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Incidence of alien Asteraceae in Telangana and residual Andhra Pradesh and possible ecological implications

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The introduction of alien Asteraceae into the states of Telangana and residual Andhra Pradesh is described based on extensive field studies, together with screening available herbarium specimens, floras and taxonomic reports. The centres of origin, growth and life-form nature, habit, habitats they occupy, year of first report, minimum residence time, and district-wise occurrence are compiled. Possible ecological implications of the incidence of these alien species are discussed.

Keywords: Alien Asteraceae, invasives, introductions, natural ecosystem.

INVASIONS by exotic plant species are occurring at unprecedented rates due to human activities that have increased the number of introductions and the rate of spread of many species[1]. Elton[2], 'the father of invasion ecology', introduced the words 'invaders' and 'invasion'. A biological invader is a plant, animal or microbe species which, most usually transported inadvertently or intentionally by humans, colonizes and spreads into new territories some distance from its native range[3]. Plant invasions have been recognized as one of the most serious environmental problems which impact the structure, composition and function of natural and semi-natural ecosystems[4,5]. Plant invasions are found to reduce native species diversity and induce alterations in ecosystem functioning[6]. Increase in the number and spread of alien invasive plants into productive ecosystems causes significant economic losses[7]. Also, biological invasion has been homogenizing the world's flora and fauna[8]. For these reasons, the study of plant invasions not only provides fascinating tests of ecological and evolutionary theory, but also lends a hand in resolving major challenges to natural resource management. The importance of invasive species is underlined by Article 8(h) of the Convention on Biological Diversity[9], which asks for measures 'to prevent the introduction, control or even root out of those alien species which threaten ecosystems, habitats or species'.

The Asteraceae (Compositae) form one of the largest of flowering plant families in the world, with an estimated 22,750 species in 1528 genera[10]. This family is of economic, ecological and environmental importance since

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a large number of its members are weedy, highly adaptive and proven to be invasive and destructive outside their native ranges. There is a limited amount of previous work in India which demonstrates these qualities. For example, the characterization of alien aquatic flora of Kashmir-Himalaya[11] revealed two species of *Bidens* (Asteraceae) that are threatening the freshwater ecosystems. More broadly, Reddy *et al.*[12] enlisted the invasive alien flora of India that included 33 species of Asteraceae. Since there is no census of historic introductions and extent of spread of alien Asteraceae into peninsular India, we attempted to gather this information from two States: Telangana and the residual Andhra Pradesh (AP). The data thus gathered may be of help in assessing the ecological implications of the incidence of these species.

The Compositae of *Flora of the Presidency of Madras*[13] comprised 186 species of 66 genera occurring in the now-residual AP (i.e. in the 'undivided' AP state minus Telangana; terms explained below). There are 17 further additions to the Asteraceae of the 'undivided' State in *Flora of India*[14]. For *Flora of Andhra Pradesh*, Raju and Raju[15] recorded 99 species of 64 genera, in addition to the 6 cultivated genera/species for the family. In 2008, Murthy *et al.*[16] compiled 23 alien species of Asteraceae from AP, since Gamble's[13] publication in 1921.

An alien species (non-indigenous, foreign and exotic) is a species or infraspecific category occurring outside its natural range (past or present) and dispersal potential. However, an alien invasive species which becomes established in natural or semi-natural ecosystems is an agent of change and threatens native biological diversity[17]. The origin, residence time and possible threats of aliens to the native ecosystems of India need to be documented regionally, to begin with. An earlier census of weed flora of disturbed sites in the 'undivided' AP revealed the presence of several alien species that appeared to be expanding their ranges and therefore need to be closely monitored[18]. The primary objective of this communication is to have a census of alien Asteraceae of the newly constituted Telangana State and 'residual' AP. The second objective is to provide information on their up-to-date and currently accepted scientific names, alien species build-up, country of origin, growth and life-form, habitat, early (first) report time, minimum residence time (MRT), and whether the species are naturalized yet or not. Such information is needed for policy development on exotic invasives of natural ecosystems of the Indian states.

