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Diversity, Invasion Status and Usages of Alien Plant Species in Northeastern Hilly State of Tripura: A Confluence of Indo-Barman Hotspot

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Abstract

The present study has explored the first authentic catalogue of the alien flora of the foot Himalayan hilly region along with their diversity, uses, various ecological aspects and invasion status. Environmentally similar south and tropical American aliens are higher in numbers in this region. A total of 216 plant species under 158 genera belonging to 58 families have been compiled in this catalogue. This alien flora occupies ~14.5% of the state flora, while 3.47% is invasive. Families having a large number of alien species are Asteraceae followed by Caesalpiniaceae and Solanaceae. Most of the alien species (61.57%) are of American origin followed by Asia (15.28%) and African continent (12.04%). Life form analysis shows that herbs (42.6%) are dominated alien. Among all the aliens, 67 species are used as ornamental plant, followed by 50 medicinally useful plants. In the state neutralized aliens are (36.57%) followed by invasive alien (24.07%). The present study also reports five alien species for the first time from the study site. This base line study would be the foundation for further advance studies on the invasion ecology and for the future assessment and management of invasive species in this biodiversity rich zone. Present work obviously helps in the agricultural sector of the state as well as the country and gives a clue for further introduction of new species in the country.

Keywords

Alien Flora, Plant Invasion, Invasion Status, Tripura, NE India

1. Introduction

Biological invasions of alien species are widely recognized as a significant component of human-caused global environmental changes, associated with signifi-

cant thrashing in the economic value, biodiversity, and the physiochemical structure of invaded ecosystem [1]-[9]. Studies on alien plants provide us with unique opportunities for research into ecological relationship, where the topic is apparent as having serious practical importance [10] [11].

Although, many alien plants are economically beneficial and often cultivated, and may provide food, medicines, fuel and fodder to the local communities [12], their invasion is considered as second leading threat to the plant diversity after the habitat destruction [13]. These species often produce enormous seeds that are dispersed widely and remain viable in the soil for a long period of time [14]. Faster rate of growth and higher reproductive efficiencies of the alien species make them be well adopted on new habitat [15] [16] and noxious to the environment, habitats, ecosystem, native biodiversity, economics and even human health [17]. They can change the hydrology and ecosystem function [18] and also can show all allopathic inhibition to the different abiotic conditions [19]. Nonetheless, both the biotic and abiotic properties of the target habitat are likely to be as important as the autecological attributes for the influencing of invasive success [20].

Due to drastic breaching of the biogeographical barriers, earth's biota is transforming local and regional floras and faunas, which were isolated continentally for millions of years [21]. Such biotic humanization is a result of increasing global trade and transport; consequently, the number of flora and faunas is trans-located by the peoples, either deliberately or accidentally [1] [22] [23] [24] [25]. Peoples also introduce the alien species into the new habitat [26] for their economic benefit over the native species [27], whereas, neutralized species are introduced species that consistently reproduce without direct interference of publics [28] [29]. Country introduces many alien species to fulfill their over demand as ornamental uses, which were primarily neutralized to the new habitat but, sometimes a number of species become invasive to that habitat and harshly disturb the native ecosystem.

Therefore, it is an apparent need for a region or country to develop an authentic database of flora on invasive alien species for monitoring their spread, their application by local inhabitants, their ecological impacts on native ecosystem and their invasion status in the region. In view of the above facts, the present study was aimed to compile the first authentic catalogue of the alien flora of foot Himalayan hill in the state Tripura, NE India, along with supplementation of some information of each species *viz.* origin, life form, habit, habitat, use, invasion status, mode/purpose of introduction and their diversity assessment. Such base line study would be the foundation of further advance studies in the invasion ecology and for the future assessment of invasive species in this biodiversity-rich zone.

2. Methodology

2.1. Study Site

Tripura is the third smallest undulating hilly state having 10,491.69 km^2 area,

geographically lies between 22˚56' and 24˚32'N latitude to 91˚09' and 92˚20'E longitude, in the Indo-Burma biogeographical region of India (Figure 1). The state is well known for its natural sights, green vegetation and highly diversified flora and fauna. The mean annual rainfall is 2024.4 mm while, temperature ranges from a minimum of 6˚C in December to a maximum of 39˚C in March. The relative humidity of the state is over 60%, except during the month of November to January. The soil is generally red laterite to sandy loam and alluvial in the river catches. Within the state the elevation is ranges 12.5 m in the plains of west to 914 m in the east border of Mizoram. Maximum of the forests are conserved within north south directed five parallel hill ranges in the central to northern part of the state and few are in the southern part of the state, which are now affected by mono culturing practices. Botanically the state is of great interest because of its hot summer and favorable environmental condition, which support the growth of the tropical aliens. As a result many alien plants species are vigorously propagating and naturalizing in this region and altering native vegetation.

2.2. Methods

The intensive field survey was conducted in various season of the year, July 2013 to July 2015 to document and enlist the maximum number of alien flora from various habitat viz.-Sanctuaries, national park, forests, avenue, park, road side, public and official gardens, eco-sites, waste land, fellow lands, river catches, dry

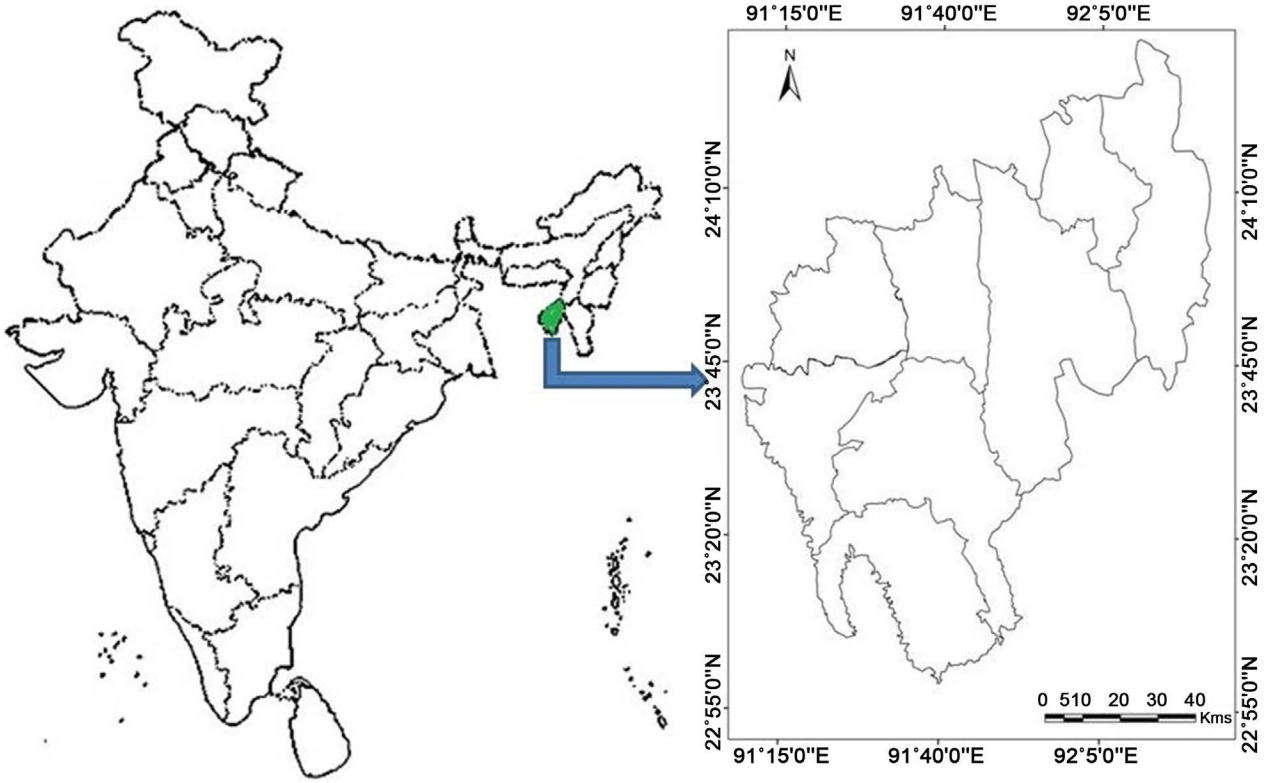

Figure 1. Map of study site.

