4.70 |
| ***Cannabis sativa*** Linnaeus [Cannabaceae]; *S. Moktan & AP Das 0455* | C. Asia | AH | N | 300 | 3000 | 4.78 | 5.32 |
| ***Cestrum aurantiacum*** Lindley [Solanaceae]; *S. Moktan & AP Das 0421* | C. America | S | O | 1500 | 2100 | 4.60 | 3.85 |
| ***Cestrum elegans*** (Neumann) Schlechtendal [Solanaceae]; *S. Moktan & AP Das 0454* | Mexico | S | O | 1500 | 2000 | 2.58 | 3.47 |
| ***Chenopodium ambrosoides*** Linnaeus [Chenopodiaceae]; *S. Moktan & AP Das 0527* | C. America | AH | W | 200 | 1600 | 2.76 | 3.63 |
| ***Cissus javana*** DC. [Vitaceae]; *S. Moktan & AP Das 0150* | Java | C | Ui | 300 | 900 | 2.21 | 3.16 |
| ***Cleome rutidosperma*** DC. [Capparaceae]; *S. Moktan & AP Das 0150* | Trop. Africa | AH | W | 100 | 300 | 2.68 | 4.52 |
| ***Clerodendrum japonicum*** (Thunberg) Sweet [Verbenaceae]; *S. Moktan & AP Das 0103* | Japan | S | Ui | 600 | 1200 | 2.02 | 3.01 |
| ***Crassocephalum crepidioides*** (Bentham) S. Moore [Asteraceae]; *S. Moktan & AP Das 0154* | Trop. America | AH | W | 200 | 2100 | 2.88 | 2.80 |
| ***Cynodon dactylon*** (Linnaeus) Persoon [Poaceae]; *S. Moktan & AP Das 0144* | Africa | PG | Ui | 850 | 2600 | 3.07 | 4.94 |
| ***Drymaria villosa*** Chamisso & Schlechtendal [Caryophyllaceae]; *S. Moktan & AP Das 0153* | Trop. America | AH | W | 200 | 2000 | 1.38 | 5.98 |
| ***Elephantopus scaber*** Linnaeus [Asteraceae]; *S. Moktan & AP Das 0218* | C. Asia | PH | Ui | 600 | 1800 | 4.60 | 1.65 |
| ***Emelia sonchifolia*** (Linnaeus) DC. [Asteraceae]; *S. Moktan & AP Das 0048* | Africa | PH | Ui | 200 | 1800 | 4.03 | 3.50 |