Telangana was formed as the 29th state on 2 June 2014 by the Government of India with 10 districts and ground area of 114,883 sq. km whereas the residual AP has 13 (9 districts in coastal Andhra and 4 in Rayalaseema regions), with a geographical area of 160,185 sq. km (ref. 19). These two states are located between 12°37′–19°55′N lat. and 76°45′–84°46′E long. Godavari and Krishna are the two major river systems with monsoon type of tropical climate, which is hot and humid in coastal Andhra, and hot and dry in Telangana. While Telangana is proximate to Deccan traps, the 'residual' AP has the Eastern Ghats traversing through it and an eastern coastal belt (along the Bay of Bengal). Henceforth, we use the terminology 'undivided AP' for the composite state, 'TS' for Telangana and the 'residual AP' for the state of present AP after the segregation of Telangana.

The survey of alien Asteraceae is based on phytosociological and taxonomic studies on one hand, and the specimen depositions in the herbaria and floristic accounts published on the other. Studies were conducted on forest vegetation in northern Telangana during 2008–2012 under the Vegetation Carbon Pool (VCP) Project, and later from July 2012 to the end of 2014 under the UGC Major Project, 'Impact of alien flora on natural ecosystems in Telangana'. Across these projects, 600 quadrats of 1 × 1 m, 240 quadrats of 5 × 5 m, and 368 line transects (10 × 1 m) were laid in the 23 districts of undivided AP covering forests, grasslands, scrub jungles, riparian systems (Godavari and Krishna, and their major tributaries), and major water bodies such as Ramappa, Laknavaram and Pakhal in Warangal, Maneru in Karimnagar, Kinnerasani in Khammam, and Kolleru in West Godavari districts. The herbaceous flora was studied using 1 × 1 m quadrats and shrubs with 5 × 5 m quadrats, to list the species present and their numbers, habit, habitat, growth and life-form details. Additional information comes from vegetation change and weed flora studies by Vatsavaya S. Raju in northern coastal Andhra (from Andhra University, Waltair: 1975–77) and in southern coastal Andhra and Rayalaseema (from Acharya Nagarjuna University, Guntur: 1977–81). The specimens collected were tagged and brought to the laboratory, and identified based on the standard floras[13–15] and e-floras; herbarium specimens have been deposited at KUW (Kakatiya University Herbarium, Warangal). Secondary sources include family accounts in the district and state floras[13,15,20,21], and taxonomic and floral additions made from time to time[22–32]. These were utilized for consolidating the list and accounting for the first early report and MRT. The information described above was used to prepare the checklist of alien Asteraceae of the two states. It is to be noted that the presence of a particular weed in a district is not indicative of the number of individuals sighted during the study or the specimen collections available. Furthermore, the alien species are classified into 'naturalized' and 'casual alien' according to Richardson *et al.*[33], and residence time after Pyšek and Jarošik[34], and Pyšek *et al.*[35]. Alien species that may flourish and even reproduce occasionally outside cultivation in an area but eventually die out because they do not form self-replacing populations, and therefore rely on repeated introductions for their persistence are called the casual aliens. The alien plants that sustain self-replacing populations for at least a decade without direct intervention by people (or despite human intervention), by recruitment from seeds or ramets (tillers, tubers, bulbs, fragments, etc.) and capable of independent growth are called naturalized species[36].

We were able to compile reports of a total of 74 alien Asteraceae in the two Indian states by virtue of their entry and establishment over a span of time (Table 1). The following are the pointers which suggest the trends of floral change due to anthropogenic activities carried out on a large scale in recent times.

Habit (growth and life-form): Majority of the alien Asteraceae listed are annual herbs (therophytes), though *Solidago canadensis* is a hemicryptophyte. Three of them are climbing shrubs (chamaephytes), viz. *Chromolaena odorata*, *Mikania micrantha* and *Tarlmounia elliptica*.

