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ALIEN AND INVASIVE PLANT SPECIES OF THE INDUS DELTA

M. Imran[1], Surayya Khatoon[2], Sahar Zaidi[3], Qadeer M. Ali[4], and Ghulam Akbar[5]

[1]*Government Degree Science College, Gulzar -e- Hijri, Karachi, Pakistan.*
Email: imranbotanist@gmail.com
[2]*Botany Department, University of Karachi, Karachi – 75270, Pakistan.*
Email: surayyakhatoon@yahoo.com
[3]*Botany Department, Federal Urdu University of Arts, Science and Technology, Gulshan-e- Iqbal, Karachi, Pakistan.* Email: saharzee@hotmail.com
[4]*Marine Reference Collection and Resource Centre, University of Karachi, Karachi – 75270, Pakistan.*
Email: taxonomist@hotmail.com
[5]*Pakistan Wetlands Programme – WWF, House No. 62, St. No. 25, Sector F-10/1, Islamabad, Pakistan.*
Email: akbarwwf@yahoo.com

ABSTRACT

Floristic survey of the Indus delta was conducted over ten years from 2001 to 2011. During this work, 31 alien or non –native species were collected for the first time from the study area, of which three species, viz. *Prosopis juliflora*, *Salvinia molesta*, and *Eichhornia crassipes* were found to be highly invasive; the first one in the terrestrial habitats and later two in freshwater to brackish aquatic ecosystems. Another 3 species were also found to be invasive, while 10 showed tendency to become invasive in future. Invasive species are recognized as a big threat to the native biodiversity. They also create many other environmental problems and even threaten the health of human beings and livestock. A comparison with the old records showed that the number of alien species has steadily increased in the recent decades. Before the present work, only 25 alien or non-native species were known from the study area and none of them was invasive. The total number of alien species is now 56.The factors responsible for the spread and establishment of alien species include increased and faster human travel, increased international trade, and destruction, fragmentation, or modification of the natural habitats. The current global climatic change may be another contributing factor in the future; therefore an effective strategy is needed to check further import and establishment of alien species.

Key-words: Alien, invasive plant species, biodiversity, environmental factors, Sindh, Indus delta, Pakistan

IINTRODUCTION

Every species has originated at certain place, from where it spread over certain area. Plant species increase the area under their populations through the dispersal of their seeds, while animals can increase their area by their active movement. The geographic area thus occupied by a species through its own natural efforts is known as the "natural range" of that species. An alien species for an area is that species which arrives there with intentional or unintentional human help over such a distance or over such a geographic barrier which it could not have crossed with its natural means; thus it is outside its natural range in the new area.

Although every alien species does not become an invasive species in its new environment, some may not even survive, but some alien species not only successfully establish at the new place but also become aggressive and invade natural and semi-natural ecosystems by out-competing the native flora or fauna. Secondary metabolites can play a role in giving them a competitive advantage (Felline *et al*., 2012). An invasive species is an alien species that invades or colonizes natural or semi-natural ecosystems or habitats, and is an agent of change, and threatens native biodiversity (Clout and Lowe, 1996; Heywood 1995). With the improvement in humankind's transportation technology, the travel of species across their natural boundaries has exponentially increased (Randall and Marinelli 1996); these may be deliberate introductions, or contaminants, or stowaways.

The invasion numbers have increased drastically over the last five centuries, this exponential increase is not leveling off, and human activities are the only reason for this phenomenon (Pascal *et al*., 2010). As both intentional and unintentional introductions increased through the 20th century, biologists gathered mounting evidence of the threat that some introductions pose for native species and ecosystems and for human well-being (Simberloff *et al*., 2013). The key factor in the susceptibility of an ecosystem for the establishment of an alien species is human-induced disturbance of ecosystem (McNeely, 1995). For example in the arid western USA the invasion of non-native plants is compounded and in some cases exacerbated by the dry-land and irrigated agriculture and urbanization, and it is modifying the structure and composition of vegetation in the riparian zones (Fleishman *et al*., 2003). The invasive species *Polygala paniculata* in Tanzania was found strongly associated with cow dung,

indicating that further increase in cattle numbers may result in further problems associated with this species (Andrew *et al.*, 2012). Many species do best in the urban fringe environments (McNeely, 1998).