| Plant name [Family]; Voucher specimen | Nativity | Growth form | Mode of Introduc-tion | Altitude (m) | | A/F ratio | IVI |
|---|---|---|---|---|---|---|---|
| | | | | Min | Max | | |
| ***Erigeron karvinskianus*** DC. [Asteraceae]; *S. Moktan & AP Das 0161* | C. America | PH | W | 200 | 2000 | 3.45 | 3.15 |
| ***Eupatorium adenophorum*** Sprengel [Asteraceae]; *S. Moktan & AP Das 0061* | Mexico | US | W | 700 | 2000 | 1.23 | 16.10 |
| ***Eupatorium odoratum*** Linnaeus [Asteraceae]; *S. Moktan & AP Das 0014* | N. America | US | W | 200 | 1450 | 1.23 | 9.81 |
| ***Fagopyrum dibotrys*** (D. Don) Hara [Polygonaceae]; *S. Moktan & AP Das 0727* | SW. China | AH | Ui | 1400 | 2800 | 3.45 | 3.15 |
| ***Fragaria nubicola*** (Hooker *f.*) Lacaita [Rosaceae]; *S. Moktan & AP Das 0615* | Temp. Europe | PH | Ui | 2000 | 3600 | 5.46 | 4.38 |
| ***Galinsoga parviflora*** Cavanilles [Asteraceae]; *S. Moktan & AP Das 0094* | Trop. America | AH | W | 900 | 2200 | 9.20 | 4.58 |
| ***Gamochaeta pensylvanicum*** (Willdenow) Cabreara [Asteraceae]; *S. Moktan & AP Das 0508* | N. America | AH | Ui | 250 | 1400 | 1.66 | 2.70 |
| ***Hyptis suaveolens*** (Linnaeus) Poiteau [Lamiaceae]; *S. Moktan & AP Das 0165* | S. America | AH | O | 200 | 400 | 2.02 | 3.01 |
| ***Lantana camara*** Linnaeus [Verbenaceae]; *S. Moktan & AP Das 0064* | Trop. America | S | O | 250 | 600 | 1.11 | 10.15 |
| ***Mikania micrantha*** Kunth [Asteraceae]; *S. Moktan & AP Das 0095* | America | C | W | 200 | 500 | 1.16 | 12.36 |
| ***Mimosa pudica*** Linnaeus [Fabaceae]; *S. Moktan & AP Das 0642* | C. America | AH | Ui | 200 | 350 | 1.84 | 2.86 |
| ***Nicandra physalodes*** (Linnaeus) Scopoli [Solanaceae]; *S. Moktan & AP Das 0155* | Peru | AH | O | 1070 | 1950 | 1.73 | 2.10 |
| ***Oxalis corniculata*** Linnaeus [Oxalidaceae]; *S. Moktan & AP Das 0116* | Europe | PH | Ui | 250 | 2400 | 2.02 | 3.01 |
| ***Oxalis corymbosa*** DC. [Oxalidaceae]; *S. Moktan & AP Das 0228* | S. America | PH | O | 200 | 900 | 4.60 | 3.85 |
| ***Oxalis latifolia*** Humboldt, Bonpland & Kunth [Oxalidaceae]; *S. Moktan & AP Das 0543* | Trop. America | PH | O | 2000 | 2400 | 5.18 | 4.20 |
| ***Parthenium hysterophorus*** Linnaeus [Asteraceae]; *S. Moktan & AP Das 0231* | N. America | AH | Ui | 150 | 1700 | 2.04 | 3.82 |
| ***Pennisetum clandestinum*** Hochstetter ex Chiovenda [Poaceae]; *S. Moktan & AP Das 0470* | E. Africa | PG | Fd | 500 | 2600 | 3.16 | 2.98 |
| ***Peperomia pellucida*** (Linnaeus) Kunth [Piperaceae]; *S. Moktan & AP Das 0208* | Trop. America | SH | Ui | 500 | 1600 | 9.20 | 2.77 |
| ***Persicaria chinensis*** (Linnaeus) H. Gross [Polygonaceae]; *S. Moktan & AP Das 0198* | China | AH | Ui | 270 | 2600 | 1.21 | 7.14 |
| ***Physalis peruviana*** Linnaeus [Solanaceae]; *S. Moktan & AP Das 0162* | Trop. America | PH | Ui | 1220 | 2100 | 2.58 | 3.47 |
| ***Plantago erosa*** Wallich [Plantaginaceae]; *S. Moktan & AP Das 0566* | Mediter-ranean | AH | Ui | 600 | 2500 | 4.60 | 2.68 |
| ***Rubus ellipticus*** Smith [Rosaceae]; *S. Moktan & AP Das 0679* | Trop. America | S | Ui | 1200 | 1900 | 2.30 | 2.45 |
| ***Senna alata*** (Linnaeus) Roxburgh [Fabaceae]; *S. Moktan & AP Das 0098* | S. America | S | O | 200 | 400 | 3.68 | 4.40 |
| ***Senna tora*** (Linnaeus ) Roxburgh [Fabaceae]; *S. Moktan & AP Das 0147* | S. America | AH | Ui | 130 | 300 | 6.04 | 4.73 |
| ***Sida acuta*** Burman *f.* [Malvaceae]; *S. Moktan & AP Das 0116* | Trop. America | AH | Ui | 200 | 1200 | 8.69 | 4.37 |
| ***Solanum torvum*** Swartz [Solanaceae]; *S. Moktan & AP Das 0012* | West Indies | US | Ui | 200 | 1250 | 2.88 | 2.80 |
| ***Solanum viarum*** Dunal [Solanaceae]; *S. Moktan & AP Das 0100* | Trop. America | AH | Ui | 200 | 2000 | 2.30 | 2.45 |
| ***Sonchus asper*** (Linnaeus) Hill [Asteraceae]; *S. Moktan & AP Das 0233* | Mediter-ranean | AH | Ui | 300 | 1500 | 3.45 | 3.15 |
| ***Stellaria media*** (Linnaeus) Villars [Caryophyllaceae]; *S. Moktan & AP Das 0716* | Mediterr anean | AH | Ui | 610 | 2500 | 2.59 | 2.63 |
| ***Stephania japonica*** (Thunberg) Miers [Menispermaceae]; *S. Moktan & AP Das 0178* | Japan | C | Ui | 300 | 1000 | 1.79 | 3.54 |