Habitat: A great majority (89.19%) are terrestrial, with a few semi-aquatic (9.46%) and aquatic (1.35%) species. This reflects the fact that the family is largely composed of annuals and shrubs (perennials), and hardly any trees or true aquatics[37]. *Bidens cernua* L., *Bidens tripartita* L. and *Cotula coronopifolia* L. are wetland species of Asteraceae found in the Himalaya, but they do not extend to the south[38]. The two species of *Bidens* mentioned above are found to be problematic in Kashmir-Himalaya[11].

Alien species build-up: Of the 74 species found (Table 1), 48 were reported present in British India as a whole by 1881 (ref. 39) and 60 for independent India as a whole by 1995 (ref. 14). The *Flora of the Presidency of Madras* (that was published in 1921 and excludes TS)[13] records 38 alien Asteraceae. In undivided AP, there were 48 species of Asteraceae introduced till 1997 (ref. 15). This number has now (till 2014) risen to 74 (an increase of 26 species, including the 10 species presently reported – cf. Table 1). During the past 17 years, on an average 3 alien Asteraceae have turned up in the region every 2 years. The present study reports 10 alien Asteraceae members (Table 1) to the two states.

Alien species richness: Alpha diversity is a measure of species richness in a habitat. It is 57 for TS and 61 for the residual AP. Of the 74 species (gamma diversity) recorded for the undivided AP, 43 are common to the separate states, with beta diversity between them being 32 (basic beta diversity index 0.723)[40].

Continental origin: In view of lack of exact information on the country of origin of many species, it is not possible to assign them to the biogeographic regions or divisions. Therefore, the species are attributed, based on the literature, to six mega habitats. Accordingly, the aliens largely originate in the New World: North America (4), Central/Tropical America and Mexico (38) and South America (7). Five species each originate in Europe–Mediterranean and tropical Africa, and 14 from Australia or other countries (excluding India) in Asia. *Anaphalis adnata* is from the Himalaya.

Invasion status: *Carthamus tinctorius*, *Cichorium intybus*, *Cosmos bipinnatus*, *C. sulphureus*, *Guizotia abyssinica*, *Helianthus annuus*, *Solidago canadensis*, *Tagetes erecta*, *Tarlmounia elliptica* and *Zinnia elegans* are the 10 casual aliens, as they constitute obvious escapes from cultivated ground and/or garden. In contrast to alien invasive species, these do not show increased geographical range over time. There are 26 naturalized species (22 found in the two states, one exclusive to TS and three to residual AP), of which some are invasive. There are 21 species which are known invasives (Table 1), while others are under the process of naturalization. Based on the number of districts they are present and relative frequency in the quadrats, we can make a rough assessment of which of these alien Asteraceae are most widespread and numerous and, therefore, of most concern. These include *Parthenium hysterophorus* in both states, *Chromolaena odorata* in coastal Andhra and northeastern TS[41], *Ageratina adenophora* in Araku valley, *Mikania micrantha* in Visakhapatnam, the species of *Acmella* in wet grounds and *Blumea* in upland crops during winter, and *Calyptocarpus vialis*, *Conyza bonariensis*, *Erigeron canadensis* and *Synedrella nodiflora* in gardens and lawns in urban environments of Hyderabad and Ranga Reddy districts. These invasive species may have a number of effects, including reducing available forage for herbivores as well as affecting human-use resources in forest ecosystems.

Residence time: The date of entrance to a target region is a measure of residence time. The residence time is an important factor determining the distribution of alien plants[34]. It is to be acknowledged that the time of entry of species into a new territory and its recorded time are usually two independent events. The time of entry of an alien species is always earlier to its first record, which usually happens after its establishment. The residence time, though useful as a criterion of the period of occupancy, has this inherent problem. The range size of an invasive species depends on how much time it has had to spread (its residence time), while the range size and spread rate are mediated by the total extent of suitable (i.e. potentially invasible) habitat[35]. In this study, 1881 was chosen as the base year from which to calculate MRT for Asteraceae, since the *Flora of British India*[39] had a comprehensive account of the family contributed by Hooker. The study included the alien plant reports up to 2014. Accordingly, 26 species have a residence time of over 93 years in the two states. An additional five species (Table 1) are reported from the residual AP for the same residence time. Of the remaining aliens, 21 have occupied the region for over two decades, 19 for over a decade, and 10 for over a year. This speaks of the rate of introduction of alien Asteraceae into the two states, which is more or less steady.

