Chapter

The Rising Threat of Invasive Alien Plant Species in Agriculture

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Abstract

A species is considered to be invasive if it establishes, persists, and spreads widely inside a natural ecosystem, stunting the growth of native plants and giving them room to overtake crops and native plants. Non-native plant species that have been brought into a new geographic area and have a negative effect on the ecosystems supporting horticulture and agriculture are known as invasive plant species. Invasive/noxious weeds, which are widely distributed in many types of ecosystems, significantly reduce crop production. Compared to native species, invading plant species have a higher potential to move their niche more rapidly and are more likely to adapt to new environments. The timing, speed, and longevity of seed germination have indeed been discovered to change as a result of climate change, which has consequences for plant invasions. More than native plant species, invasive plant species gain from atmospheric carbon dioxide (CO_2) enrichment, greenhouse gas emissions, and global warming. A loss of native biodiversity due to invasive species includes species extinction, changes in hydrology, and altered ecosystem function.

Keywords: invasive alien plant, global warming, climate change, weed shift, crop weed competition

1. Introduction

The invasive species is significant on a global importance. A non-native plant or other organism is considered an invasive species if it completely takes over an ecosystem and damages both its structure and function. Invasive species displace or harm local wildlife and plants, frequently posing major challenges to the area's biodiversity and creating unfavorable environmental conditions. There are no geographical limitations to the type or spread of invasive species. The greatest direct economic losses in crop production are caused by invasive weeds. One of the major direct causes of environmental change on a worldwide scale with a large ecological impact is biological invasion. The potential impact of invasive alien plant species on global agriculture, which continues to affect food security globally, could be significant [1]. The economic cost of plant invasion to agriculture is growing due to the increasing number of new introductions

which create a tremendous impact on crop production. The invasive alien plants / weeds have many similar biological attributes/traits relating to high reproduction and stress tolerance. The traits include germination of seeds, rapid seedling growth, vegetative and sexual reproduction at early stage aggressive spread by runners or rhizomes, diverse dispersal mechanisms and the ability to tolerate a wide range of environmental condition.

Warming of the earth surface is inevitable due to influence of greenhouse gas emission and instinctive climate variability. The average temperature of the earth has increased considerably by 1.53° C from 1900 to 2020 which has impacted the growing seasons of crops leading to reductions in crop yields [2]. Ramification of crop productivity is considerably noticeable on crop productivity. Potential growth and distribution of invasive plant species are accelerated by climate changes like rise in temperature, atmospheric carbon-dioxide level, nitrous oxide, methane gas emission, extreme weather conditions and change in rainfall pattern. Invasive plants reduce agricultural productivity by way of considerable mechanisms: competition for light, water, nutrient, allelopathy effects and decrease the crop yields and inhibition of seed germination [3].

Invasive and climate change are two of the primary factors which alter ecological systems. Temperature, precipitation, nitrogen, carbon dioxide, and measurements of organismal response in field conditions are manipulations of factors anticipated to vary with climate change. Therefore, the objective of the book chapter is to discuss the effect of climate change on invasive weed floral composition, distribution and effect on crop production.

2. Influence of invasive alien plants on N and P Pool in soil and plant

The success of invasion is mainly the result of the status of soil or growing environment of invasive alien plants (**Figure 1**). NH_4^+ concentration in soil evaded by *Chromolena odorata* was 1.43 times higher than native soil [4] and the NH_4^+ concentration of the soil invaded by *Ageratina adenophora* was 1.56–2.10 times that of soil with native plant species. The differences in soil properties and functioning point towards the contribution of root exudes and higher productivity of litter and their associated spatial variability [5]. Invasive alien plants have advantages over native plants which include higher photosynthetic rate, speeder growth rate, larger reproductive output, larger biomass, lower carbon-to-nutrient ratio in tissue, stronger capacity for nutrient absorption and higher plasticity levels [6]. The invasive species exhibit more strategic advantage for nutrient use over native plants [7] and hence lead to a greater enhancement in the N and P mineralization rates of the soil [8].

Invasive alien weeds such as *Bidens pilosa*, *Microstegium vemineum* and *Mikania micrantha* absorb nitrate over ammonium which causes competition with native crops in nitrate rich soils [9]. African native weed *Andropogon gayanus* was found to directly alter soil structure in tropical Australia which was attributed to the weed accelerating the ammonia process and increasing soil ammonium availability to four timed that of native plant soil, with more than six times higher uptake rate of ammonium than native species. The availability of N, P and N/P ratio profoundly impacted interspecific competition between invaded habitat and native weeds. Hence nutrient deposition promoted the invasiveness of alien plants in the ecosystem [10].