| Plant name [Family]; Voucher specimen | Nativity | Growth form | Mode of Introduc -tion | Altitude (m) | | A/F ratio | IVI |
|---|---|---|---|---|---|---|---|
| | | | | Min | Max | | |
| ***Synedrella nodiflora*** (Linnaeus) Gaertner [Asteraceae]; *S. Moktan & AP Das 0207* | West Indies | AH | Ui | 250 | 600 | 1.97 | 4.57 |
| ***Tiarella polyphylla*** D. Don [Saxifragaceae]; *S. Moktan & AP Das 0625* | China | PH | Ui | 2000 | 3200 | 1.84 | 2.86 |
| ***Tithonia diversifolia*** (Hemsley) A. Gray [Asteraceae]; *S. Moktan & AP Das 0694* | Trop. America | PH | O | 350 | 1200 | 1.15 | 4.06 |
| ***Torenia thouarsii*** (Chamisso & Schlechtendal) Kuntze [Scrophulariaceae]; *S. Moktan & AP Das 0713* | Trop. Africa | AH | Ui | 150 | 250 | 2.02 | 3.01 |
| ***Tridax procumbens*** Linnaeus [Asteraceae]; *S. Moktan & AP Das 0553* | C. America | PH | Ui | 200 | 1700 | 7.67 | 3.94 |
| ***Trifolium repens*** Linnaeus [Fabaceae]; *S. Moktan & AP Das 0691* | Europe | PH | Fd | 2000 | 2700 | 3.86 | 4.55 |
| ***Triumfetta rhomboidea*** Jacquin [Tiliaceae]; *S. Moktan & AP Das 0066* | Trop. America | AH | Ui | 200 | 900 | 1.38 | 5.98 |
| ***Tropaeolum majus*** Linnaeus [Tropaeolaceae]; *S. Moktan & AP Das 0517* | S. America | CH | O | 1600 | 1900 | 6.90 | 2.21 |
| ***Urena lobata*** Linnaeus [Malvaceae]; *S. Moktan & AP Das 0153* | Trop. America | PH | Ui | 200 | 1900 | 1.58 | 4.80 |
| ***Youngia japonica*** (Linnaeus) DC. [Asteraceae]; *S. Moktan & AP Das 0696* | S. America | AH | Ui | 300 | 2500 | 2.68 | 4.52 |
| ***Zephyranthes carinata*** Herbert [Liliaceae]; *S. Moktan & AP Das 0697* | Mexico | PH | O | 1200 | 2400 | 4.09 | 2.47 |

The invasive alien species were found to spread along the wide range of altitude in the Darjiling Himalaya. Species like *Ageratum conyzoides*, *Persicaria chinensis*, *Lantana camara* and *Eupatorium adenophorum* were found to be colonizing the habitat at different climatic conditions. They showed wider ecological amplitude and seem to express slight phenotypic variation with the change in altitude of the habitat. Some species like *Lantana camara* and *Parthenium hysterophorus* have high allelopathic potential and are harmful to the natural plant population (Singh *et al* 2010). *Eupatorium adenophorum* which is locally known as '*banmara'* (forest killer) prevents forest regeneration and hampers attempts of afforestation with its fast-growing dense bushy stands (Shrestha *et al* 2008). The alien species are rapidly growing and they have been dominating over the resident species of the region. The species are either human introduced or natural invasions through different sources. With the increase in the global trade and tourism, the risk of increase in the population of alien species is growing in this region which may result in the loss of genetic biodiversity and species extinction and thereby filtering and destroying the ecosystem. Further research on how these exotic plants have been invading gradually and proper planning with management control is needed in the Darjiling Himalaya to identify the infestations of these alien plants through combined effort of taxonomist, ecologist, administration and the local community as well.

