A Systematic Review on the Distribution of Invasive Plant Species Across Asia: Assessing the Rates of Invasion Success and Management

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Abstract:- The advancement of invasive plant species in a particular environment is threatening across Asia. When they are introduced, they could have a variety of different negative effects, either as minor inconveniences or a severe problem. The aim of this review is to compile a list of invasive plant species across Asia and organize a set of data according to their reproduction rates, growth rates, dispersal rates, and characterize the allelochemicals they produce and allelopathic effects they have on their environment. The target is to know the extent of their spread ability in the area that they inhibit and know what control measures can be done with that specific species. The data has been gathered by compiling research articles and obtaining pertinent data relating to the objective. This review also utilized the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist to confirm the credibility of the collected references. To achieve the needed references, keywords such as “distribution”, “invasive”, and “Asia” have been used to search for these on search engines and research journals such as Google Scholar, ScienceDirect, ResearchGate, and Directory for Open Access Journals, to be then compiled in spreadsheets and document files. The results show that the growth rate of these species varies from 7.5-60 cm per year, where Ipomoea eberhardtii has the highest growth rate of 60 cm per year. The dispersal rates of the species ranges from 0.002-2592 km from the parent plant, where animal mediated, water, and wind dispersal methods are the primary vector to spread. Allelopathic effects produced by the allelochemicals present mostly inhibit growth and seed germination. There are already implemented approaches to control these species, where biological control, physical means, and the use of chemicals are the most used strategies. In different dynamic processes, physical and chemical control measures are most utilized in this case.

Keywords:- Allelochemicals, Dispersal, Exotic, Growth, Pattern, Spread.

I. INTRODUCTION

The introduction of different exotic floras and wide distribution of invasive alien species in forest ecosystem are threatening the biodiversity across Asia. The emergence of new IAPS of novel ecosystem have been showing an intimidating concern over the past decade in the diversity of native plants yet remain an overlooked issue until now.

Interestingly, it has been a matter of debate among invasion ecologists whether IAPS are the first/second-most severe threat (only 27.3% are in favor of this) or they should be ranked further below. The anthropogenic perturbations caused by biotic invasion does not only poses problems environmentally but also to the human well-being in negative and sometimes, positive manner (Prabhat & Singh, 2020). Because of their pollen and toxins, invasive plant spread on a worldwide scale, especially in disturbed places like landfills and dumps (which can become epicenters for invasive plant species), can have a significant negative impact on human health (Plaza et al., 2018). Numerous IAPS have been observed to be invading both terrestrial and aquatic ecosystems worldwide.

Natural plant communities that are in good health offer wildlife, insects, and soil biota with a sustainable environment. They can withstand droughts and support ecosystem services like fresh water and air. When invasive plants are brought into a native plant community, there may be a variety of negative outcomes, ranging from slight inconveniences to significant issues. For instance, a non-native species may coexist in the community with very little impact, or it may be extremely invasive and completely alter it. In the latter case, invasive species can produce large numbers of highly viable seeds, outcompete native plants for water and nutrients, and profit from highly adaptable life strategies that let them make the most of available resources (Wacker, 2022). The coexistence between native and exotic species exhibits a functional and niche differences that may alter the natural habitat of plants and exacerbate competition.
This systematic review aims to address three key objectives: (1) Identify and compile a comprehensive list of invasive plant species introduced across Asia; (2) Investigate the reproduction rates and strategies employed by invasive plant species, analyzing their reproductive success, seed production, and dispersal mechanisms; (3) Identify and characterize the allelochemicals produced by invasive plant species and its potential allelopathic effects on native vegetation and ecosystem processes; and (4) Evaluate the impacts of invasive plant species on native ecosystems and biodiversity across Asia, assessing the extent of their spread, competition with native species, habitat modification, and disruption of ecosystem processes.

II. METHODOLOGY

The paper adhered to particular criteria and employed a thorough methodology to extract and amalgamate evidence-based literature and practices.

- **Data Gathering**
  For gathering of data in this systematic review, a comprehensive and structured approach is adopted. Specific inclusion while establishing exclusion criteria to ensure the selection of pertinent studies. Keywords and search terms related to the topic were also used to retrieve potential studies. The search results are then screened in two stages: title and abstract review followed by full-text review. Data extraction forms were used to systematically collect relevant information from the selected studies, including study design, population characteristics, interventions, outcomes, and results. This data is then organized and synthesized to provide a comprehensive understanding of the topic under review, ensuring transparency and reproducibility of the process.

- **Data Sources**
  In order to enhance the quality of the review process, the researchers utilized the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist to validate the credibility of the selected references. For this review, a variety of search engines and databases, including ScienceDirect, Google Scholar, ResearchGate, and Directory of Open Access Journals, were employed to identify pertinent published articles, research papers, and scientific reports.