The invasive plant species also affect the native fauna. Plant composition undoubtedly influences the faunal assemblages like birds and butterflies, these being more closely associated with floristics than with physiognomy (Fleishman *et al*., 2003). Alien species can cause severe changes in ecosystems' functioning (Felline *et al*., 2012). This is why the biological invasions are recognized as a pervasive global change, challenging the conservation of biodiversity and natural resources (Simberloff *et al*., 2013; Felline *et al*., 2012). Human well-being and survival crucially depend upon Earth's biodiversity and natural resources; the invasive species pose a direct threat to these. For this reason, the Article 8(h) of the Convention on Biological Diversity (CBD) calls upon the participating nations to "prevent the introduction of, and to control or eradicate those alien species which threaten ecosystems, habitats, or native species" (www.cbd.int).

MATERIALS AND METHODS

The area covered in the present study, measuring 3952.67 Km^2 (395267 hectares), included both the upper deltaic plain and lower deltaic plain on both sides of the Indus River and included most of the active delta. The study area lied wholly in the Thatta District, Sindh.

Field surveys and collection of specimens were done in the study area for ten years from 2001 – 2011. All those localities were covered that had been sampled in Blatter *et al.* (1929) and Flora of Pakistan; and a number of additional localities were also sampled. The Indus delta and sampling points are shown in the **Map 1**. The study area was differentiated into 3 zones on the basis of topography, soil characteristics, hydrology, and habitat types.

The Zones – 1 and 2 lied wholly in the upper deltaic plain with low hills of Khirthar foothills along their northern and northwestern margins, while the Zone – 3 included part of upper deltaic plain and lower deltaic plain. The main localities of **Zone – 1** were: Bhambore, Gharo**,** Makli**,** Ghulam Ullah, and Kullen Kote. The main localities of the **Zone – 2** were: Haleji, Thatta, Indus river bed, and Keenjhar Lake (including Jhimpir); while the main localities of the **Zone – 3** were: Mirpur Sakro, Bohara**,** Keti Bundar, and Shah Bundar.

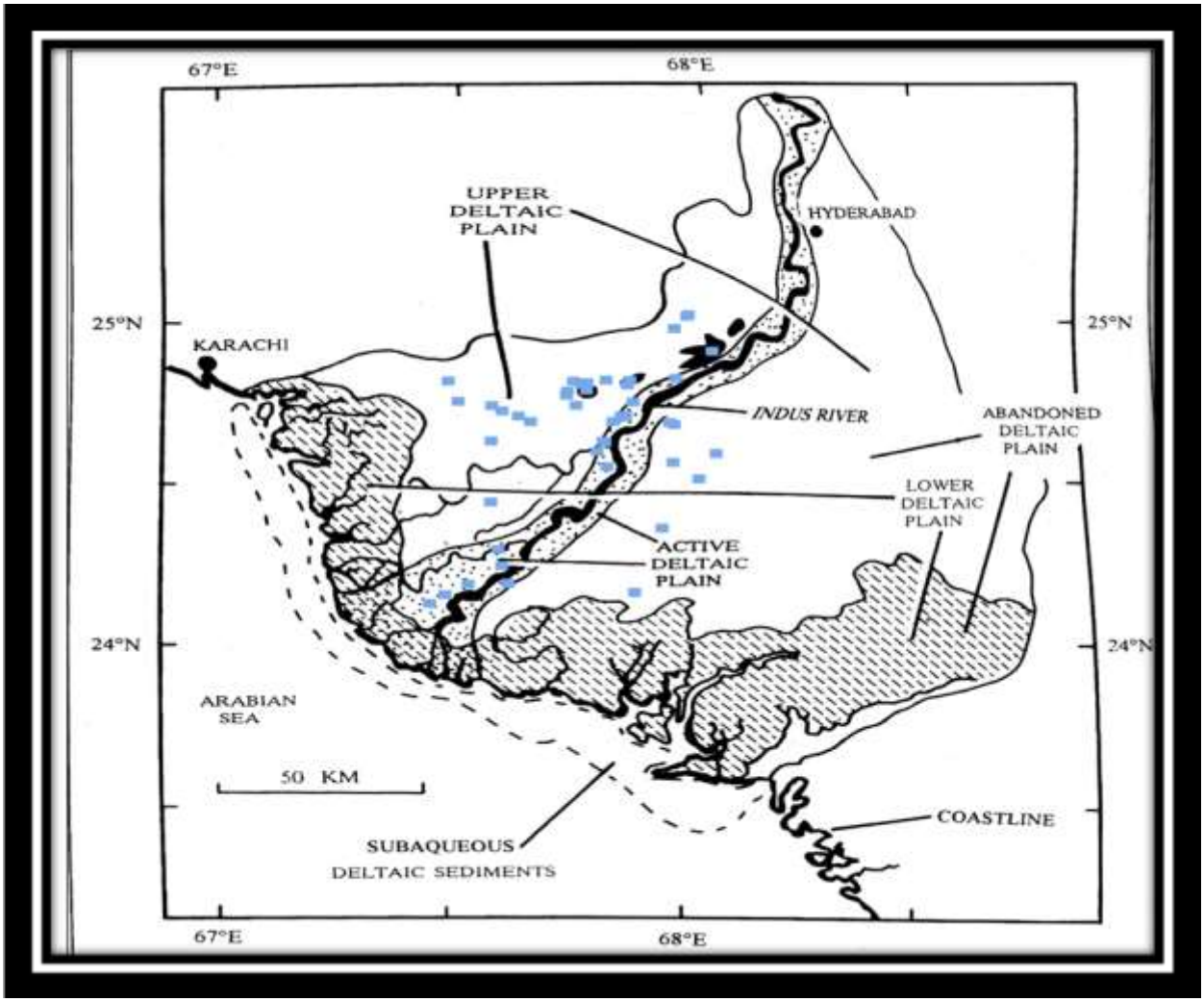
Specimens of all the available species in each locality were collected along with the relevant field data and duly pressed and dried. Plant specimens were identified with the help of Flora of Pakistan and some other relevant Floras (Nasir and Ali 1970-1989, Ali and Nasir 1989-1991, Ali and Qaiser 1992-1998, 2000- to date, Jafri 1966, Boulos 1991, Bhandari 1987). The voucher specimens will be deposited in the Karachi University Herbarium (KUH), Botany Department of University of Karachi, Pakistan.