channels, drains along highway and various crops fields, cultivated fields and other relevant ecosystems of the state. Species were identified through local floras [30]-[37] and specimens were matched with Herbarium of department of Forestry and Biodiversity, Tripura University and confirmed with the Botanical Survey of India (BSI), Shillong.

The nativities of the species were confirmed from all possible sources [38]-[50] including the specialized Internet web pages (www.efloras.org) and recently published some similar studies. We recognized the nativity of the species at Continental scale, region scale as well as Country level, *viz.*, South America, North America, Europe, Tropical America, South east Tropical Asia, Polynesia, Tropical Africa, Tropical west Asia, Mediterranean, America, Tropical east Africa, South Africa, Syria, Malaysia, Yugoslavia, Mexico, Myanmar, Brazil, Madagascar, Burma, China and Australia. Growth form, habit, habitat, uses, invasion status and mode of introductions of the plant species of the region has been considered and brief conspectuses of the terms are used in the table and their abbreviations are given below the table. Species those were entered in last one decade and not included in the state flora are marked (*) with their scientific name. We deliberately exclude those "alien plant species" whose are distributed in the borders of neighbouring country. We included all the alien plants species which are under cultivation and ornamental state but not naturalized in local ecosystem, such plant species may not be assigned as cultivated or casual alien as present but may be naturalized or invasive to the local ecosystem in future. We strictly adopted a biogeographical approach while assigning the invasion status of all the alien species viz. cultivated, casual, naturalized and invasive [28] [50] [51].

For the assessment of phytosociological status of invasive species among the all alien flora of the state, we have taken the data by random quadrate method. A total of 200 quadrates were taken in the weeding season (July 2014-November 2014) from various habitats in the state. Two m^2 quadrates were used for finding the frequency, density, abundance and their relative values and important value index (IVI).

2.3. Data Analysis

Data of the invasive species were calculated by using the following formula [52] [53] [54] with the help of Microsoft Excel 2007, in case of figure we used Origin software (version 6.0 professional)

1) Frequency = (Total number of quadrate in which the species occurs × 100)/Total number of quadrate studied
2) Relative frequency = (Frequency of individuals of a species × 100)/Total frequency of all species
3) Density = Total number of individual of a species in all quadrates/Total number of quadrates studied
4) Relative density = (Density of individuals of a species × 100)/Total density of all species
5) Abundance = Total number of individuals of a species in all quadrates/Total

number of quadrates in which the species occurred

6) Relative abundance = (Abundance of individual of a species × 100)/Total abundance of all species

7) Important Value Index = Relative frequency + Relative density + Relative abundance]

3. Results

The present investigation reveals that the alien flora of north eastern hilly state, Tripura, is comprised of 216 plant species (~14.3% of the state flora) belonging to 158 genera within 58 families. Among all the alien plant species dicotyledons comprises maximum 187 species with 136 genus and 49 families while, monocots are represented only 24 species with 18 genus and 7 families followed by five species of gymnosperm belonging to 4 genera and 2 families which include Araucariaceae and Cupressaceae only (Table 1).

Maximum numbers of alien species belonging to the families are Asteraceae (23), Caesalpiniaceae (14), Solanaceae (13), Papilionaceae (10), Malvaceae (10), Convolvulaceae and Euphorbiaceae (nine species of each), Poaceae and Cyperaceae (seven species of each) and Mimosaceae (six species). The 10 families represent 50% of the total alien flora. Relative to their total genera of the families Caesalpiniaceae represents maximum (75%) and Poaceae shows minimum (12%) alien genus in the top 10 families (Table 2). The genus *Cassia* and *Ipomoea* represents highest numbers of alien species (8 species in each) followed by

Table 1. Taxonomic composition of alien flora.

Plants group	Family	Genera	Species
Dicotyledons	49	136	187 (86.57%)
Monocotyledon	7	18	24 (11.11%)
Gymnosperm	2	4	5 (2.31%)
Total	58	158	216

Table 2. Top 10 family composition.

Family	No. of species	% of total flora	Alien genera/Total genera	Invasive genera (%)
Asteraceae	23	42	19/43	44.19
Caesalpiniaceae	14	60.86	6/8	75
Convolvulaceae	9	40.9	2/9	22.22
Cyperaceae	7	21.21	2/11	18.18
Euphorbiaceae	9	13.84	6/29	20.68
Malvaceae	10	38.46	7/11	63.63
Mimosaceae	6	28.57	4/12	33.33
Papilionaceae	10	10.63	8/46	17.39
Poaceae	7	09	6/50	12
Solanaceae	13	52	7/11	63.63

Cyperus (6), *Solanum* (5), *Hibiscus* and *Brassica* (4 species in each); *Acacia*, *Alternanthera* and *Euphorbia* (3 species in each). In terms of diversity of the species, the genus *Alternanthera* showed 100% invasiveness, followed by *Ipomoea* (88.88%), *Cassia* (87.5%) and *Brassica* (80%) (Table 3). Among the all alien plant species one hundred twenty six or 58.33% genera represents only one species (Table 4).

While estimating the contribution of source flora according to their distribution we compiled them in Tabular form (Table 5). In continental basis it is estimated that 61.57% of the alien species are of American origin followed by Asia (15.28%), Africa (12.96%), Europe (7.41%) and Oceania (3.70%).

Habit wise plants are categorised as annual (40.28%) and perennial (59.72%). Estimating the life forms of all the alien species, herbs shows maximum (42.6%), followed by shrubs (23.61%), tree (22.22%), climber (5.09%), grass and sedges (3.24% each). About 23.61% of the species are abundant in various ornamental garden, followed by cultivated field, waste lands, road side and in forest ecosystem are 18.05%, 11.11%, 8.33% and 5.55% respectively. Seven species are found solely from aquatic habitat, nine from crop field, four from moist place, two each from river bed and home garden and one species *Hevea brasiliensis* is cultivating vigorously in the state. Remaining all the species are distributed in various habitat. A total of 66 (30.55%) species have been introduced intentionally for various economic, medicinal and ornamental purposes and remaining 150 (69.44%) species were introduced unintentionally by way of various unmannered trades (Figure 2).

