Why plant species become invasive?
Characters related to successful biological invasion

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Abstract

The impact of Invasive Plant Species (IPS) on biodiversity is irreversible and enormous because plant invasions can alter the functioning of an ecosystem dramatically. They also have a negative impact on environmental, economic and public wellbeing. Invasiveness of a species is dependent on any of five key factors: regional climate, microclimate, the site, past disturbance patterns, and individual species characteristics. The main focus of this paper is on species characteristics. Invasive species show high reproductive fecundity and great capability of spreading throughout their new location. Invasive species have characteristics that allow them to thrive in the area where they are introduced. However, how the characters of invasive alien species (IAS) determine their invasiveness is one of the key questions in invasion biology and this paper describes key characters of IPS, which are of great significance for their invasiveness. Compared to the native specialists' plants, the IPS are generalists, capable of surviving in a wide range of climatic conditions, which produce diverse habitats and soil variations. Therefore, IAS possess a broad habitat compatibility. In their new environment, IPS are not subjected to the damages of natural herbivores and diseases to maintain their maximum population densities, and hence they monopolize habitats. IPS enhances their invasive habit successfully by efficient competition for resource utilization and creating allelopathic effects to native biota. Invasive species also have high rates of growth and reproduction with early maturity. As a result, invasive species flourish in the settled landscapes as they produce many offspring and spread in to new area rapidly (high reproductive fecundity). Phenotypic plasticity and genetic differentiation are the two major strategies of IAS, which facilitate them to adapt to new habitats and environmental heterogeneity. Characteristics that make IPA successful in our environment are discussed with appropriate examples from IPS of Sri Lanka. However, generalizations can be misleading, because studies reveal different responses of native plants to the presence of IPS. Therefore, there is a need to understand general trends and exceptions within a particular habitat.

1. Introduction

Invasive species have negative impacts on environment and ecosystem, socio-economy, and or human wellbeing around the world. Alien invasive species (AIS) are threatening biodiversity by altering composition, functions and dynamic equilibrium of native community (Powell *et al*., 2011; Andreu & Vila, 2011). With the invention of efficient transportation systems around the world, intentional or unintentional transport of plant and animal species in to new habitats have accelerated robustly and some of the introduced species have the selective advantage in its new habitats and can spread in an invasive manner. Hence, biological invasions of species are an important component of human-caused global environmental change. This paper describes following topics: Introduction to native and invasive species, 1negative impacts of IAS, factors determine the success of an invasive species, and characteristics of IPS.

Introduction to native and invasive species Native species:

They have evolved in a particular geographical region over thousands of years. These species have an ecological equilibrium established in their physical environment and with the native biota. During this process native plants have adapted physiologically and morphologically to the area and make them exclusively adapted to their environment. Some of these characteristics are as follows:

(1). Ability to reproduce successfully by creating sufficient numbers of progeny that are able to survive, grow to maturity, reproduce in a balanced manner and replace parent plants without impinging on the success of neighboring plants and other species.

(2).Ability to survive under prevailing above ground and below ground conditions (temperature, humidity, precipitation, light, soil type and soil health) while not outcompeting other indigenous species.

(3). Ability to live in an equilibrium with local pests such as herbivores, harmful native animals and insects and diseases such as virus, bacteria and fungi.

(4). Ability to live in an equilibrium with native biota especially co-occurrence flora and fauna and sympatric species without interfering their life cycles (growth, pollination, seed dispersal).

Sometimes they grow harmoniously similar to the symbiotic associations. Pollinator shairing is one such example. Ratnayake *et al*. (2006, 2007) found that sympatrically distributed two *Polylathia* species; *P. coffeoides* and *P korinti* are sharing the same pollinator, *Endaeus* weevil. Interestingly, peak flowering of both *Polyathia* species occur simultaneously and their habit differences help resource partitioning: while the small tree habit of *P. coffeoides* is not influenced by the shrub habit of *P. korinti.*

Invasive Species: They owe success in colonizing new ecosystems as they can tolerate a wide range of environmental conditions, grow and reproduce rapidly and gain reproductive advantage, compete aggressively for resources (nutrients or food, water, and habitats or nesting sites), and lack natural enemies or pests in the new ecosystem. The term IAS has been used in a wide context ranging from microorganisms such as viruses, cyanobacteria and bacteria, to macro organisms such as algae, bryophytes, pteridophytes, seed plants, amphibians, reptiles, birds, insects, fish, shellfish hand etc. An invasive species must be able to survive successfully and replace native species (plants or animals) to be successful in a new area. Primarily IAS should have reproductive advantage and produce sufficient amount of fertile offspring to initiate next generation (effective population size). The species should have the ability to spread in the new habitat successfully and therefore, out of a large number of species introduced to our country, only a few species have become permanently established and among them only a very few species have become IAS. If the new species can attack the existing ecological equilibrium, that would be a sign of invasiveness. Once IAS becomes established in an area, they are able to proceed to invade new habitats and these species harbor certain characteristics that can distinguish from the native species. A comparative summary of characteristics of invasive plant species and native plant species are given in the Table 1.