The native distribution of each species was traced from the on-line database USDA GRIN (2013), unless otherwise mentioned.

OBSERVATIONS AND RESULTS

A total of 56 alien (non-native) species was recorded from the study area belonging to 46 genera and 28 families. One family was of Pteridophytes, and 21 were Dicot and 6 Monocot families. Among species, one was a Pteridophyte, 38 were Dicots and 17 were Monocots. The highest number of alien species belonged to Poaceae (11 species), followed by Asteraceae (7), and Euphorbiaceae and Solanaceae (4 species each). Eleven alien genera and 31 alien species were new records for the study area. In the work of Blatter et al. (1929) there were 15 alien species, while the Flora of Pakistan reported another 11 alien species in addition to those previously known (**Table - 1**).

The total number of alien species in zone – 1 was 44, zone – 2 had 40 species and the zone – 3 had 44 species. Most of the alien species were associated with agro-ecosystems while a few were found in other kinds of habitats. Habit-wise, 29 were perennial herbs, 23 were annual herbs, and 4 were shrubs. While a majority of them appeared to be living more or less in equilibrium with the native flora, six were moderately to highly invasive in the study area, while another 10 had a tendency to become invasive in the future. In the terrestrial ecosystems, *Prosopis juliflora* was the worst invasive species; while in the freshwater bodies (lakes and canals) *Salvinia molesta* was the worst, followed by *Eichhornia crassipes*. While *Salvinia molesta* was found in freshwater bodies, *Eichhornia crassipes* occurred in both freshwater and brackish water. The complete list of alien species recorded from the study area along with brief information about each species is given in the **Table - 2**. The new records are marked with a square (□), while the invasive species are marked with double asterisk (**), and those with a tendency to become invasive are marked with a single asterisk (*):



Map – 1: Map of the whole Indus delta showing the collection points (■) of the present study (adopted and modified from Meadows & Meadows, 1999).

Table 1. Alien or non-native plant species recorded by Blatter *et al.* (1929) and Flora of Pakistan.