- **Search Strategy**
  The search terms commonly used were “distribution,” “invasive,” and “Asia.” Initial consideration was given to the first 100 relevant articles, with a preference for open-access resources. Additionally, grey literature sources such as government and non-government reports, international organization websites, news articles, and policy documents were explored for relevant information.

- **Framework of the Study**

<table>
<thead>
<tr>
<th>Steps</th>
<th>Process</th>
<th>Expected Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Gathering</td>
<td>Search articles about the prominent invasive plant species in Asia, on search engines and research databases like Google Scholar, ScienceDirect, ResearchGate, and Directory of Open Access Journals.</td>
<td>Gather about 100 articles relating to the topic</td>
</tr>
<tr>
<td>Data Screening</td>
<td>The gathered articles will be evaluated and screened using the eligibility criteria for inclusion and exclusions. The final 25 articles will be selected for the review.</td>
<td>Select 25 articles for the review.</td>
</tr>
<tr>
<td>Data Extraction</td>
<td>Relevant data will be collected from these selected papers during the review. These are the following: Invasive Species in Asia, Reproduction and Growth Rates, Dispersal Rates, Allelochemicals and Allelopathic Chemicals, and Impact on Biodiversity.</td>
<td>Relevant data and information will be collected.</td>
</tr>
<tr>
<td>Data Synthesis</td>
<td>All data will be encoded in Microsoft Excel and Microsoft Word.</td>
<td>Data will be presented in tables, figures, charts, and graphs.</td>
</tr>
</tbody>
</table>

Fig 1 Schematic Diagram Representing the Flow and Process of the Study
The determinants of reproductive characteristics, quantify dispersal distances and discuss competitive interactions. The study utilized Microsoft Excel to organize the collected references and Microsoft Words to present the findings, incorporating graphic organizers for clarity. The researcher coded the data using keywords, created themes by grouping related codes, and reviewed and revised them for accuracy. The identified themes encompassed plant species’ distribution, reproduction, growth, dispersal, allelochemicals, and ecological impacts. A total number of 100 studies were initially identified from the combination of search terms from four database (23 from ScienceDirect, 66 from Google Scholar, 15 from ResearchGate, and 8 from Directory of Open Access Journals). Using the eligibility criteria, a total of 25 studies out of the 100 articles were selected in this paper to ensure that only studies meeting the pre-set criteria were included in the review. This step helped to minimize bias and ensure that the selected studies were of high quality and relevance to the research question. Data extraction was then carried out systematically, with relevant information from each selected study being extracted and synthesized. The extracted data were then analyzed using appropriate statistical methods to identify patterns and trends in the spread of invasive plant species.

## III. RESULTS

In the results section focusing on invasive plant species in Asia, we first detail their reproductive characteristics, highlighting strategies such as prolific seed production and efficient vegetative reproduction. Quantitative data on seed numbers per plant, germination rates, and reproductive phenology are provided, alongside comparisons between native and invasive populations where applicable. This also includes the examination of dispersal mechanisms, emphasizing modes like wind, animal-mediated, and human-mediated dispersal that facilitate their spread across diverse Asian habitats. We quantify dispersal distances and discuss adaptations enhancing dispersal efficiency, such as specialized propagules. Regarding growth rates, we present data on height or biomass accumulation over time, analyzing factors like environmental conditions and competitive interactions with native species. The interplay between reproduction, dispersal, and growth is explored to elucidate how these factors collectively contribute to the invasive success of these species in Asia, offering insights crucial for effective invasive species management and conservation strategies.