On the profile of economic uses of the alien plant species, 63 (29.17%) species are ornamental in the state. The second most frequent economic uses are medicinal plant species (15.70%), followed by food (9.72%), fruit species (6.02%) while, 14.81% of the species has no use value. Other various uses like timber, as vegetables, fibre, hut making, latex collection of the alien species are documented through the consultation with local people in the state (Table 4 and Figure 3).

Table 3. Invasive alien species richness of the 9 major genera of invasive species.

Genera	IE	NIE	NAS	% AS
Acacia	0	3	3	42.85
Alternanthera	3	0	3	100
Brassica	0	4	4	80
Cassia	3	5	8	87.5
Cyperus	2	4	6	46.15
Euphorbia	1	2	3	42.85
Hibiscus	0	4	4	50
Ipomoea	5	3	8	88.88
Solanum	3	2	5	41.66

IE, Invasive elsewhere; NIE, Not invasive elsewhere, NAS, Number of alien species, AS, Alien species.

Table 4. Alien flora of Tripura.

Family/Name of the species	OR	LF	HA	HT	USES	IS	MI
Acanthaceae							
Justicia gendarussa (L.) F.	TWA	S	P	W, F	M	NT	UI
Ruellia tuberosa L.	TAM	H	A	F	NK	NT	UI
Agavaceae							
Agave cantula Roxb.	TAM	S	P	G	O	CS	UI
Furcraea foetida (L.) Haw.	SAM	S	P	G	O	CS	UI
Amaranthaceae							
*Alternanthera brasiliana** (L.) Kuntze	BZ	H	P	G, AR	O	IN	I
Alternanthera philoxeroides Mart.	TAM	H	P	RB	NK	IN	UI
Alternanthera sessilis (L.) DC.	TAM	H	P	AR	M	IN	UI
Amaranthus spinosus L.	TAM	H	A	AR	M, V	IN	UI
Gomphrena celosioides Martius	SAM	H	A	G, F	NK	IN	UI
Annonaceae							
Annona reticulata L.	TAM	T	P	CF	FT	NT	I
Annona squamosa L.	TAM	T	P	CF	FT	NT	I
Apiaceae							
Anethum graveolens L.	SETA	H	A	CF	FD	CL	UI
Apium graveolens L.	EU	H	A	CF	FD	CL	I
Coriandrum cyminum L.	MDT	H	A	CF	FD	CL	UI
Coriandrum sativum L.	MDT	H	A	CF	FD	CL	UI
Erygium foetidum L.	SAM	H	P	CF	FD	CL	UI
Foeniculum vulgare Mill.	EU	H	A	CF	FD	CL	UI
Apocynaceae							
Catharanthus roseus (L.) G. Don.	TAM	H	A	G	O	NT	UI
Plumeria alba L.	TAM	T	P	CF	O	CS	UI
Plumeria rubra L.	MEX	T	P	CF	O	CS	UI
Thevetia peruviana (Pers.) Merr.	TAM	T	P	G, HG	O	NT	UI
Araceae							
*Caladium bicolor** (Ait. ex Dryand.) Vent.	SAM	H	P	G, AR	O	IN	UI
Pistia stratiotes L.	TAM	H	P	A	M	NT	UI
Araucariaceae							
Araucaria excels R. Br.	AU	T	P	G	O	CS	I
Arecaceae							
Borassus flabellifer L.	TAF	T	P	CF	HU, TM	NT	UI
Asclepiadaceae							
Asclepias curassavica L.	TAM	H	P	AR, G	O	NT	UI
Calotropis gigantea (L.) R. Brown	TAF	S	P	W, AR	M	NT	UI

Continued

Asteraceae							
Acmella radicans (Jac.) R. R. Janses	MEX	H	A	AR	NK	NT	UI
Ageratum conyzoides L.	TAM	H	A	W, F	M	IN	UI
Blumea lacera (Burm. F.) DC.	TAM	H	A	W	M	IN	UI
Chromolaena odorata (L.) King & Robinson	SAM	S	P	AR, F	M	IN	UI
Chrysanthemum coronarium L.	SETA	H	A	G	O	CS	I
Chrysanthemum indicum L.	SETA	H	A	G	O	CS	I
Cosmos bipinnatus Cav.	AM	H	A	G	O	CS	I
Cosmos sulphureus Cav.	AM	H	A	G	O	CS	I
Eclipta prostrata (L.) Mant.	TAM	H	A	AR	NK	IN	UI
Eupatorium adenophorum Sprengel	MEX	S	P	AR, F, W	NK	IN	UI
Ganaphalium polycaulon Pers.	TAM	H	A	A,	NK	NT	UI
Grangea maderaspatana (L.) Pori.	SAM	H	A	A	M	NT	UI
Helianthus annuus L.	TAM	H	A	G, CF	O	CS	I
Mikania micrantha Kunth	AM	C	A	F, AR	M	IN	UI
Parthenium hysterophorus L.	NAM	H	A	W, AR	NK	IN	UI
Synedrella nodiflora (L.) Gaertn.	WI	H	A	W	NK	IN	UI
Tagetes erecta L.	AM	H	A	G	O	CS	I
Tithonia tagetiflora Desf.	AM	H	P	G	O	CS	I
*Tridex procumbens** L.	TAM	H	A	AR, F	M	IN	UI
Vernonia cinerea L.	SAM	H	A	AR, F	M	IN	UI
Xanthium strumarium L. P. P.	TAM	H	A	W	NK	IN	UI
Zinnia elegans Jacq.	AM	H	A	G	O	CS	I
Zinnia linearis Benth.	MEX	H	A	G	O	CS	I
Bignoniaceae							
Jacaranda mimosifolia D. Don.	BZ	T	P	G	O	CS	UI
Kigelia pinnata Jacq.	TAF	T	P	F	NK	CS	UI
Millingtonia hortensis L.f.	MY	T	P	F, G	O	CS	UI
Pyrostegia venusta (Ker-Gawl) Miers.	BZ	C	P	G	O	CS	UI
Spathodea campanulata Beauv.	TAF	T	P	AR	NK	CS	UI
Bixaceae							
Bixa orrellana L.	BZ	T	P	CF	D	NT	I
Brassicaceae							
Brassica campestrs L.	MDT	H	A	CF	FD	CL	I
Brassica juncea (L.) Czern.	TWA	H	A	CF	FD	CL	I
Brassica oleracea L.	EU	H	A	CF	FD	CL	I
Rorippa dubia (Pers.) Hara.	TAM	H	A	W	NK	CS	UI