S. No.	**Alien species at the time of Blatter *et al.* (1929)**	S. No.	**Alien species reported in the Flora of Pakistan (Additional to those reported earlier)**
1.	*Amaranthus viridis*	1.	*Conyza aegyptiaca*
2.	*Celosia argentea*	2.	*Gnaphalium polycaulon*
3.	*Chenopodium murale*	3.	*Heliotropium curassavicum*
4.	*Cleome viscosa*	4.	*Lepidium didymum* (Synonym: *Coronopus didymus*)
5.	*Euphorbia hirta*	5.	*Passiflora incarnata*
6.	*Portulaca oleracea*	6.	*Persicaria glabra*
7.	*Eclipta prostrata*	7.	*Lantana camara*
8.	*Datura fastuosa*	8.	*Fimbristylis cymosa*
9.	*Physalis divaricata*	9.	*Paspalum paspalodes*
10.	*Phyla nodiflora*	10.	*Najas minor*
11.	*Cynodon dactylon*	11.	*Stuckenia pectinata* (Synonym: *Potamogeton pectinatus*)
12.	*Echinochloa colona*		
13.	*Echinochloa crus-galli*		
14.	*Setaria verticillata*		
15.	*Typha domingensis*		

Table 2. Alien and invasive plant species of Indus Delta.

S. No	Family Name with Scientific and Common Names	Brief remarks on occurrence	Invasiveness	Native Distribution
1	Salviniaceae ***Salvinia molesta*** □ (Water fern, Kariba weed)	This root-less free floating fern was found abundantly in freshwater bodies like lakes and canals, particularly in the zones 2 and 3. In the zone 3 several canal surfaces were found completely covered by this plant (**Fig. 1**). In zone 2 as well some canal surfaces were found fully covered by it. In the initial years of the study, it was recorded from along the south eastern bank of the Keenjhar lake, which is a much visited picnic spot. It was absent across the lake at Jhimpir coast at that time. However, now it has invaded the Jhimpir coast as well (**Fig. 2**).	Highly invasive.	Brazil.
2	Acanthaceae ***Ruellia tuberosa*** □	This perennial herb was occasionally found at wet places near cultivated areas in the zone-1.	Not invasive at present	South America
3	Amaranthaceae ***Amaranthus viridis*** (Green Amaranth)	This annual/perennial herb was frequently found at wet places near cultivated areas in all the three zones.	Not invasive at present	Origin obscure, possibly South America
4	***Celosia argentea*** (Feather Cockscomb, Silver cockscomb.	This species was occasionally found on rocky slopes in the zone-3.	Not invasive at present	Exact native range obscure, perhaps India
5	Asteraceae ***Conyza aegyptiaca***	It was frequently found at wet places in and around cultivated lands of all three zones.	Apparently not invasive at present	Tropical and subtropical Africa
6	***Conyza bonariensis*** □	This species was frequently found at wet places in and around cultivated lands in the zone 1 and 3.	Not invasive at present.	South America
7	***Eclipta prostrata*** (Eclipta, False Daisy)	This herbaceous species was found at water margins in freshwater lakes and canals in all the three zones.	Not invasive at present	N. America and S. America
8	***Flaveria trinervia*** □ (Clustered yellow tops, Speedy weed)	This species of wet places was found only at one locality in the southern-most part of zone-3, in the premises of a farmhouse.	Not invasive at present.	Southern USA, Mexico, Caribbeans, Central, Tropical & S. America.
9	***Gnaphalium polycaulon*** (Western Cudweed)	This small herb was occasionally found in wet soils in agricultural fields of zone 1 and 2.	Not invasive at present.	Northern Africa
10	***Tridax procumbens***	This annual/perennial herb was found on wet soils near cultivated fields in zone 1 and 2. Invasiveness: Although it forms pure populations, at present it may not be regarded as an invasive species; however, it has a tendency to become an invasive in the future.	Has a tendency to become invasive	Northern and South America, Brazil (Atlas of Florida)

Table 2. (Cont'd.)