### List of Invasive Plant Species Across Asia

<table>
<thead>
<tr>
<th>Name of species</th>
<th>Common name</th>
<th>Country of origin and natural habitat</th>
<th>Country of distribution in Asia</th>
<th>Growth Rate per year (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acacia mangium</td>
<td>Black wattle</td>
<td>Australia and Papua New Guinea</td>
<td>Southeast Asia</td>
<td>40</td>
</tr>
<tr>
<td>Ageratina Adenophora</td>
<td>Crofton weed</td>
<td>Mexico</td>
<td>Southern India and Southeast Asia</td>
<td>10</td>
</tr>
<tr>
<td>Ageratum conyzoides</td>
<td>Billygoat-weed</td>
<td>Brazil</td>
<td>East Asia, Philippines &amp; India</td>
<td>15</td>
</tr>
<tr>
<td>Ambrosia trifida</td>
<td>Giant Ragweed</td>
<td>Canada, US, and Northern Mexico</td>
<td>China</td>
<td>15.5</td>
</tr>
<tr>
<td>Argemone mexicana</td>
<td>Mexican prickly poppy</td>
<td>Mexico and Central America</td>
<td>Southeast Asia, India, Yemen &amp; Syria</td>
<td>20</td>
</tr>
<tr>
<td>Bunias orientalis</td>
<td>Warty Cabbage</td>
<td>North America</td>
<td>China</td>
<td>20</td>
</tr>
<tr>
<td>Chromolaena odorata</td>
<td>Siam Cabbage</td>
<td>America</td>
<td>Southeast Asia</td>
<td>30</td>
</tr>
<tr>
<td>Clidemia hirta</td>
<td>Koster’s curse</td>
<td>Southern Mexico and Central America</td>
<td>Brunei, India, Japan and Singapore</td>
<td>10</td>
</tr>
<tr>
<td>Cytisus scoparius</td>
<td>Scotch Broom</td>
<td>Western and Central Europe</td>
<td>Northern Asia</td>
<td>7.5</td>
</tr>
<tr>
<td>Eichhornia crassipes</td>
<td>Water Hyacinth</td>
<td>South America</td>
<td>India, Indonesia, Malaysia &amp; Philippines</td>
<td>20</td>
</tr>
<tr>
<td>Imperata cylinrica</td>
<td>Cogon grass</td>
<td>Africa and some parts in Asia</td>
<td>South and Western Asia</td>
<td>43</td>
</tr>
<tr>
<td>Ipomoea eberhardtii</td>
<td>Morning Glory</td>
<td>Mexico</td>
<td>Nepal</td>
<td>60</td>
</tr>
<tr>
<td>Lantana Camara</td>
<td>Red Sage</td>
<td>Central and South America</td>
<td>India and South-East Asia</td>
<td>50</td>
</tr>
</tbody>
</table>

Table 1 Invasive species in Asia
Table 1 shows the list of invasive plants geographical distribution across Asia and their most common habitat particularly in Western countries. It also displays the corresponding growth rates of the species.

➢ Growth Rates

Figure 2 depicts the growth rate of the following species. Each species follows the geometric type of growth rate.
Dispersal Rates and Mechanism

Table 2 Dispersal Rates and Mechanisms

<table>
<thead>
<tr>
<th>Species</th>
<th>Distance from the parent plant (km)</th>
<th>Primary Vector</th>
<th>Reference/Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acacia mangium</td>
<td>0.5</td>
<td>Animal-Mediated, Wind-Dispersed</td>
<td>Dhamodaran &amp; Chacko (2017)</td>