Spread: The range size and spread rate depend on the frequency and intensity of introductions (propagule pressure), the position of founder populations in relation to the potential range, and the spatial distribution of the potential range. In the present study, we assessed the spread simply as the number of districts in which each species occurs. Nine species of alien Asteraceae (*Acanthospermum hispidum*, *Ageratum conyzoides*, *Blumea*

Table 1. Alien Asteraceae of Telangana and residual Andhra Pradesh: nativity, minimum residence time, habitats they occupy and distribution

Taxon	Year described/ NC or NN made	Origin	Early/first report FBI 1881	FPM 1921	FI 1995	FAP 1997	Later than 1997 Till 2014	MRT (India/TS/RAP) (up to 2014)	Habitat TE/AQ/ SA	Distribution (No. of districts) TS (10)	RAP (13)
Acanthospermum hispidum DC.*¶	1836	Brazil	+	+	+	+		133/93/93	TE	10	13
Acmella calva (DC.) R.K. Jansen*¶	1834/1985	S. Am.	+	+	+	–	2002[30]	133/–/02	SA	–	3
Acmella ciliata (Kunth) Cass.¶	1818/1822	S. Am.	–	–	+	–	PS	19/01/–	SA	1	–
Acmella paniculata (Wall. ex DC.) R.K. Jansen*¶	1836/1985	T. Africa, T. Am.	+	+	+	+		133/93/93	SA	3	2
Acmella radicans (Jacq.) R.K. Jansen¶	1791/1985	Central Am.	–	–	+	–	2008[30]	19/07/07	SA	1	3
Acmella repens (Walter) Rich. ex Pers.¶	1788/1807	T. Am.	–	–	–	–	1999[25]	15/–/15	SA	1	1
Acmella uliginosa (Sw.) Cass.*¶	1788/1822	W. Indies	–	–	+	–	2008[30]	19/06/–	SA	1	–
Adenostemma macrophyllum (Blume) DC.	1826/1836	SE Asia	+	–	+	+		133/–/17	AQ	–	1
Ageratina adenophora (Speng.) R.M. King & H. Rob*¶	1826/1970	Mexico	–	–	+	+		19/–/17	TE	–	2
Ageratum conyzoides L.*¶	1753	T. Am.	+	+	+	+		133/93/93	TE	10	13
Ageratum houstonianum Mill.¶	1768	Mexico	–	–	+	+		19/–/17	TE	–	1
Anaphalis adnata Wall. ex DC.#	1838	Himalaya	+	–	++	+		133/–/17	TE	–	2
Artemisia japonica Thunb.	1784	SE Asia	+	+	+	+		133/–/93	TE	–	1
Bidens bipinnata L.	1753	T. Am.	–	+	+	–	2010[21]	19/04/–	TE	2	3