Continued

Cactaceae							
Opuntia elatior Miller	SAM	S	P	G	HP	NT	UI
Opuntia vulgaris Miller	SAM	S	P	G	HP	NT	UI
Caesalpiniaceae							
Bauhinia variegata L.	CH	T	P	F	TM	CS	UI
Caesalpinia bonduc (L.) Roxb.	NAM	S	P	F	M	NT	UI
Caesalpinia pulcherrima (L.) Sw.	TAM	S	P	AR	O	CS	I
Cassia alata L.	SAM	S	P	W	M, O	IN	I
Cassia fistula L.	NAM	T	P	AR	TM, O	NT	I
Cassia nodosa Buch.-Ham.	MY	T	P	G, F, AR	O, TM	NT	UI
Cassia occidentalis L.	SAM	H	p	W	M	IN	UI
Cassia renigera Wall. Ex Benth.	BUR	T	p	AR	O	NT	I
Cassia siamea Lamk.	SETA	T	P	CF, F	BF	NT	I
Cassia sophera L.	TAM	S	A	W	M	NT	UI
Cassia tora L.	TAM	S	A	AR	M	IN	UI
Delonix regia (Bojer ex Hook.) Raf.	MD	T	P	AR	O	NT	I
*Peltophorum pterocarpum** DC.	SETA	T	P	G, AR	O, TM, M	NT	UI
Tamarindus indica L.	TAF	T	P	AR	FT	NT	I
Caricaceae							
Carica papaya L.	TAM	S	P	HG	FD	NT	UI
Caryophyllaceae							
Dianthus chinensis L.	SETA	H	A	G	O	CS	I
Casurarinaceae							
Casuarina equisetifolia Forst.	AU	T	P	G	O	CS	I
Chenopodiaceae							
Chenopodium album L.	EU	H	A	AR, W	V	NT	UI
Chenopodium ambrosioides L.	TAM	H	A	W	NK	NT	UI
Spinacia oleracea L.	EU	H	A	CF	V	CL	I
Convolvulaceae							
Evolvulus nummularius (L.) L.	TAM	H	P	W	NK	IN	UI
Ipomoea alba L.	TAM	H	P	HG, AR	V	IN	UI
Ipomoea aquatica Forst.	CH	H	A	A	FD	IN	UI
Ipomoea batatas (L.) Lamk.	TAF	C	A	CF	FD	CL	UI
Ipomoea fistulosa Mart.	TAM	S	P	G	BF	IN	UI
Ipomoea hederifolia L.	TAM	H	P	G	O	NT	UI
Ipomoea pestigridis L.	TEAF	H	A	W	M	NT	UI
Ipomoea purpurea (L.) Roth	SAM	H	A	C, W	M, FO	NT	UI
Ipomoea quamoclif L.	TAM	H	P	W	M, O	IN	I

Continued

Cupressaceae							
Cupressus sempervirens L.	AU	T	P	G	O	CS	UI
Juniperus communis L.	YU	T	P	G	O	CS	I
Thuja occidentalis Bailey	NAM	T	P	G	O	CS	I
Thuja orientalis L.	CH	T	P	G	O	CS	I
Cusutaceae							
Cuscuta reflexa Roxb.	MDT	C	P	F, AR	M	IN	UI
Cyperaceae							
Cyperus cyperoides L.	TAM	SE	P	F	NK	NT	I
Cyperus difformis L.	TAM	SE	A	C	FO	NT	UI
Cyperus diffuses Vahl.	SETA	SE	P	MP	NK	NT	UI
Cyperus haspan L.	NAM	SE	P	C	NK	NT	UI
Cyperus iria L.	TAM	SE	A	C	FO	IN	UI
Cyperus rotundus L.	TAF	SE	P	C	NK	IN	UI
Fuirena ciliaris (L.) Roxb.	TAM	SE	A	C	NK	NT	UI
Dioscoreaceae							
Dioscorea oppositifolia L.	CH	C	A	F	FD, M	NT	UI
Euphorbiaceae							
Croton bonplandianum Baill.	TAM	S	P	W, AR	M	IN	UI
Euphorbia hirta L.	TAM	H	A	F, AR	M	IN	UI
Euphorbia milii Des Moulins	MD	S	P	G	O	CS	UI
Euphorbia pulcherrima Willd. ex. Klotz.	MEX	S	P	G	O	CS	UI
Hevea brasilensis Muell. Arg.	BZ	T	P	PF	LC, BF, TM	CL	I
Jatropha curcas L.	TAM	S	P	CF	BF	CL	I
Jatropha gossypifolia L.	TAM	S	P	AR, F	BF	NT	UI
Manihot esculenta Crantz.	TAM	T	P	F	FD	NT	UI
Ricinus communis L.	SAF	S	P	CF	BF, FI	NT	UI
Lamiaceae							
Hyptis capitata Jacq.	MEX	H	A	AR, W	NK	IN	UI
Hyptis suaveolens (L.) Poit.	TAM	H	A	AR	M	IN	UI
Ocimum americanum L.	TAF	S	P	G	O	NT	UI
Salvia coccinea (L.) Mant.	AM	H	A	G	O	CS	UI
Lauraceae							
Cinnamomum camphora (L.) Sieb.	CH	T	P	HG, CF	SP	NT	UI
Liliaceae							
Asparagus tenuifolius Cav.	TAM	H	A	CF	M	CL	UI
Hemerocallis fulva L.	CH	H	A	G	O	CS	UI

Continued

Lythraceae							
Lagerstroemia indica L.	CH	S	P	F, AR	TM	NT	UI
Magnoliaceae							
Magnolia grandiflora L.	NAM	T	P	CF	O	CS	I
Magnolia pumila Anders.	CH	T	P	CF	O	CS	UI
Malvaceae							
Abelmoscheus esculentus Moench.	TAF	S	P	CF	V	CL	UI
Althea rosea (L.) Cav.	EU	H	A	G	O	CS	I
Gossypium hirsutum L.	AM	S	P	CF	FI	CL	I
Hibiscus mutabilis L.	CH	S	P	G	O	CS	UI
Hibiscus rosasinensis L.	CH	S	P	G	O	CS	UI
Hibiscus schizopetalus (Masters) Hook. f.	TAF	S	P	G	O	CS	UI
Hibiscus syriacus L.	SY	S	P	G	O	CS	UI
Malvaviscus arboreus Cav. Var. *penduliflorus* (DC.) Schery.	TAM	S	P	G	O	CS	UI
Sida acuta Burm. f.	TAM	H	A	W	M, FI	IN	UI
Urena lobata L.	TAF	S	P	W	FI	IN	UI
Mimosaceae							
Acacia auriculiformis A. Cunn. Ex. Benth.	AU	T	P	AR	TM	NT	I
Acacia farnesiana (L.) Willd.	SAM	S	P	AR, F	NK	NT	UI
*Acacia mangium** Willd.	AU	T	P	CF	TM	NT	I
Leucaena leucocephala (Lam.) de Wit	TAM	T	P	AR, F	BF	NT	I
Mimosa pudica L.	BZ	H	P	F, AR	M	IN	UI
Samanea saman (Jacq.) Merr.	SAM	T	P	AR	TM, O	NT	I
Myrtaceae							
Callistemon linearis DC.	AU	T	P	G	O	CS	I
Eucalyptus maculata Hk.	AU	T	P	CF, F	TM	NT	I
Pimenta dioica (L.) Merr.	WI	T	P	CF	FD	CL	I
Psidium guajava L.	TAM	T	P	HG, F	FT	NT	UI
Psidium guinensis Swartz.	SAM	T	P	HG, F	FT	NT	UI
Nyctaginaceae							
Bougainvillea glabra Choisy.	BZ	C	P	G	O	NT	UI
Bougainvillea spectabilis Willd.	BZ	S	P	G	O	NT	UI
Mirabilis jalapa L.	TAM	H	A	G	O	NT	I
Nymphaea micrantha Guill. & Perr.	TAF	C	A	A	V	IN	UI
Onagraceae							
Ludwigia octavilis (Jacq.) Raven	TAF	H	A	MP	M	IN	UI
Ludwigia perennis L.	TAF	H	A	MP	NK	NT	UI