</tr>
<tr>
<td>Ageratina adenophora</td>
<td>100</td>
<td>Wind-Dispersed, Water-Dispersed</td>
<td>Chuan et al. (2021)</td>
</tr>
<tr>
<td>Ageratum conyzoides</td>
<td>100</td>
<td>Wind-Dispersed, Water-Dispersed</td>
<td>Amarpeet et al. (2023)</td>
</tr>
<tr>
<td>Ambrosia trifida</td>
<td>20</td>
<td>Vegetative Propagation</td>
<td>Dong et al. (2020)</td>
</tr>
<tr>
<td>Argemone mexicana</td>
<td>5</td>
<td>Wind-Dispersed, Water-Dispersed</td>
<td>Namkeleja et al. (2018)</td>
</tr>
<tr>
<td>Bunias orientalis</td>
<td>0.002</td>
<td>Animal-Mediated</td>
<td>Corli et al. (2021)</td>
</tr>
<tr>
<td>Chromolaena odorata</td>
<td>200</td>
<td>Wind-Dispersed</td>
<td>Midori &amp; Hisashi (2023)</td>
</tr>
<tr>
<td>Clidemia hirta</td>
<td>10</td>
<td>Animal-Mediated, Water-Dispersed</td>
<td>Cao et al. (2018)</td>
</tr>
<tr>
<td>Cytisus scoparius</td>
<td>0.005</td>
<td>Vegetative Propagation</td>
<td>Gudžinskas &amp; Taura (2022)</td>
</tr>
<tr>
<td>Eichhornia crassipes</td>
<td>10</td>
<td>Water-Dispersed</td>
<td>Lekame et al. (2020)</td>
</tr>
<tr>
<td>Imperata cylindrica</td>
<td>100</td>
<td>Vegetative Propagation, Wind-Dispersed</td>
<td>Muhammad (2020)</td>
</tr>
<tr>
<td>Ipomoea eberhardtii</td>
<td>14.75</td>
<td>Animal-Mediated, Water-Dispersed</td>
<td>Thi et al. (2019)</td>
</tr>
<tr>
<td>Lantana Camara</td>
<td>12</td>
<td>Vegetative Propagation, Water-Dispersed</td>
<td>Negi et al. (2019)</td>
</tr>
<tr>
<td>Leucaena leucocephala</td>
<td>9</td>
<td>Wind-Dispersed</td>
<td>Padma et al. (2020)</td>
</tr>
<tr>
<td>Merremia boisana</td>
<td>4.10</td>
<td>Animal-Mediated, Water-Dispersed</td>
<td>Thi et al. (2019)</td>
</tr>
<tr>
<td>Mikania Micrantha</td>
<td>100</td>
<td>Wind-Dispersed</td>
<td>Liu et al. (2020)</td>
</tr>
<tr>
<td>Mimosa pigra</td>
<td>9.76</td>
<td>Water-Dispersed, Human Activity</td>
<td>Amali &amp; Florentine (2022)</td>
</tr>
<tr>
<td>Myroxylon balsamum</td>
<td>0.5</td>
<td>Animal-Mediated</td>
<td>Loayza-Cabezas et al. (2018)</td>
</tr>
<tr>
<td>Opuntia stricta</td>
<td>1500</td>
<td>Animal-Mediated</td>
<td>Venter et al. (2022)</td>
</tr>
<tr>
<td>Parthenium hysterophorus</td>
<td>400</td>
<td>Wind-Dispersed</td>
<td>Bashar et al. (2023)</td>
</tr>
<tr>
<td>Phyllostachys pubescens</td>
<td>0.012</td>
<td>Vegetative Propagation</td>
<td>Xu et al. (2020)</td>
</tr>
<tr>
<td>Pistia stratiotes</td>
<td>2592</td>
<td>Water-Dispersed</td>
<td>Silva et al. (2020)</td>
</tr>
<tr>
<td>Prosopis juliflora</td>
<td>203</td>
<td>Animal-Mediated</td>
<td>Patnaik et al. (2017)</td>
</tr>
<tr>
<td>Tamarindus indica</td>
<td>0.0258</td>
<td>Animal-Mediated</td>
<td>Oyebamiji et al. (2018)</td>
</tr>
<tr>
<td>Ulex Europeaus</td>
<td>0.005</td>
<td>Explosion of pods</td>
<td>Juliana (2019)</td>
</tr>
</tbody>
</table>