Bidens cynapiifolia Kunth	1818	Central Am.	–	–	–	+		17/17/–	TE	1	–
Bidens pilosa L.*	1753	T. Am.	+	+	+	+		133/93/93	TE	6	13
Blainvillea acmella (L.) Philipson*	1753/1950	T. Am.	+	+	+	+		133/93/93	TE	7	6
Blumea bifoliata (L.) DC.*	1753/1834	SE Asia	+	+	+	+		133/93/93	TE	3	3
Blumea eriantha DC.*	1834	T. Am.	+	+	+	+		133/93/93	TE	1	1
Blumea lacera (Burm.f.) DC.*	1768/1834	T. Am.	+	+	+	+		133/–/93	TE	2	2
Blumea membranacea DC.*	1836	T. Am.	+	+	+	+		133/93/93	TE	1	4
Blumea obliqua (L.) Druce*	1771/1917	T. Am.	+	+	+	+		133/93/93	TE	10	13
Calyptocarpus vialis Less.¶	1832	Mexico	–	–	+	–	2013[32]	19/01/–	TE	1	1
Carthamus tinctorius L.**	1753	Egypt	–	–	–	+		17/17/17	TE	3	3
Chromolaena odorata (L.) R.M. King & H. Rob.*¶	1759/1970	T. Am.	+	–	+	+		133/17/17	TE	2	5
Chrysanthellum americanum (L.) Vatke	1753/1865	T. Africa	+	–	+	+		133/17/–	TE	3	–
Cichorium intybus L.**	1753	Eurasia	–	–	–	@		74/74/–	TE	1	2
Conyza bonariensis (L.) Cronquist¶	1753/1943	Argentina	–	–	+	–	2008[30]	19/07/07	TE	1	7
Conyza japonica (Thunb.) Less. ex Less.	1784/1836	Japan	+	+	+	–	1997[24]	133/17/17	TE	1	1
Cosmos bipinnatus Cav.**	1791	Mexico	–	–	–	–	PS	01/01/01	TE	2	7
Cosmos sulphureus Cav.**	1791	Mexico	–	–	–	+		17/17/17	TE	3	2
Crassocephalum crepidioides (Benth.) S. Moore	1849/1912	T. Am./ Africa	–	+	+	+		19/–/93	TE	–	2
Cyanthillium cinereum (L.) H. Rob.*	1753/1990	T. Asia	+	+	+	+		133/93/93	TE	10	13
Cyanus segetum Hill	1753/1762	Mediter.	+	–	+	–	PS	133/01/–	TE	1	–
Dicoma tomentosa Cass.*	1818	T. Africa	+	+	+	+		133/93/93	TE	4	3
Echinops echinatus Roxb.*	1832	Afghanistan	+	+	+	+		133/93/93	TE	10	13
Eclipta prostrata (L.) L.*	1753/1771	T. Am.	+	+	+	+		133/93/93	SA	10	13
Emilia sonchifolia (L.) DC. ex DC.*	1753/1834	T. Am.	+	+	+	+		133/93/93	TE	6	6
Erechtites hieraciifolia (L.) Raf. ex DC.	1753/1838	T. Am.	+	–	+	+		133/17/–	TE	2	–
Erigeron canadensis L.¶	1753	T. Am.	+	+	+	+		133/93/93	TE	3	1
Flaveria trinervia (Spreng.) C. Mohr.	1800/1901	Central Am.	–	+	+	+		19/17/17	TE	8	1