3. Negative impact of Invasive species on ecosystems

❖ Invasive species can negatively impact ecosystems in various ways. They candisplace native species and reduce the quality of their habitats, reduce forest health, productivity of agricultural ecosystems, alter ecosystem composition and processes, cause diseases, act as predator or parasites, hybridizing with native species and degrade recreation areas and therefore, it is a threat to biodiversity. Invasive Alien Species (IAS) rank second only to habitat destruction as a threat to biodiversity (McGinley and Duff, 2011) and IAS are considered as a greater threat to native biodiversity than pollution, harvest, and disease all together. Biodiversity of some ecosystems isat risk because of the effects IAS alone or their impacts combined with the other ecosystem processessuch as pollination, seed dispersal, herbivoreyand nutrient cycling etc. Ultimately it causes economic losses and reduces values of the eco system. For a example, *Ulex europeaus* compete with native plants in Horton plains (Plate 5d)

4. Factors determine the success of an invasive species

All species have specific characteristics that determine their ability to live in a particular area and to co-exist with all the other species. Success of a species relative to another is determined by one or more of these characteristics. Fig.1depicts a summary of species characteristics of IAS.Though some species are successful invaders, process of invasion is complex. Invasiveness of a species is dependent on any of five key factors: regional climate, microclimate, site, past disturbance patterns, and these characteristics are interrelated (Fig 2). Therefore, a combination of factors determines the general abundance of any particular species and its invasiveness in an ecosystem.

4.1 Climate: All species are adapted to a particular climatic range where temperature and rainfall (amount and distribution) play a significant role in tropical areas. It is possible to find similar regions of climate in different parts of the earth (biomes). In this way, species become established outside of their native range. Invasive species can tolerate a wide range of climatic and edaphic conditions, than that of native species. Therefore, a species became an invasive species when they have high tolerance levels to diverse conditions. For instance, *Pinus caribaea* is a plant generally growing in temperate biomes, which did not spread naturally in Sri Lanka, is now showing an invasive behavior in the Knuckles (Medawatte *et al.,* 2008).

Fig 1: Species characteristics of an IAS

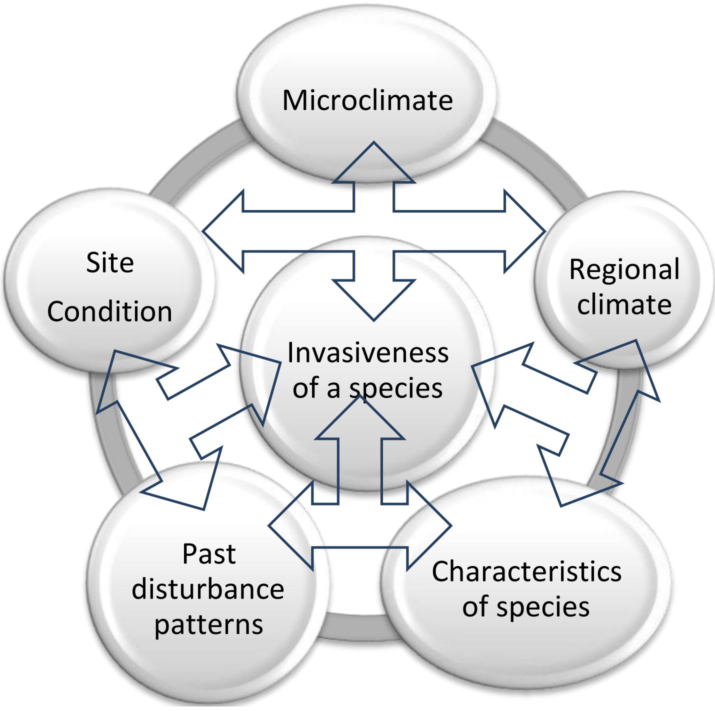


Fig 2. Factors that determine the invasiveness of a species and interrelatedness
Note: all interrelatedness are not indicated to maintain clarity of the figure (e.g., site conditions and characteristics of spp. regional climate and past distributions)

4.2 Microclimate: Habitats differ in their features such as light intensity, vegetation cover, wind, drainage and other edaphic factors and those can influence survival of a species in a specific habitat. Most of the native species have very specific microclimatic desires, but most of the IAS will be unaffected by the fluctuations and changes in microclimate.For example, phenotypic plasticity to variable microclimatic conditions has been identified as a critical trait contributing to the invasiveness of *Altenathera philoxeroides* (Geng*et al*., 2006; Zhang *et al*., 2006). IAS are more plastic in a variety of traits than the native species (Davidson *et al*., 2001)

4.3 Site and land use Patterns: Especially for plants, site-specific variables like edaphic properties play a key role in determining establishment and survival of a species in any particular area. Most of the IAS are able to flourish in diverse site conditions.The existing land use patterns and past disturbance regime of any specific area have a significant influence on what species will survive and where. While most of native species prefer relatively undisturbed habitats, IAS succeed better in both undisturbed and disturbed areas. Many IAS are capable of surviving over a range of land use patterns. Most of the terrestrial IAS thrive better in disturbed habitats. High genetic diversity within a speciesis one of major strategies that IAS possesses, which helps them to overcome habitat heterogeneity (Sheng and Bao, 2006). Further colonization of newly introduced species may be confined to restricted habitats until their mutations are favorable enough for wider habitat heterogeneity.

4.4 Species characteristics: Every species is genetically adapted to thrive on a set of specific environmental conditions. The genetic makeup defines its capacity to grow, to resist pests or predators, to resist diseases, and reproductive fecundity. Invasive species exhibit a wide genetic pool, which enhance their invasive potential (Fig.3). These allow them to be successful in the area to which they are introduced and allowing them to displace slower growing native species. Fig.4 shows the relationship between native and IAS with respect to some variables associated with them. When populations of IPS increases, native plant populations decrease and it is irreversible once IAS has successfully established. Phenotypic plasticity is also one of the major tactics that IAS have, which help them to adapt habitat heterogeneity (Sheng and Bao, 2006) and also microclimatic variations.