Table 2 provides information on the dispersal rates and mechanisms of various plant species. Each species is associated with a specific distance from the parent plant and the primary method of dispersal, as documented by different researchers in various studies.
Figure 3 represents the count and percentage of primary dispersal mechanisms for vegetation. The figure shows the prevalence of different dispersal methods, including explosion, vegetative propagation, wind, animals, humans, and water.

➢ Allelochemicals and Allelopathic Effects

Table 3 Allelochemicals are Present in each Invasive Plant Species.

<table>
<thead>
<tr>
<th>Species</th>
<th>ALLELOCHEMICALS PRESENT</th>
<th>REFERENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acacia mangium</td>
<td>Catechin, gallic acid, condensed tannins</td>
<td>Dhamodaran &amp; Chacko (2017)</td>
</tr>
<tr>
<td>Ageratina adenophora</td>
<td>2-coumaric acid glucoside, eupatorin</td>
<td>Chuan et al. (2021)</td>
</tr>
<tr>
<td>Ageratum conyzoides</td>
<td>Alkyl resorcinol, pyrrolizidine alkaloid</td>
<td>Amarpeet et al. (2023)</td>
</tr>
<tr>
<td>Ambrosia trifida</td>
<td>Protocatechuic acid p-hydroxybenzoic acid, glyphosate</td>
<td>Dong et al. (2020)</td>
</tr>
<tr>
<td>Argemone mexicana</td>
<td>Cinnamic and benzoic acids, mimosine</td>
<td>Namkelela et al. (2018)</td>
</tr>
<tr>
<td>Bunias orientalis</td>
<td>Glucosinolates, terpenes</td>
<td>Corli et al. (2021)</td>
</tr>
<tr>
<td>Chromolaena odorata</td>
<td>Pyrrolizidine alkaloid, chromomonic acid</td>
<td>Miodri &amp; Hisashi (2023)</td>
</tr>
<tr>
<td>Clidemia hirta</td>
<td>Kaempferol, coumarins, steroids, triterpenoids</td>
<td>Cao et al. (2018)</td>
</tr>
<tr>
<td>Cytisus scoparias</td>
<td>Spartine, quercetin, condensed tannins, lupanene, gallic acids</td>
<td>Gudžinskas &amp; Taura (2022)</td>
</tr>
<tr>
<td>Eichhornia crassipes</td>
<td>Juglone, 2-methoxy-1,4-naphtoquinone, gallic acid,limonene, sorgoleone.</td>
<td>Lekamge et al. (2020)</td>
</tr>
<tr>
<td>Imperata cylinrica</td>
<td>Imperactacylin A, imperanine</td>
<td>Muhammad (2020)</td>
</tr>
<tr>
<td>Ipomoea eberhardii</td>
<td>Caffeic acid, ferulic acid, and p-coumaric acid, Terpenoids, and carotenoids</td>
<td>Thi et al. (2019)</td>
</tr>
<tr>
<td>Lantana camara</td>
<td>Lantadene A&amp;B luteolin, quercetin, gallic acid, gallotannins</td>
<td>Negi et al. (2019)</td>
</tr>
<tr>
<td>Leucaena luecocephala</td>
<td>Mimosine and quercetin</td>
<td>Padma et al. (2020)</td>
</tr>
<tr>
<td>Merremia boisiana</td>
<td>Phenolic compounds, Terpenoids, and alkaloids</td>
<td>Thi et al. (2019)</td>
</tr>
<tr>
<td>Mikania micrantha</td>
<td>Sesquiterpene lactones, caffeic acids</td>
<td>Liu et al. (2020)</td>
</tr>
<tr>
<td>Mimosa pigra</td>
<td>Phytotoxin mimosine,catechin, leucenol, piperidine alkaloids.</td>
<td>Amali &amp; Florentine (2022)</td>
</tr>
<tr>
<td>Myroxylon balsamum</td>
<td>Caffeic acid, chlorogenic acid, furfural acid, myricetin, and quercetin</td>
<td>Loayza-Cabezba (2018)</td>
</tr>
<tr>
<td>Opuntia stricta</td>
<td>Opuntiol, ascorbate, carotenoids, betalains, and phenolic acids</td>
<td>Venter et al. (2022)</td>
</tr>
<tr>
<td>Parthenium hysterophorus</td>
<td>Parthenin, ambrosin, caffeic acids, chlorogenic acid, ferulic acid</td>
<td>Bashar et al. (2023)</td>
</tr>
<tr>
<td>Phyllostachys pubescens</td>
<td>Quercetin, kaempferol, gallotannins, guaiacyl lignin</td>
<td>Xu et al. (2020)</td>
</tr>
<tr>
<td>Pistia stratiotes</td>
<td>Gallic acid, kaempferol</td>
<td>Silva et al. (2020)</td>
</tr>
<tr>
<td>Prosopis juliflora</td>
<td>Quercetin, kaempferol, juliprosopine</td>
<td>Patnaik et al. (2017)</td>
</tr>
<tr>
<td>Tamarindus indica</td>
<td>Gallotannins, catechin, glycosides.</td>
<td>Oyebamiji et al. (2018)</td>
</tr>
<tr>
<td>Ulex europeus</td>
<td>Quinolizidine alkaloids, methanolic, eugenol, verbenone, terpinen-4-ol</td>
<td>Juliana (2019)</td>
</tr>
</tbody>
</table>

Table 3 presents the allelopathy found in the invasive plant species through the production and release of allelochemicals signaling chemicals to suppress competing plant species.
Figure 4 highlights the significant effects of allelochemicals released in the environment leading to their successful invasion.

Implemented Management Approaches

Table 4 Implemented Management Approaches

<table>
<thead>
<tr>
<th>Species name</th>
<th>Awareness</th>
<th>Biological control</th>
<th>Competition</th>
<th>Chemicals</th>
<th>Drivers</th>
<th>Physical</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ageratina adenophora</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
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<td>✔</td>
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<tr>
<td>Acacia mangium</td>
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<td>✔</td>
<td>✔</td>
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<td>✔</td>
<td>✔</td>
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<td>Ageratum conyzoides</td>
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<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Clidemia hirta</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
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<tr>
<td>Cytisus scoparius</td>
<td>✔</td>
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<td>Eichhornia crassipes</td>
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<td>✔</td>
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<tr>
<td>Imperata cylindrica</td>
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<td>✔</td>
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Table 4 represents in the research article this focus the implemented management approaches of invasive plant species across Asia. These are the list of invasive plant species that have a classification of Public awareness (by informing local people about the impacts), biological control, competition (removing invasive species by competing with native species), drivers (by knowing factors that import invasive species), physical (manual removal), and uses (using plants as green manure or for bedding of livestock).
Figure 5 shows the percentage of implemented management approaches which demonstrates the following chart. The invasive plant species of awareness has 10.3 percent management approaches. The biological control rates at 16.7 percent approaches, in competition that has 13.5 percent approaches, chemicals figure at 19.0 percent of management approaches, drivers rates at 9.5 percent approaches, physical reaches at 15.9 percent of its approaches, finally the uses were taken at 15.1 percent implemented management approaches. This classification of plant species helps identify responsible factors to manage invasive species.