(*Contd*)

Table 1. (*Contd*)

Taxon	Year described/ NC or NN made	Origin	Early/first report FBI 1881	FPM 1921	FI 1995	FAP 1997	Later than 1997 Till 2014	MRT (India/TS/RAP) (up to 2014)	Habitat TE/AQ/ SA	Distribution (No. of districts) TS (10)	RAP (13)
Gaillardia pulchella Foug.	1788	Central Am., Mexico	–	–	–	–	2008[20]	06/–/06	TE	–	1
Galinsoga parviflora Cav.*	1796	T. Am.	+	+	+	+		133/93/93	TE	1	3
Gamochaeta coarctata (Willd.) Kerguelen	1804/1987	S. Am.	–	–	–	–	1999[27]	15/15/–	TE	1	–
Gamochaeta polycaulon Pers.	1807	T. Am.	–	+	+	+		19/17/17	TE	1	6
Glossocardia bidens (Retz.) Veldcamp*	1788/1991	SE Asia to Australia	+	+	+	+		133/–/93	TE	–	3
Glossocardia bosvallea (L.f.) DC.*	1781/1834	Eastern Asia	+	+	+	+		133/93/93	TE	6	3
Gnaphalium purpureum L	1753/1961	T. Am.	+	–	+	–	2008[30]	133/06/06	TE	1	1
Grangea maderaspatana (L.) Poir.*	1753/1812	T. South Am.	+	+	+	+		133/93/93	TE	5	7
Guizotia abyssinica (L.f.) Cass.**	1781/1829	T. Africa	+	+	+	+		133/–/93	TE	–	4
Helianthus annuus L.**	1753	N. Am.	–	–	–	+		17/17/17	TE	5	6
Lagascea mollis Cav.¶	1803	Central Am.	+	+	+	+		133/93/93	TE	4	7
Laphangium luteoalbum (L.) Tzvelev	1753/1994	N. Am. (California)	+	–	+	+		133/–/17	TE	–	1
Mikania micrantha Kunth¶	1818	T. Am.	+	–	+	–	2009[31]	133/–/05	TE	–	2
Oligochaeta ramosa (Roxb.) Wagenitz	1832/1962	Western Asia	+	+	+	+		133/93/93	TE	6	8
Parthenium hysterophorus L.¶	1753	T. South Am.	–	–	+	+		200$/19/19	TE	10	13
Pulicaria foliolosa DC.	1836	Afghanistan	+	–	+	+		133/17/–	TE	1	–
Pulicaria wightiana (DC.) C.B. Clarke	1833/1876	T. Am.	+	+	+	+		133/93/93	TE	8	4
Solidago canadensis L.**	1753	T. Am.	–	–	–	–	PS	01/01/01	TE	1	1
Sonchus asper (L.) Hill	1753/1769	Mediter.	+	–	+	–	2000[28]	133/14/–	TE	1	–
Sonchus brachyotus DC.	1838	SE Asia, Japan, Thailand	+	+	+	+		133/–/17	TE	–	1
Sonchus oleraceus (L.) L.	1753	Mediter.	+	+	+	+		133/93/93	TE	8	10
Sphagneticola trilobata (L.) Pruski¶	1759/1996	T. Am.	–	–	+	–	PS	19/01/01	TE	2	3
Symphyotrichum ericoides (L.) G.L. Nesom	1753/1995	N. Am.	–	–	–	–	2010[21]	04/04/–	TE	1	–
Synedrella nodiflora (L.) Gaertn.¶	1755/1791	W. Indies	+	+	+	+		133/93/93	TE	1	3
Tagetes erecta L. (incl. *T. patula* L.)**	1753	S. Am.	–	–	–	–	PS	01/01/01	TE	3	3
Taraxacum javanicum Soest	1963	Java	–	–	+	–	PS	19/01/–	TE	3	–
Tarlmounia elliptica (DC.) H.Rob. *et al.***	1834/2008	Myanmar	–	–	–	–	PS	01/01/01	TE	3	4
Tithonia diversifolia (Hemsl.) A.Gray	1881/1883	Central Am.	–	–	+	–	PS	19/–/01	TE	–	1
Tridax procumbens (L.) L.*¶	1753	Central Am.	+	+	+	+		133/93/93	TE	10	13
Verbesina encelioides (Cav.) Benth. & Hook.f. ex A. Gray	1793/1876	T. Am.	–	–	+	+		19/17/17	TE	1	1
Xanthium strumarium L.*¶	1753	N. Am.	+	+	+	+		133/93/93	TE	10	13
Youngia japonica (L.) DC.	1767/1838	Eastern Asia	+	+	+	–	1999[26]	133/15/15	TE	1	1
Zinnia elegans L.**	1793	Mexico	–	–	–	–	PS	01/01/01	TE	1	1

AQ, Aquatic; FAP, Flora of Andhra Pradesh (1997); FBI, Flora of British India (1881); FI, Flora of India (1995); FPM, Flora of the Presidency of Madras (1921); MRT, Minimum residence time; NC, New combination; NN, Nomen nova; PS, Present study; RAP, Residual Andhra Pradesh; SA, Semi-aquatic; TE, Terrestrial; TS, Telangana State. *Naturalized; **Casual alien; ¶Invasive; #Native exotic; @Reported in 1940 (ref. 22), but not included in FAP. $*Parthenium hysterophorus* is believed and widely quoted to have entered India through Maharashtra in 1956, as reported by Rao[42]. In fact William Roxbourgh, the *Father of Indian Botany*, has recorded in 1814 its accidental introduction from West Indies into East India Company Botanic Garden at Calcutta in 1810 (refs 43, 44). Therefore, its entry time is much earlier and is about 200 years ago. Am, America; N, North; S, South; SE, Southeast; T, Tropical; +, Reported; –, Not reported.