5. Characteristics of invasive plant species

Strategies used to control invasive species include keeping potential invaders out, eradicating potential invaders soon after invasion, biological control, chemical control, and mechanical control. Success of IPS control depends on the characteristics of them. IAS possesses characteristics that make them especially suited for colonizing new ecosystems and those allow them to out-compete native plants for resources. Hence, successes of the control methods are impeded by vegetative, reproductive, life history, biochemical, genetic and ecological characteristic of IAS. Knowledge of the reproductive biology, especially pollination, phenological patterns and dispersal characteristics, of potential invaders are valuable for developing measures to prevent their spread, which is often easier than controlling large, established populations (Goodall & Erasmus, 1996).

Invasiveness cannot be predicted from a limited number of criteria, and is the result of a combination of several characteristics (Fig.4). Invasive species exhibit a particular ecological profile rather than a biological profile. A species‘ traits determines their success or failure in the transition between different stages of the invasion process (Fig. 5), and only particular trait combinations are assumed to make a species invasive. Among the combination of characters important for the invasiveness of a species, some are more influencing than the others. For example, even though seed production of *Sphagneticola trilobata*is comparatively low in Sri Lanka (Weerakoon and Ratnayake, 2014), its vegetative propagation efficiency is very high.

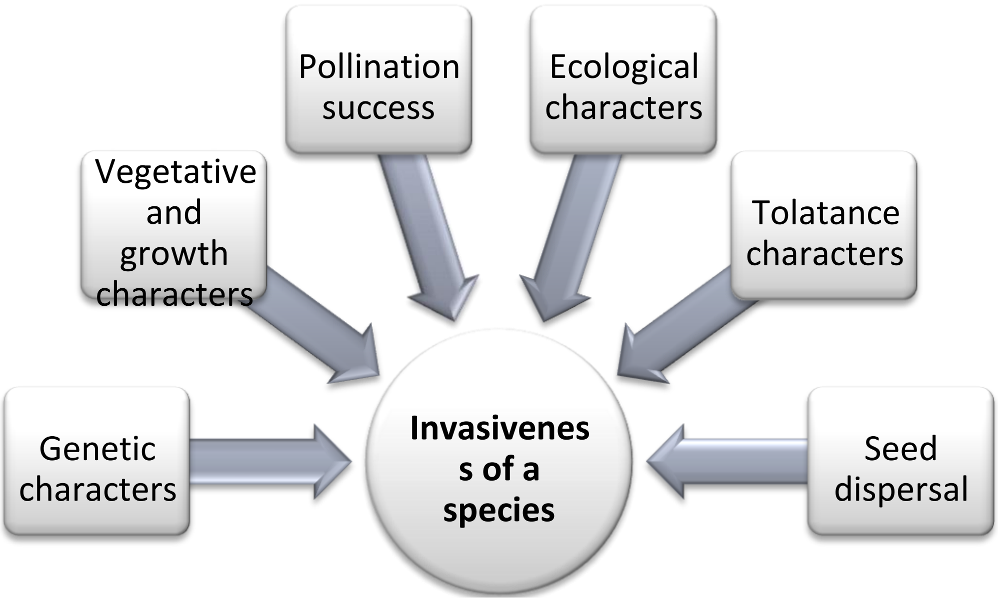
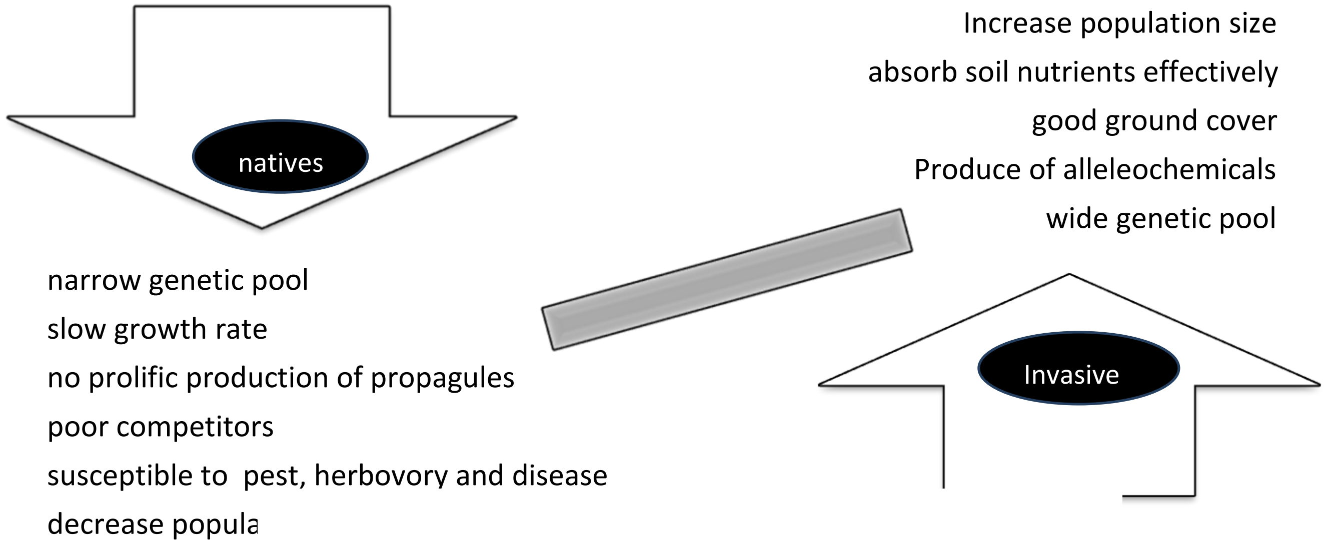