Control Measures

Table 5 Control Measures of Invasive Plant Species in Different Dynamic Processes

<table>
<thead>
<tr>
<th>Plants species</th>
<th>Physical</th>
<th>Chemical</th>
<th>Mechanical</th>
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<tr>
<td>Acacia mangium</td>
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<td>Ageratina adenophora</td>
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<td>Ageratum conyzoides</td>
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<td>Ambrosia trifida</td>
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<td>Argemone mexicana</td>
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<td>Bunias orientalis</td>
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<td>Clidemia hirta</td>
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<td>Eichhornia crassipes</td>
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<td>Ipomoea eberhardtii</td>
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<td>Myroxylon balsanum</td>
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<td>Parthenium hystrophorus</td>
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<td>Ulex europeaeus</td>
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Table 5 shows the control measures that have significant impacts on the environment. The check marks represent the presence of each invasive plant species which classifies in three categories. Physical, Chemical and Mechanical. Physical control measures which specify cutting trees, leaf removal, hand pulling and many other physical activities. Chemical control measures include the uses of herbicides like metsulfuron-methyl, glyphosate, pendimethalin and other sources of chemicals. Mechanical control measures illustrate the control machine that includes tractors that reduce the damage of vegetation in that area. Overall, the attributes of these invasive plant species are vital for maintaining ecological balance and protecting biodiversity. Invasive plant species often grow rapidly and spread aggressively, outcompeting native flora and leading to a reduction in biodiversity.
Figure 6 highlights the numerical count of control measures used in the invasive plants species. Physical control measures have numerical value of 16 invasive plant species present in the table shown above. Chemical control measures have numerical value of 22 invasive plants species presence to its impact. Lastly, mechanical control measures have numerical value of 11 invasive plants species presence. Overall, the total attributes of physical, chemical, and mechanical control measures have 49 total counts in the category. Each strategy has advantages and disadvantages, but when used together, they can achieve long-term management while preserving ecosystem health and diversity.

IV. DISCUSSION

This paper assesses the factors that influence the performance of invasive plant species under competition-free environment. The identification of the different levels of reproduction, dispersal, and growth rates denotes the ability of exotic plants to persist in any environment causing ecological imbalance by the significant increase of biotic occupation.

- List of Invasive Plant Species Introduced Across Asia

The following species shown in Table 1 is composed of grasses such as *Imperata cylindrica* and *Phyllostachys pubescens*; shrubs such as *Prosopis juliflora*, *Cytisus scoparius*, *Clidemia hirta*, and *Chromolaena odorata*; trees such as *Tamarindus Indica*, and *Acacia mangium*; and aquatic plants such as *Eichhornia crassipes* and *Pistia stratiotes*. A majority of these species are flowering plants, which might be an advantage to them to propagate. These species mostly originate from the Americas, specifically in Canada, United States, Mexico, Brazil, Peru, Argentina, and Caribbean nations in Central America such as Trinidad and Tobago. There are also species that originate in Europe, Africa, Oceania, and within Asia as well. The regional distribution for these plants is shown to spread out across Asia but are less common in Northern Asia. Most of these species like *Ageratina Adenophora*, *Pistia stratiotes*, *Mimosa pigra*, and *Ageratum conyzoides*, are prevalent in both South and Southeast Asia.

- Growth Rates

Reproductive success in the given data, several species exhibit relatively high reproductive success, such as *Eichhornia crassipes*, *Phyllostachys pubescens*, *Prosopis juliflora*, *Tamarindus Indica*, *Lantana Camara*, *Ipomoea eberhardtii*, and *Pistia stratiotes*, with growth rates ranging from 20 to 60 cm per year.

These species are likely to produce a significant number of seeds or propagules, which enhances their ability to disperse and establish in new habitats. High reproductive success can lead to the rapid colonization of available resources and the outcompeting of native species. It allows invaders to quickly establish self-sustaining populations, leading to successful invasions.

Species with fast growth rates can outcompete native species for limited resources such as light, nutrients, and space. In the given data, species like *Phyllostachys pubescens*, *Prosopis juliflora*, *Tamarindus Indica*, *Lantana Camara*, *Pistia stratiotes*, *Acacia mangium*, and *Imperata cylindrica* exhibit relatively high growth rates ranging from 40 to 60 cm per year.

These fast-growing species can quickly establish dominance over native vegetation, forming dense stands and altering ecosystem dynamics. Rapid growth allows invaders to exploit available resources efficiently and create conditions unfavorable for the survival of native species. As a result, their growth success contributes significantly to invasion success.
Comparing the species listed, it is evident that those with higher growth rates and reproductive success tend to be more successful invaders. Species like Phyllostachys pubescens, Prospopis Juliflora, Tamarindus Indica, Lantana Camara, Ipomoea eberhardtii, and Pistia stratiotes exhibit both high growth rates and reproductive success. These species have successfully invaded various regions.