S. No	Family Name with Scientific and Common Names	Brief remarks on occurrence	Invasiveness	Native Distribution
11	***Xanthium strumarium**** □ (Cocklebur)	This robust perennial shrub was found along water margins at Keenjhar lake in zone-2, and in an agricultural field in zone-3.	At Keenjhar lake it formed a pure population in small area; therefore it shows a tendency to become invasive.	North America
12	Boraginaceae ***Heliotropium curassavicum*** (Seashore Heliotrope, Smooth Htliotrope)	This glabrous species of *Heliotropium* was found along water bodies margins, both fresh and brackish, and on moist saline soils in all the three zones.	Not invasive at present.	USA, Mexico, Caribbean, Central America, South America
13	Brassicaceae ***Lepidium didymum**** □ (Syn: *Coronopus didymus*)	This small herb was found in some agricultural fields in the zone 2 and 3.	In isolated cases it was found to form dense pure populations, showing a tendency to become invasive.	South America
14	Capparidaceae ***Cleome viscosa*** (Tickweed, Wild mustard)	This summer annual was found on sandy-silty and gravelly surfaces in all the three zones.	Apparently not invasive at present.	Probable origin tropical Asia
15	Chenopodiaceae ***Chenopodium album*** (Fat-hen, White Goose foot)	This winter annual was frequently found in agricultural fields and fallow fields in all the three zones.	In spite of being frequent, it did not show gregarious nature or dense pure populations. Therefore apparently not invasive at present.	N.Africa, Europe, Temperate Asia
16	***Chenopodium murale***	Also a winter annual, this species was also frequently found in agricultural fields and fallow fields in all the three zones.	It did not show any pure populations therefore, apparently not invasive at present.	probably native to southern and southeastern Asia (Atlas of Florida)
17	Convolvulaceae ***Ipomoea carnea**** (Bush Morning Glory)	This robust shrub was frequently found on wet places and along water margins, both fresh and brackish, in all the three zones.	It forms dense pure populations therefore, shows a tendency to become invasive. It may have already replaced certain native species in the zone-3. It may be considered as moderately invasive	Mexico, Caribbean, South America
18	Euphorbiaceae ***Croton bonplandianus****	This perennial herb/sub-shrub was recorded from agricultural fields from two localities, one each in the zone 1 and 2.	Not invasive at present, but has a tendency to become invasive	S. America

Table 2. (Cont'd.)

S. No	Family Name with Scientific and Common Names	Brief remarks on occurrence	Invasiveness	Native Distribution
19	***Euphorbia heterophylla*** □ (Mexican fire plant)	It was recorded from only two localities in the zone 1 and 3, where just a few individuals were present.	Not invasive at present.	Southern USA, Mexico, Caribbean, Central America, Tropical S.America
20	***Euphorbia hirta*** (Asthma plant, Garden Spurge)	This small herb was recorded from wet places near cultivated places, particularly as a lawn weed, in all the three zones.	Not invasive at present.	Southern USA, Mexico, South America
21	***Euphorbia serpens*** □	This delicate herb was found in moist soils of agricultural fields in all the three zones.	Not invasive at present.	USA, Mexico, South America
22	Mimosaceae ***Prosopis glandulosa**** □ (Honey Mesquite)	This large shrub was recorded from all the three zones, mainly from roadsides. It was comparatively more frequent in the zone-3.	Apparently not invasive at present, but may become so in future.	USA, Mexico
23	***Prosopis juliflora**** (Algarraba-bean, Mesquite)	This large shrub/tree was frequently found in all the three zones of study area in all kinds of terrestrial habitats. It forms dense, large, pure populations almost everywhere. Exceptionally large populations were seen in the Indus river bed at Sujawal-Thatta crossing, and on road sides in zone 1 and 2.	Highly invasive in natural and semi-natural ecosystems.	Mexico, Central America, Tropical S. America
24	Nyctaginaceae ***Boerhavia repens***	This perennial herb was recorded from only one locality in the zone-1, found on sandy loam and gravelly surfaces.	Not invasive at present.	Exact native range obscure
25	Oxalidaceae ***Oxalis corniculata*** □ (Creeping Lady's-sorrel, Creeping wood-sorrel)	This delicate herb was recorded from moist places in zone 2 and 3.	Not invasive at present.	Origin obscure
26	Papilionaceae ***Trifolium alexandrinum*** □ (Berseem Clover)	This species was found in three localities in all the three zones (one each) in agricultural field margins and fallow fields.	Not invasive at present.	Probable origin south west Asia
27	Passifloraceae ***Passiflora incarnata*** (Apricot-vine, Maypop Passion flower)	This herbaceous climber was found in two localities of zone-1.	Not invasive at present.	USA
28	***Passiflora suberosa*** □ (Syn: *Passiflora minima*)	It was found in one locality each of the zone-1 and zone 3.	Not invasive at present.	West Indies (Flora of Pakistan)

Table 2. (Cont'd.)