Fig 3. Invasiveness is a result of a combination of several characteristics

Table 1. A comparative summary of characteristics of invasive plant species and native plant species

Native/ indigenous species	Invasive Species
Able to reproduceby producing sufficient numbers of propagules that are adequate to continue their next generations	Prolific propagules producers that are sufficient to increase their expansion by invading new area
Able to survive under specific above ground and below ground conditions, but not out-competing the other indigenous species. (Narrow habitat compatibility)	Have high tolerance and fast growth rate that help spreading in a broad habitat range and able to out-compete other indigenous species. (Broad habitat compatibility)
Ability to live in an equilibriumwith the native fauna (pests and herbivores), microorganisms (pathogens) and the other neutral biota (Population dynamics of the native biota are controlled by other biota to a certain extent.	Not affected by native fauna (pests and herbivores), microorganisms (Pathogens) and the other native biota (Population dynamics of IAS is not influenced by the native biota in the periphery).
Less competitive with co-occurring flora and fauna and sympatric species or their life cycles (growth, pollination, seed dispersal etc.)	high competition for resources with native species
Low survival under high habitat heterogeneity	High survival under habitat heterogeneity
low phenotypic plasticity	high phenotypic plasticity
Broken stick or log normal rank abundance curves is characteristic for the floristic composition of native community.	Geometric series or log series rank abundance curves is characterize floristic composition of IPS community



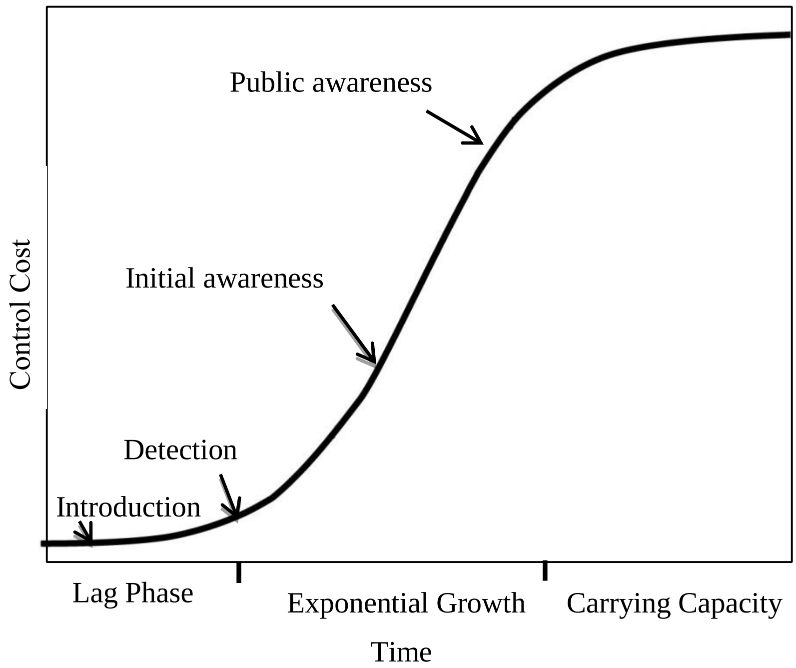


Fig. 5. A species' traits determines their success or failure in the transition between different stages of the invasion process

5.1. Vegetative and growth characteristics of IAS:

Rapid growthofinvasive plants allowsthem to invade disturbed land faster than the native species. Early leafing out and remaining green for longer allows them to photosynthesize more efficiently and survive for extended periods. This in turn allows them to grow faster and produce more vegetative biomass. The growth rates of most of the IAS identified in Sri Lanka are higher than that of indigenous species and hence, disturbed areas/ ecosystems are occupied by them more easily. For instances, plants had been reported from minute portions of stem cuttings of *Sphagneticola trilobata* (Plate 1 d & e) in organic manure (Nayanakantha, 2007). *Panicum maximum* (Plate 2 f) has a fast growth rate, which is enhanced by C-4 photosynthesis. *Alternanthera philoxeroides* had a higher biomass than *A. sessilis* (Sun and Frys, 2010). *Alternanthera philoxeroides* spared vegetatively by stem cuttings (Plate 5a) and *Colocasia esculenta* by corm (Plate 5c).

❖ Production of dense shade and ground coverincreases the ability of invasive plants to grow, reproduce, and out compete native plants for sunlight. Research suggests that *Sphagneticola trilobata* (Plate 2b) (Nayanakantha, 2007) and *Clusia rosea* (Ratnayake, 2008) cover the entire area within a very short period of time.