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## LITERATURE CITED

Bhujel, R.B. 1996. *Studies on the Dicotyledonous Flora of Darjeeling district,* Ph.D. Thesis, University of North Bengal.

Blackburn, T.M.; Cassey, P.; Duncan, R.P.; Evans, K.L. & Gaston, K.J. 2004. Avian extinction and mammalian introductions on oceanic islands. *Science* 305: 1955 – 1958.

Booth, B.D.; Murphy, S.P. & Swanton, C.J. 2003. *Weed Ecology in Natural and Agricultural Systems.* CABI Publishing, Willingford, Oxfordshire, UK. Pp. 288.

Carlton, J.T. 2003. Community assemblage and historical biogeography in the North Atlantic Ocean: The potential role of human-mediated dispersal vectors. *Hydrobiol.* 503: 1 – 8.

Das, A.P. 1995. Diversity of the angiospermic flora of Darjeeling Hills. In *Taxonomy and Biodiversity*, ed. A.K. Pandey. 118 – 127. CBS, New Delhi.

Das, A.P. 2002. Survey of naturalised exotics in the flora of Darjiling Hills, West Bengal, (India). *J. Econ. Tax. Bot*. 26(1): 31 – 37.

Das, A.P. 2004. Floristic studies in Darjeeling Hills. *Bull. Bot. Surv. India.* 46(1-4): 1 – 18.

Das, A.P. & Chanda, S. 1986. Notes on some naturalized exotics in Darjeeling Hills, West Bengal (India). *Indian Bot. Rep.* 5(2):144 – 147.

Das, A.P. & Chanda, S. 1987. Flowering calendar of the angiospermic flora of Darjeeling Hills, West Bengal (India). *Trans. Bose Res. Inst*. 51(4): 99 – 133.

Das, A.P. & Lahiri, A.K. 1997. Phytosociological studies on the ground covering flora in different types of vegetation in Tiger Hill, Darjeeling District, West Bengal (India). *Indian For.* 123 (12): 1176 – 1187.

Ellstrand, N.C. & Schierenbeck, K. 2000. Hybridization as a stimulus for the evolution of invasiveness in plants? *Proc .Nat. Acad. Sci. USA.* 97: 7043 – 7050.

Gaertner, M.; Den Bree, A.; Hui, C. & Richardson, D.M. 2009. Impacts of alien plant invasions on species richness in Mediterranean-type ecosystems: a meta-analysis. *Prog. in Physical Geog.*. 33: 319 – 338.

Ghosh, C. 2006. *Biology of Tea Garden Weeds in Darjiling District of West Bengal (India)*. Ph.D. Thesis, University of North Bengal.

Grierson, A.J.C. and Long, D.G. 1983-1987. *Flora of Bhutan*, Vol. 1, Pts. 1-3, RBG, Edinburgh.

Grierson, A.J.C. & Long, D.G. 1991, 1999, 2001 *Flora of Bhutan*, Vol. 2, Pts. 1, 2 & 3. RBG, Edinburgh.

Hara, H. 1966. *The Flora of Eastern Himalaya.* Rep.I, Tokyo.

Hara, H. 1971. *The Flora of Eastern Himalaya.* Rep.II, Tokyo.

Holway, D.A.; Lach, L.; Tsutsui, N.D. & Case, T.J. 2002. The causes and consequences of Ant invasions. *Ann. Rev. Ecol. Syst.* 33: 181 – 233.

Hooker, J.D. 1872 – 1897. *The Flora of British India*. Vols. 1 – 7. L. Reeve & Co., Kent, London.

Hulme, P.E. 2003. Biological invasions. Winning the science battles but losing the conservation war? *Oryx.* 37: 178 – 193.

Hulme, P.E. 2009. Trade, transport and trouble: managing invasive species pathways in an era of globalization. *J. App. Ecol*. 46: 10 – 18.

IUCN 2000. *IUCN Guidelines for the Preservation of Biodiversity Loss caused by Alien Invasive Species.* Gland, Switzerland.

Jain, S.K. & Rao, R.R. 1977. *A Handbook of field and Herbarium Methods*. Today and tomorrow's Printers and Publishers, New Delhi.