Continued

Oxalidaceae							
Oxalis corniculata L.	EU	H	P	W	M, V	NT	UI
Papaveraceae							
Argemone mexicana L.	TAM	H	A	W	M	IN	UI
Eschscholzia californica Cham.	MEX	H	A	G	O	CS	UI
Papaver orientale L.	MD	H	A	G	O	CS	UI
Papilionaceae							
Aeschynomene indica L.	NAM	H	A	A	M	NT	I
Calopogonium mucunoides Desv.	TAM	C	A	F, W	M	IN	UI
Crotalaria pallida Ait.	TAF	S	P	AR	M	IN	UI
Crotalaria mucronata Ait.	TAM	S	P	AR	M	NT	UI
Dolichos lablab L.	TAF	C	A	HG, CF	V	CL	I
Lens culinaris Medik	EU	H	A	C	FD	CL	I
Phaseolis vulgaris L.	AM	C	A	HG, CF	FD	CL	I
Pisum sativum L.	EU	H	A	CF	FD	CL	I
Sesbania bispinosa (Jacq.) W. F. Wight	TAM	S	A	G	O	NT	UI
Sesbania sesban (L.)	SAF	T	P	HG, CF	BF, FD	CL	I
Passifloraceae							
Passiflora foetida L.	TAM	C	A	F	NK	NT	UI
Piperaceae							
Peperomia pellucid (L.) Kunth	SAM	H	A	AR	NK	IN	UI
Poaceae							
Cynodon dactylon (L.) Pers	TAF	G	P	AR, G, CF	FO	NT	I
Pennisetum polystachyon (L.) Schult.	TAF	G	P	F, AR	NK	IN	UI
Echinochloa colona (L.) Link	TAM	G	A	C	FO	NT	UI
Imperata cylindrica (L.) Raeusch.	TAM	G	P	W	R	NT	UI
Saccharum spontaneum L.	TWA	G	P	RB	M, BF	NT	UI
Zea mays L.	TAM	G	A	CF	FD, FO	CL	I
Polygonaceae							
Muehlenbeckia platyclados (Muell.) Meissn.	POL	H	P	G	O	CS	UI
Pontederiaceae							
Eichornia crassipes (Mart.) Solms-Laub	SAM	H	A	A	M	IN	UI
Monochoria vaginalis (Burm. F.) C. Presl.	TAM	H	P	MP	M, V	IN	UI
Echinochloa crusgalli (L.) Beauv.	TAM	G	A	C	FO	IN	UI
Portulacaceae							
Portulaca oleracea L.	SAM	H	A	W	M, V	IN	I
Portulaca quadrifida L.	TAM	H	A	W	NK	NT	UI

Continued

Ranunculaceae							
Nigella sativa L.	EU	H	A	CF	SP	CL	I
Eriobotrya japonica (Thunb) Lindl.	CH	T	P	CF	FT	CL	UI
Prunuscom munis L.	EU	T	P	CF	FT	CL	I
Prunus persica (L.) Stokes	CH	T	p	CF	FT	CL	I
Rubus ellipticus Smith	TAM	S	P	W	FT	NT	UI
Rubiaceae							
Ixora coccinea L.	CH	S	P	G	O	CS	UI
Spermacoce hispida L.	TAM	H	P	AR, W	M	NT	UI
Rutaceae							
Citrus maxima (Burm.) Merr.	ML	T	P	HG	FT	NT	UI
Sapindaceae							
Litchi chinensis Sonn.	CH	T	P	HG, CF	FT	CL	UI
Sapotaceae							
Manilkara achras (Mill.) Fosg.	TAM	T	P	HG, F	FT	CL	UI
Scrophulariaceae							
Mecardonia dianthera (Sw.) Pennell.	TAM	H	A	G	O	NT	UI
Scoparia dulcis L.	TAM	H	P	W	M	IN	UI
Solanaceae							
Brunfelsia americana L.	WI	S	P	G	O	CS	I
Brunfelsia hopeana Benth.	TAM	S	P	G	O	CS	I
Capsicum annuum L.	AM	S	P	CF	FD	CL	I
Cestrum diurnum L.	AM	S	P	G	O	CS	I
Cestrum nocturnum L.	AM	S	P	G	O	CS	I
Datura stramonium L.	SAM	S	P	W, AR	M	NT	UI
Nicotiana tabacum L.	SAM	H	P	CF	SM	CL	I
Physalis minima L.	TAM	H	A	W	FT, M	IN	UI
Solanum myriacanthum Dun.	SAM	S	P	F	NK	NT	UI
Solanum nigrum Sw.	TAM	H	A	CF	M, FT	IN	UI
Solanum sisymbriifolium Lamarck	SAM	S	P	AR, W	NK	IN	UI
Solanum torvum Sw.	WI	S	P	F, AR	M, V	NT	UI
Solanum tuberosum L.	AM	H	A	CF	FD	CL	I
Sterculiaceae							
Dombeya mastersii Hook. f.	TAF	T	P	F	FO, FI	NT	UI
Melochia corchorifolia L.	TAM	H	P	W	FI, V	NT	UI
Pterospermum semisagittatum Buch.-Ham.	MY	T	P	F	NK	NT	UI
Theaceae							
Camellia sinensis (L.) Kuntze.	CH	S	P	CF	DR	CL	I
Corchorus aestuans L.	TAM	H	A	W	M	NT	UI

Continued

Tiliaceae							
Corchoru solitorius L.	TAF	H	A	CF	M, FI	CL	UI
Triumfetta pilosa Roth.	TAF	H	A	C, AR	NK	NT	UI
Triumfetta rhomboidea Jacq.	TAM	H	A	W	M	NT	UI
Urtiaceae							
Pilea microphylla (L.) Liebm.	SAM	H	A	AR	NK	NT	UI
Verbenaceae							
Clerodendrum phillippinum Schauer.	CH	S	P	G	O	CS	UI
Duranta repens L.	MEX	S	P	G	O	CS	UI
Lantana camara L.	TAM	S	P	AR, F	BF, SB	IN	UI
Stachytarpheta jamaicensis L.	TAM	H	P	C	O, M	IN	UI

Abbreviations: *= Newly introduced alien plant species (not included in the state flora). **OR, Origin:** NAM-North America; CH-China; TAM-Tropical America; AU-Australia; EU-Europe; SAM-South America; BUR-Burma; SETA-South East Tropical Asia; POL-Polynesia; MD-Madagascar; TAF-Tropical Africa; WI-West Indies; TWA-Tropical west Asia; BZ-Brazil; MDT-Mediterranean; MY-Myanmar; AM-America; MEX-Mexico; TEAF-Tropical East Africa; YU-Yugoslavia; SAF-South Africa; SY-Syria; ML-Malaysia. **LF, (Life form):** H-Herb; C-Climber; US-Undershrub; S-Shrub; SE-Sedges; B- Bamboo; T-Tree; G-grass; **HA, (Habit):** A-Annual; P- Perennial. **HT, (Habitat):** W-Wasteland; CF-Cultivated field; F-Forest; AR-Along roadside; A-Aquatic; P-Parasites; C-Crop field; RB-River beds; G-Garden; MP- Moist place; RF-Rice field; PF- Plantation Forest; HG-Home Garden; **U, (Used):** AD-Adulteration; B-Basket making; BF-Biomass fuel in rural area; BR-Bio-fertilizer; TM-Timber; M-Medicinal; V-Vegetable; FI-Fibre; FO-Fodder; HP-Hedge plant; SM-Smoking; SB-Soli binder; FT-Fruit; LC-Latex Collection; NK-Not Known; HB-House building; FD-Food; O-Ornamental; HU-Hut; DR-Drink; D-Dye; SP-Spices; **MI, (Mode of Introduction):** AF-Agro forestry; UI- Unintentional; I-Intentional; **Invasion status:** CL = Cultivated alien; CS-Casual alien; NT-Naturalized alien; IN-Invasive alien.