❖ Dense root mass productionby invasive species prevents the establishment of roots by native plants and provides for massive carbohydrate storage, which makes control efforts very difficult.Efficient competition of resource utilization makes IAS more invasive (Sheng and Bao, 2006), which is facilitated by a good root system e.g. *Pamicum maximum* possess a good fibrous root system

❖ Root systems of some IPS are deepercompared to native plants and it usually accompanied byearly, rapid root growth. This increases the invasive ability to sequester valuable water on dryland ranges, *e.g. Pinus caribaea*

Lack ofnative predators**:** The advantage ofliving in an alien site free from their native predators allows IAS to thrive in the face of pests that would naturally control the growth and abundance of native species. For instance *Parthenium hysterophorus* does not have natural enemies like insects and diseasesand it is responsible for its rapid spread in introduced areas (Sankaran, 2008). Resistance to grazing can allow invasive plants to grow and spread more rapidly than neighboring, grazing sensitive native plants. For instance, *Sphagneticola trilobata* and *Pennisetum polystachyon* are not preferred by farm animals (personal observations). *Opuntia dillenii* (Plate 3 f), *Mimosa pigra* (Plate 1 f) and *Prosopis juliflora* (Plate 3a &b) possess thorns or spines to protect from herbivory. High tolerance of *A. philoxeroides* to herbivory under a variety of environmental conditions contributes to the success of *A. philoxeroides* compared to the native congeneric plant, *A. sessilis* (Sun and Frys, 2010). No diseases or pests have been recorded on *Sphagneticola trilobata* (Nayanakantha, 2007).

5.2 Reproductive characteristics of IAS:

❖ **Species with multiple reproductive strategies**: Most of the IAS are adapted for both vegetative and sexual reproduction. Hence they spread efficiently via multiple pathways: root and stem cuttingsas well as byseeds.As an example, *Clusia rosea* (Plate 2c & Plate 1e) has efficient vegetative as well as sexual reproduction system (Ratnayake, 2008).When compared to sexual reproduction, vegetative reproduction system saves more energy.Some IAS are able to reproduce from small fragments of roots or stems left in the soil, e.g. *Sphengeticola trilobata*. In addition to multiple reproductive strategies (vegetative and sexual reproduction) plants with multi-seeded fruits are also good colonists (Anne *et al*., 2001). Excellent examples for multi seed bearers are *Lantana camara* (Plate 3 d), *Annona glabra* (Plate 2e) and *Mimosa pigra* (Plate 4d). Pagad (2010) found that *Leucaena leucocephala* has a successful mixed mating system and is pollinated by both geitonogamy and xenogamy. It is pollinated by a wide range of generalist insects including large and small bees and can re-sprout after cuttingin the main stems.

❖ **Long or extended flowering and fruiting periods**: production of flowers for extended period of time facilitates high rate of success in pollination. Long fruiting periods also enhance survival of their next generations if the environmental conditions are unfavorable. Providing floral rewords for a long period is important for continuous association between native pollinators and IAS. However this method has a reproduction cost associated. Pagad (2010) found that flowering and seeding of *Leucaena leucocephala* continue throughout the year as long as moisture permits.

❖ **Production of large quantities of seeds or offsprings:** Prolific flowering increases the number of seeds produced. Large numbers of propagules/ seeds produce in each reproductive cycle allows invasive species to establish many progenies in a larger area. Many invasive plants reproduce by seeds that are spread by the wind. Small seed mass is associated with a greater number of seeds produced, which are better dispersed, *e.g*. a single plant of *Parthenium hysterophorus* produces up to 100,000 seeds per lifecycle. More than 340 million seeds/ha can be present in the surface soil (Sankaran, 2008). Seeds do not have a dormancy period and are capable of germinating anytime when moisture is available (Sankaran, 2008). Seed production of *Chromolaena odorata* in the sun varied from 2000 (<1-year old site) to 2, 60,000 (10 year) seeds/m^2/year (Witkoeski and Wilson, 2001).One *Mimosa pigra*, within an average stand, can produce more than 9000 seeds annually (Marko, 1999). In a typical thicket, this would average to about 220,000 seeds/year (Lonsdale, 1992). *Leucaena leucocephala* releases 5500 seeds/m^2/year (Marques *et al*., 2014).

❖ **Short life cycle:** Short life cycles allow invasive species to overtake native species in disturbed lands more quickly. As an example, lowering of *Parthenium hysterophorus* occurs about a month after plant establishment (Sankaran, 2008). Short life cycle is connected with the habit of the plant. e.g. *Alternanthera philoxeroides, Clidemia hirta* (Plate 3 e), *Parthenium hysterophorus, Salvinia molesta* (Plate 2h) and *Eichhornia crassipes* (Plate 2g) all are herbs.

❖ **Early maturity:** Early maturityallows IAS to release seeds and grow before the native plants do. Some annual IAS attain their reproductive maturity within few weeks. A short juvenile period may also be related to the fast growth.Its increased photosynthetic rate contributes to early maturity. *Chromalena odorata shows* rapid attainment of reproductive maturity (Witkoeski and Wilson, 2001) and *Leucaena leucocephala* flowering starts within a year of germination (Binggeli, 1997).

❖ **High initial germinability:** This is important to overcome dormancy and it guarantees the survival of at least few individuals. Example of AIS with such lifehistory characteristics include germinable seed density of *Chromolaena odorata* (Plate 5f) 158–511/m^2 under shade (Witkoeski and Wilson, 2001)

Efficient seed dispersal mechanism enables most of the invasive plants to rapidly spread and invade large areas. Dispersal by abiotic vectors is the most energy saving method of seed dispersal and IAS also adapted to wind dispersal. Depending on the size of the wind dispersed seeds, a species may spread in to short distance or long distance. *Pennisetum polystachyon* (Plate 3 c) *Chromalena odorata* and *Austroeupatorium inullifolium* (Plate 4e) produce easily dispersed seeds by wind (Witkoeski and Wilson, 2001). The seeds of *Prosopis juliflora* (Plate 3 a) are dispersed by cattle as well as by elephants that eat the pods (Wijesundara, 2010). *Panicum maximum* seed dispersed by birds too (Plate 5b).