obliqua, *Cyanthillium cinereum*, *Echinops echinatus*, *Eclipta prostrata*, *Parthenium hysterphorus*, *Tridax procumbens* and *Xanthium strumarium*) are found in all districts; at the other extreme, 33 species are known from single collection (neophytes) each from a district (15 from Telangana and 10 from the residual AP, and 8 from both the states; Table 1). We are yet to know the effect of residence time of individual invading species at local scale, the natural ecosystem, e.g. a forest, lake or river. However, it may be stated that the rag weed/congress grass (*Parthenium hysterophorus*) has put up MRT of 58 (ref. 42) to 200 (refs 43, 44) years by 2014. As stated earlier, the time of entry of a plant alien into a country (1814)[44] is always earlier to its first report (1956)[42]. By its prolific seed setting habit, ability to spread and residence time in India, the congress grass by now has become a competitive, persistent and pernicious (noxious) environmental weed all over the country.

The present study documents plant invasions in two states in the country, by taking the example of just one family. The list thus generated (Table 1) hints at the magnitude of plant invasions for all taxa taken together. Given what we know about the detrimental effects of invasive species on natural as well as agricultural ecosystems, it is of great importance to document and monitor the introduction and spread of alien plants into India. In addition, steps must be taken, at both policy and implementation levels, to assess and control the impacts of invasive plants.

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Food resource exploitation in ladybirds: consequences of prey species and size

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In the present study, preference between larger and smaller instars of *Acyrthosiphon pisum* and *Aphis craccivora* by small and large female variants of ladybirds *Menochilus sexmaculatus* and *Propylea dissecta* has been investigated. Results reveal that both ladybird species consumed smaller prey, *A. craccivora* over larger prey, *A. pisum* when kept individually and/or in combination. Although small and large female variants of both ladybird species consumed smaller and larger instars of *A. craccivora* respectively, they preferred smaller instars of *A. pisum*. Similar results were also recorded within combinations. Thus, food resource exploitation in both ladybirds is due to both prey species and size.

Keywords: Aphids, food resource exploitation, ladybirds, prey species and size resource polymorphism.

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IN a biological community, resources are used and exploited both inter- and intra-specifically through resource partitioning and resource polymorphism respectively. While resource partitioning is differential use of resources, such as food and space by different competing species[1,2], resource polymorphism is the occurrence of discrete intraspecific variants that differ in size, colour, behaviour and/or life-history traits and show differential niche use, usually through discrete differences in feeding biology and habitat use[3–5]. Thus, by developing dissimilar resource requirements, resource partitioning allows different species and resource polymorphism allows variants or life stages of the same species to differentially utilize resources[1,6,7].

Although both resource partitioning and resource polymorphism have been widely studied in fish, amphibian and bird predators[4,8,9]; in insect predators, resource partitioning, rather than resource polymorphism has been investigated[10–12]. Within a community, competing insect predators generally partition their prey resources on the basis of their own size and/or size of their prey[10–13]. Amongst insect predators, size-based resource partitioning commonly occurs in ladybirds (Coleoptera: Coccinellidae)[11,12], a group of predatory insects with considerable potential as biocontrol agents of aphids and other pest species[14].

According to Sloggett's[12] prey size–density and Dixon's[15] hypotheses, when both large and small ladybird species have equal probabilities of catching smaller species of prey, small ladybird species will capture all instars of prey, whereas large ladybird species will capture larger instars. In contrast, when prey is large, small ladybird species will capture smaller instars, whereas large ladybird species will exploit all instars. Thus, large and small competing ladybird species coexist in the same agricultural fields, feeding on the same prey resources, owing to partitioning of prey resources on basis of their size.

However, aphidophagous ladybirds also show natural intraspecific size variations (within the same sex) under laboratory conditions (even when reared on *ad libitum* aphid prey[16]), and both small and large males/females are found within small (e.g. *M. sexmaculatus* and *Propylea dissecta* (Mulsant))[16] and large (e.g. *Coccinella septempunctata* (L.) and *C. transversalis* Fabricius)[17] ladybird species. In agricultural fields, different sized variants of a ladybird species also coexist (pers. obs.). Similarly, aphid