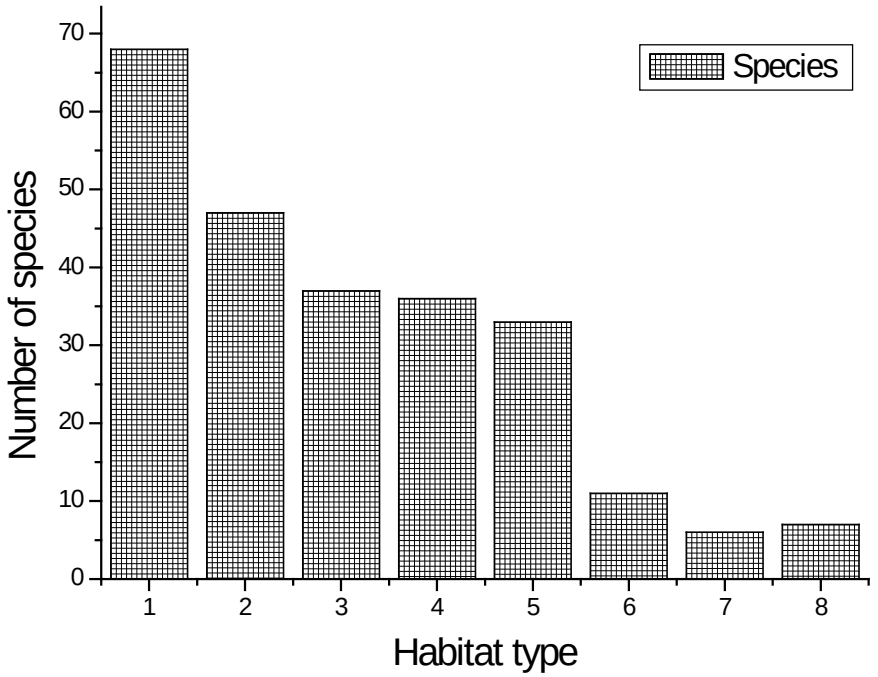

Figure 2. Number of alien species (N = 216) in various habitat. Species may occur in more than one habitat: 1 = Ornamental gardens, home gardens; 2 = Cultivated fields; 3 = Forests; 4 = Road sides, grass lands; 5 = Waste places; 6 = Crop fields; 7 = Moist places; 8 = Aquatic.

Table 5. Percentage of alien plant species belonging to different categories.

Category	Sub-category	Number of species	Percentage of species
Origin	Tropical America (TAM)	70	32.40
	South America (SAM)	23	10.64
	Tropical Africa (TAF)	21	9.72
	China (CH)	16	7.40
	America (AM)	13	6.02
	Europe (EU)	11	5.09
	Brazil (BZ)	8	3.70
	Mexico (MEX)	8	3.70
	Australia (AU)	7	3.24
	North America (NAM)	7	3.24
	South east Tropical Asia (SETA)	7	3.24
	West Indies (WI)	4	1.85
	Mediterranean (MDT)	4	1.85
	Madagascar (MD)	3	1.39
	Tropical West Asia (TWA)	3	1.39
	Myanmar (MY)	3	1.39
	South Africa (SAF)	2	0.92
	Malaysia (ML)	1	0.46
	Burma (BUR)	1	0.46
	Polynesia	1	0.46
	Syria (SY)	1	0.46
	Tropical East Africa (TEA)	1	0.46
	Yugoslavia (YU)	1	0.46
Habit	Perennial (P)	129	59.72
	Annual (A)	87	40.28
Life form	Herbs (H)	92	42.6
	Shrub (S)	51	23.61
	Tree (T)	48	22.22
	Climber (C)	11	5.09
	Grass (G)	7	3.24
	Sedge (SE)	7	3.24
Mode of Introduction	Unintentionally (UI)	150	69.44
	Intentionally (I)	66	30.55
Invasion Status	Naturalized (NT)	79	36.57
	Invasive (IN)	52	24.07
	Casual alien (CS)	51	23.61
	Cultivated alien (CU)	34	15.74

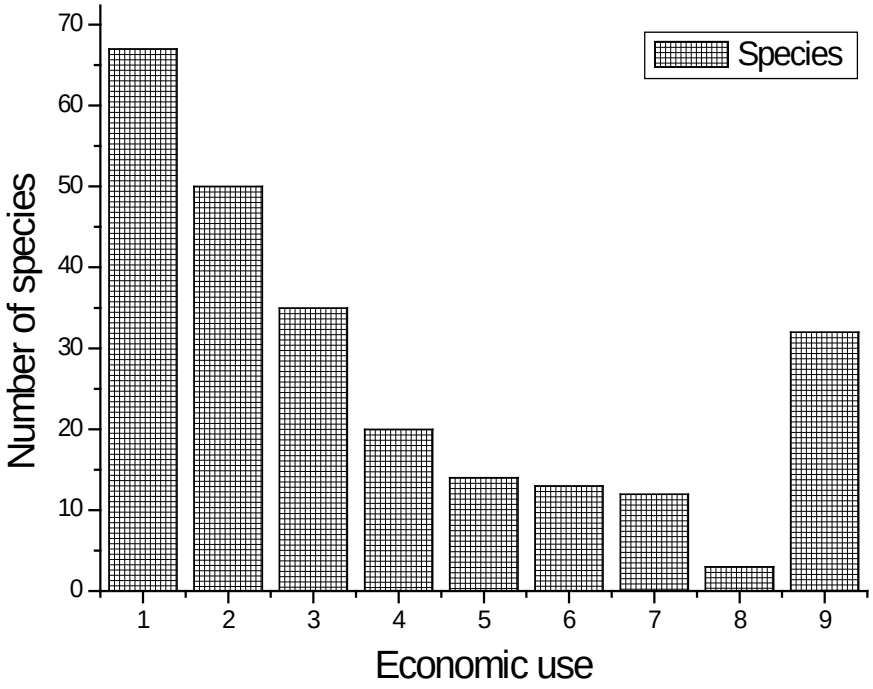

Figure 3. Economic uses of alien plants ($N = 216$). Species may have more than one use 1 = Ornamental; 2 = Medicines; 3 = Food, vegetables, spices, drink; 4 = Fodder, fibre, house binder, hut; 5 = Fruit; 6 = Bio fuel, smoke; 7 = Timber, house binder, hut making; 8 = Soil binder, dye, soil binder; 9 = Not known.