Moving soil around has also been responsible for dispersing the seeds of many invasive plant species from one location to another; this is especially true for plants in agricultural settlements, urban areas, where movement of soil or organic amendments (cow dong) is often practiced e.g. *Panicum maximum*. Moving infested soil from one location to another is one sure way of introducing plants like *Mimosa pigra* and *Leucaena leucocephala* into new areas. Seeds may also attach themselves to articles of clothing or vehicles and then be transported well outside the currently infested area. *e.g. Mimosa pigra* seeds are transported to terrestrial habitats by river sand transported for construction works, irrigation water and machinery, (Marambe, 2000). *Parthenium hysterophorus* seeds are mainly dispersed through water currents, animals and through the movement of vehicles, machinery, livestock, grain, and to a lesser extent by the wind. Most of the long distance spread is through vehicles, farm machinery and flooding (Sankaran, 2008). Therefore, multiple methods of seed or fruit dispersal is an advantage for IAS for their efficient spread.

❖ **Long seed dormancy and staggered germination** allows IAS to have seeds ready to grow over longer periods of time and during different growing seasons. More than 70% of *Parthenium* seeds buried at 5 cm below the soil surface survived for at least 2 years (Sankaran, 2008). Seed viability of *P. hysterophorus* for 20 years has also been recorded (Sankaran, 2008). *P. hysterophorus* seeds do not have a dormancy period and are capable of germinating anytime when moisture is available (Sankaran, 2008).The hard seed coat of *Leucaena leucocephala* helps to remain viable for a long period (at least for 20 years) in the soil (Pagda, 2010).However, Marques *et al*. (2014) found that *L. leucocephala* seeds persistent in seed bank for 1–5 years. *L. leucocephala* seed viability remained >80% after two years of in situ storage (Marques *et al*., 2014). *Mimosa pigra* seed bank remains significantly viable nearly for 10 years after stand removal under the grass cover (Lukitsch & Elliott, 2012). Hence seeds of some IAS can withstand adverse conditions.

5.3 Ecological and biological characteristics of IAS:

❖ **Good competitors***:* With their ability of rampantly use of new habitats, IAS can violently eliminate native species from the landscape. *Alternanthera philoxeroides* will continue to be invasive and compete with native species, *A. sessilis,* under varying environmental conditions even if more native herbivores accumulate (Sun and Frys, 2010). Light exposure significantly affects total biomass and the root to shoot ratio of *A. sessilis*, but has no effect on *A. philoxeroides* (Sun and Frys, 2010). Therefore, *A. philoxeroides* is a goodcompetitor under varied environmental conditions than *A. sessilis. Parthenium* is very competitive and has been reported to gain an advantage over a C_4 pasture grass (*Cenchrus ciliaris*) as atmospheric CO_2concentrations increase, despite being a C_3 plant (Navie*et al*., 2005). *Parthenium* is reportedly photoperiod and thermoperiod insensitive and can flower year-round (Mahadevappa, 1997). Seed germination can take place over a wide temperature range (Tamado, Schutz, and Milberg, 2002). *Clusia rosea* is another interesting semi-epiphytic IAS with CAM photosynthesis during the epiphytic life and once rooted in soil, it turns into a C3 plant.The flowers of *Cestrum aurantiacum* (Plate 4c) are pollinated by an endemic bird, the Sri Lanka White Eye. The fruits of *C. aurantiacum* are dispersed by an endemic bird, the Yellow eared bulbul. Due to the abundance of *C. aurentium* in montane forest fringe, these two bird species are now found mostly in those areas and the pollination and dispersal of native plants are affected (Wijesundara, 2010).

❖ **High plasticity to novel ecosystems**: Generally, IAS have a greater phenotypic plasticity than that of co-occurring non-invasives. This is truefor several traits of IPSunder a range of resource conditions (Davidson, 2011). *Clidemia hirta* showed more plasticity when plants were exposed to extreme soil nutrient conditions (Weerasinge*et al*., 2008). *Parthenium hysterophorus* seeds can germinate from 8 ° C to 30° C range (Sankaran, 2008).

❖ **High adaptability to novel ecosystems and wide habitat range**: *Parthenium* grows luxuriantly in wastelands and vacant lands, orchards, forestlands, flood plains, agricultural areas, scrub/shrublands, urban areas, overgrazed pastures and along roadsides and railway tracks. Drought, and subsequent reduced pasture cover, creates an ideal situation for *Parthenium* to establish. It prefers alkaline, clay loam to heavy black clay soils, but can tolerate a wide variety of soil types. The weed grows well in areas where the annual rainfall is greater than 500 mm. It can grow up to an elevation of 2200 m above sea level (Sankaran, 2008). *Mimosa pigra* can survive both a sevenmonth dry season and flooding season in the wet season (Marko, 1999). *Sphengeticola trilobata* has a wide ecological tolerance range, and seems to be equally suited to dry and moist sites. Although it seems to prefer and do best in sunny sites, it survives in shady sites as well. It grows well on almost all soil types, including bare limestone and nutrient poor sandy beaches and swampy or water logged soils. It is known to give no chance for other plants to grow and suppressing the growth of even legume cover crops as well as native biota found in rubber plantations (Naynakantha, 2007). *Panucum maximum* resprout after fire and *Pinus caribaea* not affected by annual occurrences of ground fire (Ratnayake, 2001).