S. No	Family Name with Scientific and Common Names	Brief remarks on occurrence	Invasiveness	Native Distribution
29	Polygonaceae ***Persicaria glabra**** □ (Smooth smartweed)	This emergent aquatic herb was found in freshwater bodies in the zone 2 and 3, particularly in Haleji and Keenjhar lakes in shallow water.	This species forms pure populations; however not invasive at present, but may become so in future.	Exact native range Obscure
30	Portulacaceae ***Portulaca oleracea*** (Purslane, Little Hogweed)	This fleshy herb was found in all the three zones on moist soils, being more frequent in zone-3.	Not invasive at present.	Origin unknown
31	Sapindaceae ***Cardiospermum halicacabum*** (Balloonvine)	This climber was found in two localities of zone 1 and 3 (one each), in moist places.	Not invasive at present.	Exact native range obscure, probable origin neotropics
32	Solanaceae ***Nicotiana plumbaginifolia*** □	This herbaceous species found in two localities of zone 1 and 3 at wet places near cultivated areas.	Not invasive at present.	Mexico, Caribbean, C.America, S, America
33	***Datura fastuosa*** (Downy thorn apple)	This robust herb was frequently found in all the three zones around cultivated areas and inhabited areas.	Not invasive at present.	Possible origin West Indies
34	***Physalis divaricata*** (Green Goose-berry, Annual Ground Cherry)	This species was found occasionally in all the three zones at wet places and along fresh water margins.	Not invasive at present.	Possible origin Neotropics
35	***Physalis peruviana*** □ (Cape Goose-berry, Golden berry)	This species was also found occasionally in all the zones near cultivated areas.	Not invasive at present.	South America
36	Sphenocleaceae ***Sphenoclea zeylanica*** □ (Chickespike, gooseweed)	This somewhat fleshy aquatic species was found in rice paddies at one locality in the zone-1, where it formed a moderate sized population.	Not invasive at present.	Africa
37	Tiliaceae ***Corchorus aestuans***	This herbaceous species was found occasionally in all the three zones at moist places.	Not invasive at present.	Mexico,Caribbean, C.America, S.America
38	Verbenaceae ***Lantana camara*** (Common Lantana)	This shrubby species was found only at one locality in zone-1 on moist soil.	Not invasive at present.	Mexico,C.America, S.America, Caribbean
39	***Phyla nodiflora**** (Carpet weed, Cape weed)	This prostrate perennial herb was frequently found at wet places and along freshwater margins in all the three zones. It was found quite abundant at Keenjhar.	This species forms dense pure populations therefore, shows a tendency to become invasive.	Perhaps native only in New World
40	Cyperaceae ***Fimbristylis cymosa*** □	This semi-aquatic species was found from only one locality in the zone-2.	Not invasive at present.	Australia, Mexico, Caribbean, tropical South America
41	Najadaceae ***Najas minor**** (Brittle Naiad, Brittle water nymph)	This aquatic species was recorded from freshwater bodies in zone 1 and 3.	Not invasive at present, but shows a tendency to become so in future.	Europe

Table 2. (Cont'd.)