Invasion status of the total alien flora (216) are categories as casual 51 (23.61%), cultivated 34 (15.74%) naturalized 79 (36.57%) and invasive alien 52 (24.07%) which are the 3.4%, 2.67%, 5.27% and 3.47% of the state flora respectively (Table 5).

The present study also reports five newly introduced plant species for the first time from the state. These are includes: *Acacia mangium* Willd. (Mimosaceae), *Tridex procumbens* L. (Asteraceae), *Alternanthera brasiliana* (L.) Kuntze (Amaranthaceae), *Caladium bicolor* (Ait. ex Dryand.) Vent. (Araceae), *Peltophorum pterocarpum* DC. (Caesalpiniaceae).

The present work also analysed the diversity of 52 invasive alien species from this alien flora. For evaluating their phytosociological attributes the data pertaining to frequency, density, abundance and their relative values and Important Value Index were recorded from the various habitats (Table 6). The most frequent invasive species in the study area is *Chromolaena odorata* (71%), followed by *Ageratum conyzoides* (60.5%), *Alternanthera philoxeroides* (50.5%) and *Mikania micrantha* (49%). The most densely species in the study area is *Chromolaena odorata* (6.11) followed by *Ageratum conyzoides* (5.02), while *Ipomoea alba* (0.10) shows least. *Chromolaena odorata* (8.60) is the most abundant species in the study area followed by *Parthenium hysterophorus* (7.76). IVI calculated for the individual invasive species in the study area, *Chromolaena odorata* shows highest (18.82) followed by *Ageratum conyzoides* (15.74), *Hyptis suaveolens* (12.16) and lowest in *Ipomoea alba* (1.40).

Table 6. Phytosociological attributes of invasive plant species in the state.

Sl. No.	Name of the plant	F	RF	D	RD	A	RA	IVI
1	*Peltophorum pterocarpum* (L.) King & Robinson	71	4.76	6.11	9.72	8.60	4.34	18.82
2	*Ageratum conyzoides* L.	60.5	4.05	5.02	7.99	7.33	3.70	15.74
3	*Hyptis suaveolens* (L.) Poit.	44	2.95	3.36	5.35	7.65	3.86	12.16
4	*Euphorbia hirta* L.	45.5	3.05	3.32	5.28	7.30	3.69	12.02
5	*Synedrella nodiflora* (L.) Gaertn.	53	3.55	3.03	4.82	5.72	2.89	11.26
6	*Parthenium hysterophorus* L.	33	2.21	2.56	4.07	7.76	3.92	10.20
7	*Cassia tora* L.	42.5	2.85	2.41	3.83	5.57	2.81	9.49
8	*Pennisetum polystachyon* (L.) Schult.	35	2.34	2.33	3.71	6.66	3.36	9.41
9	*Alternanthera philoxeroides* Mart.	50.5	3.38	2.13	3.39	4.23	2.13	8.90
10	*Mimosa pudica* L.	49	3.28	1.96	3.12	4	2.02	8.42
11	*Mikania micrantha* Kunth	47	3.15	1.93	3.07	4.11	2.07	8.29
12	*Sida acuta* Burm. f	48.5	3.25	1.33	2.12	2.75	1.39	6.76
13	*Eclipta prostrata* (L.) Mant.	19	1.27	1.18	1.88	6.21	3.14	6.29
14	*Eichornia crassipes* (Mart.) Solms-Laub	17.5	1.17	1.07	1.70	6.14	3.10	5.97
15	*Gomphrena celosioides* Martius	28.5	1.91	1.20	1.91	4.21	2.13	5.95
16	*Evolvulus nummularius* (L.) L.	33.5	2.24	1.19	1.89	3.57	1.80	5.93
17	*Ludwigia perennis* L.	22.5	1.51	1.11	1.77	4.95	2.50	5.78
18	*Peperomia pellucid* (L.) Kunth	24.5	1.64	1.11	1.77	4.55	2.30	5.71
19	*Croton bonplandianum* Baill.	44.5	2.98	0.98	1.56	2.20	1.11	5.65
20	*Lantana camara* L.	32.5	2.18	1.07	1.70	3.31	1.67	5.55
21	*Alternanthera brasiliana* (L.) Kuntze	25.5	1.71	1.05	1.67	4.10	2.07	5.45
22	*Urena lobata* L.	34.5	2.31	0.94	1.49	2.72	1.37	5.17
23	*Argemone Mexicana* L.	3.5	2.34	0.18	0.21	5.14	2.59	5.14
24	*Cyperus iria* L.	34	1.61	1.05	1.67	3.09	1.56	4.84
25	*Physalis minima* L.	20.5	1.37	0.67	1.07	4.55	2.30	4.74
25	*Echinochloa crusgalli* (L.) Beauv.	31.5	2.11	0.80	1.27	2.54	1.28	4.66
26	*Eupatorium adenophorum* Sprengel	21	1.41	0.80	1.27	3.83	1.93	4.61
27	*Vernonia cinerea* L.	33	2.21	0.74	1.18	2.24	1.13	4.52
28	*Cyperus rotundus* L.	29	1.94	0.75	1.19	2.60	1.31	4.44
29	*Tridex procumbens* L.	28	1.88	0.75	1.19	2.70	1.36	4.43
30	*Cassia occidentalis* L.	30	2.01	0.71	1.13	2.38	1.20	4.34
31	*Alternanthera sessilis* (L.) DC.	14	0.94	0.65	1.03	4.64	2.34	4.31
32	*Hyptis capitata* Jacq.	18.5	1.24	0.67	1.07	3.62	1.83	4.14
33	*Ipomoea aquatica* Forst.	21	1.41	0.65	1.03	3.09	1.56	4.00
34	*Amaranthus spinosus* L.	27	1.81	0.61	0.97	2.28	1.15	3.93
35	*Crotalaria pallida* Ait.	27.5	1.84	0.59	0.94	2.14	1.08	3.86
36	*Portulaca oleracea* L.	15	1	0.74	1.18	3.29	1.66	3.84

Continued

37	*Ludwigia octavilis* (Jacq.) Raven	24	1.61	0.59	0.94	2.46	1.24	3.79
38	*Xanthium strumarium* L. P. P.	22	1.47	0.55	0.87	2.50	1.26	3.60
39	*Ipomoea fistulosa* Mart.	17.5	1.17	0.53	0.84	3.06	1.54	3.55
40	*Cassia alata* L.	23	1.54	0.50	0.79	2.19	1.11	3.44
41	*Solanum sisymbriifolium* Lamarck	25.5	1.71	0.48	0.76	1.90	0.96	3.43
42	*Blumea lacera* (Burm. F.) DC.	25.5	1.71	0.47	0.75	1.86	0.94	3.40
43	*Solanum nigrum* Sw.	26	1.74	0.46	0.73	1.77	0.89	3.36
44	*Scoparia dulcis* L.	14.5	0.97	0.42	0.67	2.93	1.48	3.12
45	*Monochoria vaginalis* (Burm. F.) C. Presl.	13.5	0.90	0.34	0.54	3.18	1.60	3.04
46	*Stachytarpheta jamaicensis* L.	18	1.21	0.40	0.64	2.22	1.12	2.97
47	*Calopogonium mucunoides* Desv.	10.5	0.70	0.33	0.52	3.14	1.58	2.80
48	*Ipomoea quamoclit* L.	15	1	0.31	0.49	2.10	1.06	2.55
49	*Cuscuta reflexa* Roxb.	11.5	0.77	0.22	0.35	1.96	0.99	2.11
50	*Caladium bicolor* (Ait. ex. Dryand.) Vent.	14	0.94	0.22	0.35	1.57	0.79	2.08
51	*Nymphaea micrantha* Guill. & Perr.	9.5	0.64	0.17	0.27	1.79	0.90	1.81
52	*Ipomoea alba* L.	6.5	0.43	0.10	0.16	1.61	0.81	1.40

Abbreviation: F, Frequency; RF, Relative frequency; D, Density; RD, Relative density; A, Abundance; RA, Relative abundance; IVI, Important Value Index.