5.4 Biochemical and genetic characteristics of IAS

❖ **Allelopathy:** Some IPS produce and release chemicals into the peripheral area that inhibit or reduce the growth surrounding native species, especially applicable for plants as they are sessile and their substrate is soil. This leads to create monoculture strand of IPS and indicate their monopolization ability. Interfering competition with native species based on allelopathy boosts invasiveness of IAS (Sheng and Bao, 2006). Complete failure of seed germination of *Eragrostis tef* was recorded in 10% concentrated leaf extract of *Parthenium hysterophorus* (Tefera, 2002). *P. hysterophorus* releases plant growth inhibitors like lactones and phenols into the soil through leaching, exudation of roots and decay of residues. These growth inhibitors suppress the growth and yield of native plants (Sankaran, 2008). Addition of high quantity of *Lantana camera* leaves cause for reduced vegetative and reproductive growth in rice plant (Wickramasinge and Ranwala, 2008). Allelopathic effects of extracts of *Sphengeticola trilobata* on seed germination and seedling growth of *Phaseolous vulgaris* (Bean) has been recorded (Perera, 2014**)**

6. Discussion

Most of the IPS have rapid growth and efficient vegetative reproductionmethods and thus they have the ability to cover large areas suppressing the growth of other important native flora. Subsequently, plantinvasions can alter the functioning of an ecosystem dramatically by increasing fire frequency, changing hydrology or by accelerating theturnover of nutrients.The IPS not only affects the native florabut also fauna (Nayanakatha, 2007). Most of the IPS are not studied in relation to native fauna. Once IPS are the dominant in a field, there is a less chance of surviving for more native fauna due to shortage of foods, habitats and protection. While some examples clearly show that IPS can competitively replace native plant species (Caujapé-Castellsetal., 2010), the other examples exist wherehigh regeneration of certain native plants is facilitated by presence of some IAP in the area (Lugo, 2004, Kueffer *et al*., 2007).

Characteristics that make invasive species so successful in our environment are, lack of predators, pathogens, and diseases to keep population numbers in check, produce copious amounts of viable seeds, use successful dispersal mechanisms, thrive on disturbance, very opportunistic, fast-growing and habitat generalists. IPS does not have specific or narrow growth requirements, alleleopathic to plants nearby, and alter soil and habitat conditions where they grow to better suit their own survival and expansion. However, these inherent characters need to study in detail. Interrelationships among these characters in relation to climate and edaphic properties of the landscape are essentialin understanding the invasion and prevention. However, generalizations can be misleading, because studies reveal that there are different responses of native plants to the presence of IAP. Therefore, there is a need to understand general trends and exceptions within a particular habitatin relation to the climatic changes. Among the species characteristics, propagation, establishment and spread due to disturbance and competitive ability of IAS are considered for the development of post-entry risk assessment protocol for invasive alien flora in Sri Lanka.

Among several characters, the effectiveness of inversion of an IPS mainly depends on its reproductive fecundity. Enhanced reproductive output of invasive plants found in the communities indicates that more food resources become available for pollinators in IPS than that of the native plants. The diverse food resources provided by IAS include flower buds, petals, nectar, pollen and fruits for the pollinator. The diverse supportive and competitive pollination syndromes of different invasive plants have supported different fauna including mammals, birds, reptiles and insects. After an alien plant is introduced there is a "lag phase" of decades to centuries before an exponential spread phase (Murren *et al*., 2014, Baskin, 2002). Thus, some species that currently appear non-invasive may eventually begin to spread rapidly. Therefore, detail studies on potential invasive species also important. *e.g.* current spreading of *Muntingia calabura* (Plate 5e) in the Mahaweli river basin at Tennakumbura, Kandy can be a problematic plant species in near future, However, no risk assessment was done yet to confirm its invasiveness in Sri Lanka.

Finally, it is true that the reproductive biological characters of IAS (floral, herbivory, pollinator competition, effective epollination and seed dispersal, etc.) that can affect the ecosystems are not completely understood yet. Hence, detail studies onthose important charterers are of great importance.

Plate 1. Invasive plants. a co-occurence of *Clidemia hirta* and *Mikania micrantha*. b. co-occurence *Clidemia hirta, Panucim maxaimum, Chromolaena odorata* and *Mikania micrantha i*n a same habit. c- Pollinator attractive flowers of *Tithonia diversifolia,* d- Under shade *Sphagneticola trilobata* grow as errect plant, e- No herbivory attrack to *Clusia rosea,* f- Thorny *Mimosa Pigra* plant not attactive to farm animals, g- flowers of *Sphagneticola trilobata a*ttract bees which are main pollinators of main economic crops.© R M C S Ratnayake.