On the other hand, species with lower growth rates and reproductive success, such as Cytisus scoparius, OpuntiaStricta, Ageratina Adenophora, Mimosa pigra, and Argemone mexicana, are likely to be less successful invaders. Although they may still colonize certain areas, their slower growth and lower reproductive output limit their ability to establish and spread as extensively as the more successful invaders.

- **Dispersal Mechanisms and their Efficacy**

  The dispersal mechanisms of invasive plants are primarily driven by wind and water, which account for 55.6% of the total dispersal. Wind is a significant dispersal vector for many invasive plant species with 25% of the total dispersal. Wind can disperse seeds, fruits, and other plant parts over long distances, often exceeding hundreds of kilometers. Wind-dispersed diaspores can persist over winter and form new plants at a density of about 2 plants per m² at 500 m away from the source (Li & Shen, 2020). Water is another important dispersal vector for invasive plants with 30.6% total dispersal. Rivers, in particular, have been found to be a significant vector for the spread of invasive plant species. For instance, the invasive plant species spread rapidly along the Yangtze River in China, with model predictions suggesting that the species will quickly spread along the river and colonize large areas within a few years (Gippet et al., 2017).

  Animals with 25% total dispersal, are essential in dispersing seeds of invasive plant species. Frugivores, such as birds and mammals, consume fruits and seeds, and then deposit the seeds in new locations, often with a higher probability of germination. Frugivorous birds have been found to disperse seeds of invasive shrubs, with germination success of both depulped and ingested seeds being high (> 80%). Human activities, such as trade, transportation, and tourism, are crucial contributors to the spread of invasive plant species. Human-mediated dispersal can occur through the intentional or unintentional movement of plant materials, such as seeds, fruits, and cuttings (Juncosa-Polzella et al., 2023). Vegetation also has the potential to aid in the spread of invasive plant species, accounting for 5.6% of total dispersal. Invasive shrubs can act as shelters for versatile consumers, enabling them to carry and scatter seeds of indigenous plants (Malo et al., 2021).

  Successful invaders, characterized by their ability to rapidly spread and establish populations in new habitats, often exhibit efficient dispersal mechanisms that contribute to their success. Species like Parthenium hysterophorus, with a dispersal distance of 400 km through wind dispersal as reported by Bashar et al. (2023), and Pistia stratiotes, dispersing over 2592 km solely through water dispersal according to Silva et al. (2020), are case of successful invaders that utilize effective dispersal strategies to colonize vast areas. These species demonstrate the importance of long-distance dispersal mechanisms in facilitating their invasive success. On the other hand, less successful invaders may exhibit limitations in their dispersal rates and mechanisms, hindering their ability to establish widespread populations. Species like Bunias Orientalis, which disperses over a minimal distance of 0.002 km through animals as noted by Corli et al. (2021), and Ulex Europeaus, with a dispersal distance of 0.005 km through the explosion of pods according to Juliana (2019), may face challenges in spreading efficiently across diverse landscapes. These species may struggle to compete with more successful invaders that possess greater dispersal capabilities. The analysis also uncovers how particular dispersal mechanisms influence the success of invaders. Species like Ambrosia trifida and Leucaena Leucocephala, with moderate dispersal rates through vegetation and wind dispersal respectively, may fall in between the spectrum of successful and less successful invaders, as documented by Dong et al. (2020) and Padma et al. (2020). The effectiveness of dispersal mechanisms in facilitating rapid spread is evident in the varying success rates of invasive species in colonizing new territories.

- **Allelochemicals and Allelopathic Effects**

  The “novel weapons hypothesis” states that detrimental plant biochemicals, such as the exudate from allelopathic antimicrobial roots, which directly impede plant development and soil microbial activity, are essential to the success of invading species. Nevertheless, little is known about how invasive plants use allelopathy to combine their direct and soil-mediated effects (Qu et al., 2021). The allelopathy inhibits the ability of plants from germinating and suppressing their growth in its vicinity to further propagate through releasing secondary metabolites, which are known as allelochemicals. A diverse range of phenotypic methods are employed by invasive species to establish themselves in new habitats leading to their successful occupation exterminating the native ones. According to a recent meta-analysis on the direct allelopathic impacts on plants, neighboring plants’ performance was, on average, 25% lower (Zhang et al., 2020). But anti-microbial allelopathic substances can potentially change the availability of nutrients in the soil (Zhang et al., 2019) or even kill soil microorganisms directly, upsetting plant-microbial mutualisms which are essential for plant resource acquisition. Some of the major allelochemical compounds that includes flavanoids, phenols, tannins, alkaloids, parthenin and lactones which are released in the environment may offer significant benefits in individual specie but poses a threat to the biological process of native ones. Allelopathic compounds help invasive species outcompete native species by modifying seed germination, inhibiting seedling growth, and interfering with nutrient cycling. These alterations in the ecosystem, driven by allelochemicals, give invasive plants a growth advantage, leading to their successful establishment. Plants such as Lantana camara, Mikania micrantha, Opuntia stricta and Eichhornia crassipes have shown a wide geographical distribution in Asia particularly in southern and eastern part interpreting their competitive advantage over native species.
The most substantial influence of the chemical produced by these species hinders the germination of seeds interfering the activity and expression of enzymes disrupting the enzymatic processes necessary for a plant’s growth and development.