S. No	Family Name with Scientific and Common Names	Brief remarks on occurrence	Invasiveness	Native Distribution
42	Poaceae ***Chloris barbata*** (Giant ginger grass, Purple top chloris)	This species was frequently found near cultivated places in all the three zones.	Not invasive at present.	Origin obscure
43	***Cynodon dactylon***	This rhizomatous species was frequently found in all the three zones.	Not invasive at present.	Origin obscure
44	***Echinochloa colona*** (Barnyard Millet)	This species was frequently found at irrigation channels' margins and other wet places in all the three zones.	Not invasive at present.	Origin obscure
45	***Echinochloa crus-galli*** (Cockspur Grass, Barnyard Grass)	This species was found only in one locality on wet saline soil in zone-3.	Not invasive at present.	Origin obscure, likely tropical Asia
46	***Echinochloa frumentacea*** □	This species was found occasionally in agricultural fields in zone 1 and 3.	Not invasive at present.	Temperate Asia, China (USDA NRCS)
47	***Paspalum paspalodes*** (Couch Paspalum, eternity grass, Ginger grass)	This species was occasionally found at wet places in the zone 1 and 2.	Not invasive at present.	Exact native range obscure, probably origin neotropics
48	***Paspalum vaginatum**** □ (Biscuit Grass, seashore Paspalum)	This rhizomatous species was frequently found along the margins of irrigation channels and cultivated fields' periphery in all the three zones.	Not invasive at present, but shows a tendency to become so in the future.	Africa, temperate and tropical Asia
49	***Pennisetum purpureum*** (Barner/Elephant grass)	This species was found only one locality in the zone-3.	Not invasive at present.	Tropical Africa
50	***Phragmites australis**** □ (Common/Ditch reed)	This robust rhizomatous species was frequently found in all the three zones in moist places, water-logged fields, and in shallow water, particularly in Haleji lake.	Highly invasive.	Exact native range obscure
51	***Setaria verticillata*** (Bristle pigeon grass, Bristly foxtail)	This perennial species was infrequently found in all the three zones near cultivated areas.	Not invasive at present.	Africa, Europe, temperate Asia
52	***Sporobolus nervosus*** □	This species was found at two localities in the zone 2 and 3.	Not invasive at present.	Africa
53	Pontederiaceae ***Eichhornia crassipes**** (Lilac-devil, Water Hyacnith)	This robust aquatic species was frequently found in all the three zones in both freshwater and brackish water bodies, frequently covering water surfaces by its aggressive growth.	Highly invasive.	South America
54	Potamogetonaceae ***Potamogeton lucens***(Shining Pondweed)	This aquatic species was found only in Keenjhar lake in zone-2.	Not invasive at present.	N. Africa, Europe, temperate Asia
55	***Stuckenia pectinata**** □ (Syn: *Potamogeton pectinatus*) (Sago Pondweed)	This aquatic species was also found in the Keenjhar lake only in the zone-2.	Not invasive at present.	Nearly cosmopolitan in wetlands
56	Typhaceae ***Typha domingensis**** (Cat tail)	This robust semi-aquatic to aquatic species was found in all the three zones in both freshwater and brackish water bodies and at wet places. Particularly abundant in water-logged fields and in shallow water at Haleji Lake margins.	Highly invasive in wet places.	Widespread in tropics, subtropics and warm temperate regions

Fig. 1. A view of canal at Ghulam Ullah, water surface covered by *Salvinia*.

Fig. 2. A view of Keenjhar lake at Jhimpir (↙) shows the propagation of *Salvinia* which was not present at this margin until 2009.

DISCUSSION

The invasive species pose one of the greatest dangers to Earth's over all biodiversity (Randall and Marinelli, 1996). `The invasive species usually out-compete native species for nutrients and space and change the structure and function of ecosystem. Besides this, they may cause various problems for human or livestock health, or navigation problems in waterways, etc. The invasive species are considered as a more pervasive threat than chemical pollution, because the chemical pollution usually begins to dilute and subside once the pollution source is blocked; but the invasive species on the other hand continue to proliferate and spread after being introduced, creating generally irreversible impacts (O'Konnen *et al.,* 1999).

Blatter *et al.* (1929) were the first to thoroughly survey the Indus delta area in 1922 and prepare a comprehensive inventory of the plants of the area along with notes on the ecology, geology, hydrology, and climate of the area. At that time, there were only 15 alien species and none of them was invasive. The Flora of Pakistan teams visited the Indus delta area in 1970s and 1980s, and reported 11 alien species in addition to those reported by Blatter *et al.* (1929), that is, the total number came to be 26. The new records of alien species in the present work exceed both the previous works and the total number of alien species has now more than doubled, i.e. 56. The trend of an increasing incidence of non-native and invasive species around the world is shown by the present data as well, and a rapid increase has occurred in the past three to four decades.

Ninety-one years back, that is, at the time of Blatter et al. (1929), the Indus delta was just sparsely populated. There was hardly any industry and agriculture was also on small scale. There was not any elaborate irrigation system; all the canals were inundation canals. The Indus River was without any dams and barrages on its entire length; therefore it flowed in its natural form inundating vast areas in its flood plain, adding nutrient-rich sediment each year to the flood plain. Most parts of the delta therefore existed in more or less undisturbed, natural condition. All the conditions of that time gradually changed with the increase in human population and developmental activities. From 1950s onwards a number of dams and barrages have been constructed on Indus River and its tributaries, and the main river has been restricted within artificial embankments in considerable part of its lower reaches. The yearly inundation of the flood plain is therefore now non-existent. The whole deltaic plain now has extensive canal system for agriculture and for other human uses. The canal system has caused severe problem of seepage leading to water logging and salinity observed in all the three zones of the study area, but were more severe in the zone-3. Most part of the study area is now predominantly agricultural and populated, therefore hardly any place can be considered as pristine or in its natural condition. The villages of the past have now grown into large towns and cities while numerous new villages and small towns have arisen. Networks of roads have also been constructed and industrialization is gaining pace. Therefore the uninhabited places are also directly or indirectly affected by human activities.