Plate 2. Invasive plant species. a- Prolific flower production of *Mikania micrantha*, b- Mat forming habit of *Sphagneticola trilobata*, c- Flowers of *Clusia rosea* attractive to pollinators, d- *Pinus caribaea* understory completely covered by *Panicum maximum*, e- *Annona glabra* invasive plant in wet zone, f- *Panicum maximum* produce large spike and large number of seeds, g & h- *Salvinia molesta* and *Eichhornia crassipes* are IAS in freshwater aquatic habitats. © R M C S Ratnayake. Photo credit K D S Swarnalatha

Plate 3. Invasive planrt species a- *Prosopis juliflora* (Fabaceae) Kalapu Andara - habit, b - *Prosopis juliflora* - flower
c - *Pennisetum polystachion* (Poaceae) Rila Walige, d - *Lantana camara* (Verbenaceae) Gadapana,
e - *Clidemia hirta* (Melastomataceae) , Kata Kalu Bovitiya, f- *Opuntia dillenii* (Cactaceae) Katu -Pathok
© R.M.C.S. Ratnayake, Photo credit - Mr. S. Ekanayake & Dr.A. Attanayake

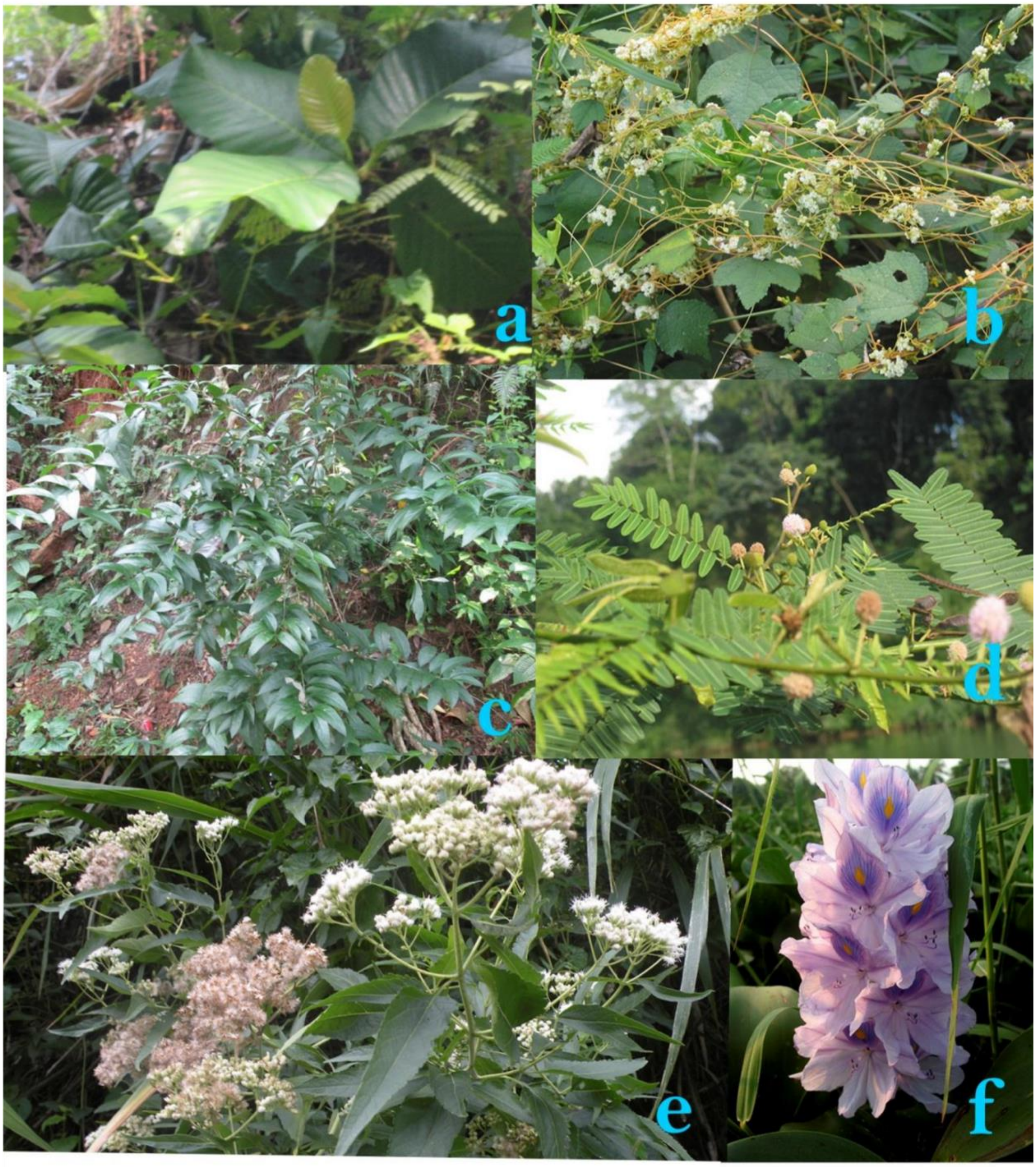


Plate 4. Invasive plant species. a- *Dillenia suffruticosa* (Dilleniaceae) Para, b- *Cuscuta campestris* (Convolvulaceae) Aga Mula Nethi Wel, c- *Cestrum aurantiacum* (Solanaceae) Rae- Manamali, d- *Mimosa pigra* (Fabaceae), Yoda Nidikumba e- *Austroeupatorium inulifolium* (Asteraceae) Pathan palu, f- *Eichhornia cassipes* (Pontederiaceae) Japan jabara,
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Plate 5. Invasive plants. a- *Alternanthera philoxeroides* (Amaranthaceae) (Alligator weed). b-*Panicum maximum* -Poaceae (Gini Grass) seeds dispersed by birds, c- *Colocasia esculenta* -Araceae (Gahala) d- *Ulex europeaus* -Fabaceae,

e- *Muntingia calabura* -Muntingiaceae (Jam) could be a potential invasive plants in near future, f- *Chromolaena odorata* - Asteraceae (Podisigho Maran).

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