4. Discussion

Although, some of the alien species are invasive and a major threat to the local ecosystem when they are introduced unintentionally outside their natural habitat, but many alien species are supporting our farming and forestry structure in an immense manner [55].

A total of 216 alien species are distributed in various ecosystems in the state which belongs to 58 families, from which only 10 families accounts the 50 % of the total alien flora. Asteraceae is the dominant alien family having 10.64% of total alien flora in the state followed by Caesalpiniaceae, Solanaceae, Papilionaceae, Malvaceae, Convolvulaceae, Euphorbiaceae, Poaceae, Cyperaceae and Mimosaceae. Our finding about the distribution of families of alien species in Tripura is in accordance with the findings of earlier workers in other parts of India [19] [50] [56] [57]. In this catalogue of alien species 18 families are represented by single species while 13 families have only two species (**Table 4**).

From the newly introduced five species those are not yet included in the state flora have some ecological impacts. *Peltophorum pterocarpum* (Caesalpiniaceae) is naturalized in terrestrial habitat and geographically originated from South East Tropical Asia. *Alternanthera brasiliana* (Amaranthaceae), *Caladium bicolor* (Araceae), and *Tridex procumbens* (Asteraceae) are invasive to the native ecosystem in the state. *Alternanthera brasiliana*, *Caladium bicolor* were originally introduced as ornamental aliens but at present they have invaded the natural flora and become establish in the local ecosystem replacing the original popula-

tion thus becomes detrimental. This kind of invasiveness of the ornamental plant was also reported from Kashmir valley [58]. Most of the invasive species are distributed along the road side of the state which matched earlier report [59]. Only one species *Acacia mangium* (Mimosaceae) was introduced in 1990s for timber production, which is geographically Australian origin.

In earlier reports [45] [60] estimated that, the contributions of alien flora in India were 40% and 18% respectively while in the state it is nearly 14.5%, which is less than the respective data to our country. Recently few studies have been conducted by few workers on alien flora of the different region of the country [38] [40] [42], the main purpose of such studies were to provide a list of "alien" within their respective region without keeping in mind any kind of invasion status of the species. On comparison with these studies we compiled here the whole alien flora in the state with the proper observation on their invasion status within the state.

The American alien plant species in the state (61.57%) exceed the total American contribution (55%) alien plant species in India [45]. The probable reasons for such higher proportions of successful introduction of the alien species in the state flora of Tripura could be the (i) more or less climatic similarities with the tropical America and/or (ii) due to increase in temperature in the region which invite the Tropical American flora. Although two decade ago the state had favourable environment and highest proportion of native forest, but now due to mono-culturing practices of *Hevea brasiliensis*, temperature is increasing and supports the adoption of the Tropical American flora. If such climate change will continue, the contribution of American flora to the country will increase and most of the species those are now naturalized in condition they could be invasive to the country in future. While, less proportion of the alien species are contributed by Oceania and Europe, which support the earlier findings [45].

Herbs are the dominant alien species (92) in the state followed by shrubs and tree which supports the findings of previous work [40] on invasive species diversity of Western Ghats, India. The 52 invasive species are creating a pressure on ecology and socio-economic structure of the state but some of them are playing a beneficial role in ecological restoration, soil conservation and healthier economy of the state. Commercial use of some invasive alien plants (e.g. *Hevea brasiliensis*) has resulted in elevated economic condition of the rural community in the state. Like earlier studies [29] [50] [61] [62] [63], the present catalogue of the state also include 34 (15.74%) cultivated alien species. Most of them are intentionally introduced from European Country.

The present study also shows the relatively higher percentage (31.02%) of ornamental alien species introduced in the state are in accordance with the observations of the earlier workers in the flora of Azores Archipelago and Taiwan [61] [62] [63]. Field survey and investigation reveal that deliberately introduce alien tree species like *Eucalyptus maculata*, *Acacia auriculiformis*, *Leucaena leucocephala*, and unintentionally introduced some woody shrubs like *Lantana camara*, *Chromolaena odorata*, *cassia tora* are supplying the rural fuel wood and timber

demand. The species like *Delonix regia*, *Lagerstromia speciosa* and *Peltophorum pterocarpum* are the colour in the state forest and they are also used as ornamental tree in the garden.

5. Ecological Impacts

The invasive alien species can rapidly adapt to a wide range of environmental condition which may assist their dispersal to a far distance from their place of origin. Some herbaceous and shrubby alien plants like *Chromolaena odorata*, *Cassia tora*, *Lantana camara*, *Ageratum conyzoides*, *Amaranthus spinosus*, *Eichornia crassipes* and *Alternanthera sessilis* are harmful to the mankind. Their invasion and rapid propagation has triggered ecological imbalance within the native floristic composition. The studies on historical and present perspective of *Lantana camera* showed that it was introduced in Indian Botanical Garden, Shivpur as an ornamental hedge at 1809 [38], but at present it is a serious invader and now invasive to the state of Tripura and it is also attacking the forest ecosystem of the state. *Chromolaena odorata* first arrived in Kerala [64] [65], later it is invaded in all hot places in the country. In the state it inhabits almost in all ecosystem through its rapid propagation which creates a serious menace to the native elements. *Croton bonplandianum* was first introduced in 1897 in East Pakistan from South America by ship [38]. The species furthered propagated along railway track and spread and invaded in various parts of India [66]. At present it is a hazardous weed in all the agricultural field of the study area. *Parthenium hysterophorus* arrived in the state just one decade ago and adversely affect the urban ecosystem as well as various river catches of the state. It was first reported from India in 1956 from western part of peninsular India [67]. *Mimosa pudica* another invasive species was introduced from Brazil and presently it is expanding at an alarming rate in the country. Now the species is vigorously attacking the grass land and creating a major threat to the grazing to livestock.

6. Conclusion

In this investigation, we have compiled all the alien flora of the state with their invasion status. Such careful compilation and categorization of regional alien flora will provide vital clues for revelation of the problem resulting from species invasion. Most of the invasive species in the catalogue are noxious to the agro-ecosystem as well as to the indigenous flora in the state. In this perspective this catalogue could be effective for the prediction of invasive aliens, their monitoring and management practices. This catalogue will obviously help in the agricultural sector in the state as well as in the whole country. It also gives a clue for further introduction of any species in the country. It may help the Department of Forest and Agriculture for further advancement of research in their related field. The present work, hopefully, will help the prologue of such aliens to any new place of Indian sub-continent, Indo barman region as well as other parts of the world.

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