The whole landscape of the study area has now changed as compared to that at the time of Blatter *et al.* (1929). Everything from habitat destruction to habitat fragmentation and habitat quality modification has taken place in the study area. Such changes are frequently reflected by changes in flora and vegetation. While the change in habitat quality would be mostly unfavourable for the existing species, it may prove favourable for some other species. The ecological niches created by these human activities are occupied by such species that were not present there before; not only through the range extension of certain native species but frequently by the alien species as well. Roadsides are among the favourable habitats for the non-native species, as are the nutrient-rich places (Menuz and Kettenring, 2013). The plant species therefore have high indicative quality, and the diversity of the plants is one of the best available predictors of the diversity of the taxa of other organisms (Kull *et al.*, 2008).

Among the alien species recorded in the present work, few species were recognized as worst invasive species, such as *Prosopis juliflora* in terrestrial ecosystems; and *Salvinia molesta* and *Eichhornia crassipes* in aquatic ecosystems. *Prosopis juliflora*, a native of West Indies and Mexico, was introduced here by the British in 1878 for afforesting the deserts of Sindh and southern Punjab (Parker, 1924). However, it acquired invasive status over the past 30 to 40 years with the increasing deterioration of natural ecosystems due to human-induced disturbance. For example, the riverine forest of *Acacia nilotica* at Thatta-Sujawal came under stress due to the lack of annual inundation by Indus River and the trees started dying, therefore *Prosopis juliflora* found a niche to invade and now *Acacia nilotica* forest at that place is non-existent. *Prosopis juliflora* has a wide ecological amplitude as it can grow in a variety of habitats, ranging from dry sand to wet saline places. It was found to have invaded even the intertidal area among mangroves at Shah Bundar and Keti Bundar, though the invasion was in its initial stage. *Salvinia molesta* was first time noticed in the Keenjhar lake in 1990s (Khatoon and Ali, 1999). In less than two decades, it has heavily infested the freshwater lakes and a number of canals in the study area. An apparent reason for its rapid spread is the nutrient load in these water bodies from the agricultural run-off. The date of introduction of *Eichhornia crassipes* is not known, but it also has heavily infested, though less than *Salvinia*, lakes and several canals in the

study area. Both species form thick mats on water surface that besides damaging the native aquatic biodiversity hinder the flow of water and movement of boats. They also transpire huge amounts of water, and by trapping large amount of sediment they may convert a wetland into a dry land.

Other alien species in the study area are although not as aggressive as the above mentioned three species, but some of them have certain other damaging characteristics. For example, *Ipomoea carnea* contains alkaloids swainsonine and calystegines (Gotardo *et al.,* 2011), and intoxication with this plant has been reported in goats, sheep, and cattle in tropical regions worldwide (Armién *et al.,* 2011). Goats readily consume *Ipomoea carnea*; but in case pregnant goats feed upon this plant, their kids suffer from various developmental problems like difficulty in recognizing their mother, difficulty in navigating through maze, and even fetal and post natal mortality (Gotardo *et al.,* 2011). In sheep it causes weight loss, early abortion, and neurologic abnormalities including depression, abnormal behaviour, musculo-skeletal weakness, etc. (Armién *et al.,* 2011). The seeds and seedlings of *Xanthium strumarium* contain the toxic chemical carboxyatratyloside which is associated with fatalities in humans and livestock; in the 2007 floods in Bangladesh 19 people died within hours of eating large quantities of *Xanthium strumarium* seedlings, after developing vomiting, altered mental status and unconsciousness (Gurley *et al.,* 2010).

Although every alien species does not become an invasive species damaging the native biodiversity, but every alien species can be considered as a latent threat; many introduced species' populations remain innocuous for extended periods before spreading and becoming invasive (Simberloff *et al.,* 2013). The behavior of presently non-invasive alien species cannot be predicted in face of the prevailing global warming and the ensuing climate change. Extreme climatic events like unusual heat waves, floods, droughts, hurricanes, etc. are projected to become more frequent and more intense in the time to come, and these can enhance invasions by promoting the transport of propagules into new regions, and by decreasing the resistance of native communities to their establishment (Diez *et al.,* 2012). Therefore preparing a comprehensive strategy including the control of existing invasive species, surveillance of the presently non-invasive alien species, and an effective check on the further introductions (particularly the intentional ones) is an urgent need of the hour.

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