Khuroo, A.A.; Rashid, I.; Reshi, Z.; Dar, G.H. & Wafai, B.A. 2007. The alien flora of Kashmir Himalaya. *Biological Invasions* 9: 269 – 292.

Khuroo, A.A.; Reshi, Z.A.; Malik, A.H.; Weber, E.; Rashid, I. & Dar, G.H. 2012. Alien flora of India: taxonomic composition, invasion status and biogeographic affiliations. *Biol. Invasions* 14(1): 99–113. DOI 10.1007/s10530-011-9981-2

Kohli, R.K.; Batish, D.R.; Singh, H.P. & Dogra, K.S. 2006. Status, invasiveness and environmental threats of three tropical American invasive weeds (*Parthenium hysterophorus* L., *Ageratum conyzoides* L., *Lantana camara* L.) in India. *Biol. Invasions* 8: 1501 – 1510.

Malhotra, S.K. 1973. Studies on the Limestone Vegetation of Sahasradhara near Dehra Dun-Phytosociological Studies: Importance Value Index. *Indian For*. 99(2): 102 – 115.

Menhinick, E.F. 1964. A Comparison of some species diversity indices applied to samples of field insects. *Ecology* 45: 858 – 868.

Mishra, R. 1966. *Ecology Work Book.* Oxford & I.B.H. Calcutta.

Noltie, H.J. (ed.) 2000. *Flora of Bhutan* Vol. 3 Pt 2. RBG, Edinburgh.

Ohashi, H. 1975. *The Flora of Eastern Himalaya.* Rep.III, Tokyo.

Pant, H.M. & Sharma, N. 2010. Inventory of Some Exotic Cultivated Tree Species of Doon Valley and Their Ethnobotanical Uses. *J. Med. Pl. Res*. 4(20): 2144 – 2147.

Philips, E.A. 1959. *Methods of Vegetation study.* Henry Holt and Co. Inc. New York, U.S.A.

Pimental, D.; Lach, L.; Zuniga, R. & Morrison, D. 2000. Environmental and economic costs of nonindigenous species in the United Stated. *BioScience* 50: 53 – 65.

Pysek, P.; Richardson, D.M.; Rejmanek, M.; Webster, G.L.; Williamson, M.; & Kirschner, J. 2004. Alien plants in checklists and floras: Towards better communication between taxonomists and ecologists. *Taxon* 53: 131 – 143.

Raghubanshi, A.S.; Rai, L.C.; Gaur, J.P. & Singh, J.S. 2005. Invasive Alien Species and Biodversity in India. *Curr. Sci*. 88(4): 539 – 540.

Rai, U.; Das, A.P. & Singh, S. 2011. Understanding the forest types in lower hills of Darjiling Himalaya using satellite and ground truth data. In C. Ghosh & A.P. Das, *Recent Studies in Biodiversity and Traditional Knowledge in India.* Sarat Book House, Kolkata. Pp. 203 – 213.

Raizada, P.; Raghubanshi, A.S. & Singh, J.S. 2008. Impact of invasive alien plant species on soil processes: A review. *Proceedings of the National Academy of Sciences India*, Section B. *Biological Sciences* 78: 288 – 298.

Shannon, C.E. & Weiner, W. 1963. *Mathematical Theory of Communication.* University of Illinios Press, Illinios, U.S.A.

Sharma, G.P.; Singh, J.S. & Raghubanshi, A.S. 2005. Plant invasions: Emerging trends and future implications. *Curr. Sci*. 88: 726 – 734.

Shrestha, K.; Wilson, E. & Gay, H. 2008. Ecological and environmental study of *Eupatorium adenophorum* Sprengel (Banmara) with reference to its gall formation in Gorkha-Langtang Route, Nepal. *J. Nat. Hist. Mus.* 23: 108 – 124.

Simpson, E.H. 1949. Measurement of Diversity. *Nature* 163: 688.

Singh, K.P.; Shukla, A.N. & Singh, J.S. 2010. State Level Inventory of Invasive Alien Plants, Their Source Regions and Use Potential. *Curr. Sci*. 99(1): 107 – 114.

Sujay, Y.H.; Sattagi, H.N. & Patil, R.K. 2010. Invasive Alien Insects and Their Impact on Agroecosystem. *Kar. J. Agri. Sci*. 23(1): 26 – 34.