**Management**

Despite a recent increase in the number of published papers, research on the control of invasive plants in South Asia remains limited. The most popular methods for removing invasive species in South Asian countries are chemical, physical, and mechanical (Raj et al., 2018). There have been initiatives to manage invasive species through physical eradication with the assistance of residents (Sullivan and York 2021), which is labor intensive. For example, the management of Pontederia crassipes through its biomass for various uses has been tried but failed due to a lack of consistent funding (Patel 2012). Unfortunately, biological control is still in its early stages and underdeveloped in South Asia due to the high initial cost and lengthy screening process. However, certain biological control agents for Ageratina adenophora, Chromolaena odorata, Lantana camara, Mikania micrantha, Parthenium hysterophorus, and Pontederia crassipes have been introduced into South Asia (Dhileepan and Senaratne 2009; Poudel et al. 2020; Shrestha et al. 2022). In Papua New Guinea, the gull fly Cecidochares connexa was discovered to successfully suppress the populations of invasive Chromolaena odorata (Day et al. 2013). In South Africa and some neighboring countries, the floral galling mite Aceria lantanae reduced Lantana camara flower production by up to 97% (Simelane et al. 2021). Furthermore, absence of natural enemies, physical disturbance, and open forest canopies all contribute to the survival of invasive species (Mandal and Joshi 2014). Passenger air travel is regarded as an introduction vector in South Asia (Early et al., 2016). Identifying the primary motivations and paths of plant invasions is critical for effective management. Lantana camara is a ubiquitous species that is difficult to eliminate using mechanical, chemical, and biological means (Love et al. 2009). In South Asia, the elimination of L. Camara is practically impossible, but its harmful effects can be mitigated by control.

V. CONCLUSIONS

Though species that are discussed are mostly equally spread across Asia, its especially prevalent in South and Southeast Asia. We can conclude that these species easily propagate in tropical regions such as the Philippines, Indonesia, Malaysia, Vietnam, Thailand, India, and Bangladesh. The country of origin of these species mostly come from the Americas, which similarly booming with biodiversity compared to Asia. A likely hypothesis of this is that the competitive ecosystem from the country of origin made it easier to spread in less competitive environments. The growth rates vary, with the lowest being 7.5 cm per year and the highest being 60 cm per year. Most of these species’ growth rates fall in ranges of 20 to 40 cm per year.

The dispersal rates of these species have a wide range, falling between 0.002 km from the parent plant being the lowest, and 2592 km from the parent plant being the highest.

The species that averages around 100 km from the parent plant relies on wind dispersion. Most of these species rely on animal mediated and wind dispersion as most of the species listed are flowering plants, which utilizes these methods to cross-pollinate. Most of the species that utilizes water dispersion ranges from 10 to 100 km from the parent plant. An outlier from these species that use water dispersion as a means of spreading, is the *Pistia stratiotes*, or the Water Lettuce which relies on stolon that are used as nodes from the parent plant.

Allelochemicals have different uses for the plant. But most of these species use these allelochemicals to inhibit growth and seed germination. This allows the plant to reproduce and multiply faster. Nutrient uptake and root growth are the allelopathic effect that is also highly prevalent among these plants as they would easily take up resources to make them reproduce faster. These species likely evolved to compete with other plants in their environment, and easily take up resources to spread faster. Toxicity is another allelopathic effect that is quite notable. These are just used as defense mechanisms to defend itself from the environment.

The most implemented control measures for these invasive species are the physical, biological, and chemical means of control. Physical means of control are especially cheap to do as it just simply means removing the plant by uprooting or removing the plant by other physical means. Using biological means is quite cheap to use as well, as it utilizes the natural enemies of these plants, like insects, to control the population. There is also the chemical means of control, which uses chemicals like herbicides to kill the plant population. All these control measures are generally cheap, or at least commercially viable to use.

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