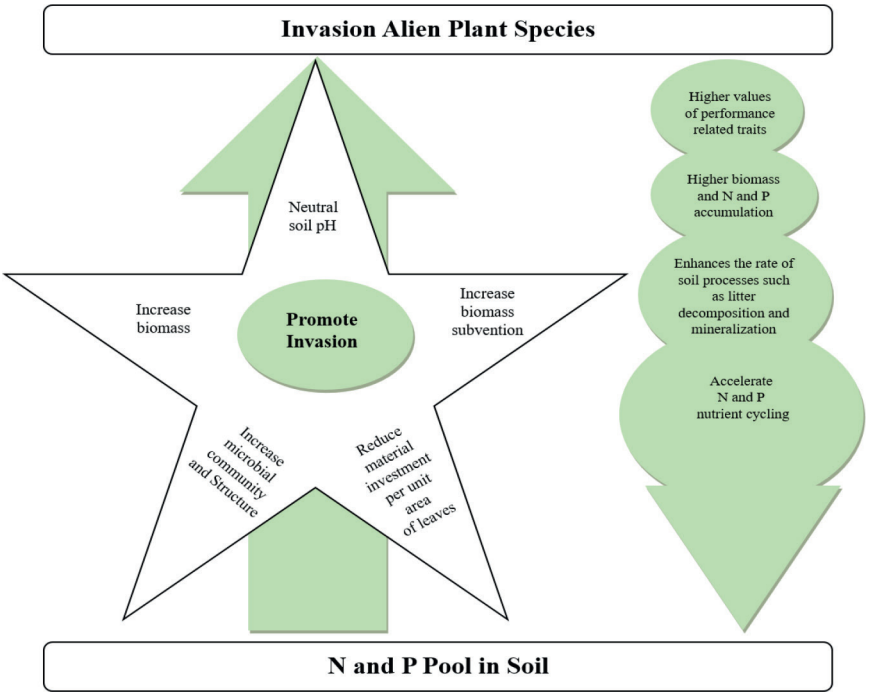

Figure 1.
Influence of nutrient fluctuation caused by N and P on the invasiveness of alien plants.

3. Climate change and weed invasion

Climate is known as the main environmental driver of species distribution, and there have been extensive studies on the distribution areas of invasive plants in determining invasive spreading [11]. Movement of weed species from native range to new areas naturally makes non-native species invasive with negative impact on native species of arable ecosystem. Climate change provides the opportunity for weeds to invade new ecosystems. Climate changes enhances the adaptability of the introduced plants to the new host range and increasing the risk of invasion in native and managed ecosystem since they are suited to new environments and successful in resource utilization in elevated CO_2 concentration. Interactions between climate change and management practices may turn invasive species with high potential to spread widely causing impact on productivity. Weeds can be highly response to increased CO_2 concentration [12]. Invasive and climate change are two of the primary factors which alter ecological systems.

Manipulation of factors likely to change with climate is temperature, precipitation, nitrous oxide levels and carbon dioxide and measurement of organismal response under field conditions integrate the biotic and abiotic factors individuals. Invasive species are most commonly defined as a non-native plant or other organism that dominates the encountered ecosystem and impairs its function and structure. Invasive species displace or damage native fauna and flora often posing serious threats to local biodiversity and causing adverse environment stress. Invasive alien species are one of the major threats to global and local diversity. The threats caused by invasive plant species in agricultural ecosystem include hybridization and species completion.

Global warming may result in the expansion in the habitat range of invasive species and the contraction or displacement of the habitat range of indigenous species [13].

Plant invasion is a serious threat to global biodiversity and hence deleterious to ecology and nature biodiversity. Invasive plants metamorphose the landscape ecology in a highly complex manner leading to ecological explosion. Global terrestrial crops are invaded by various invasive weed species [14]. Alien species that endanger ecosystems, habitats, or species, as well as agricultural production, are considered invasive species. Recent advances in genetics and molecular biology have paved the way for impacts on ecology and global biodiversity. The histories of invasion and agriculture are internally linked with many crops being invasive species. Agricultural biotechnology which is the insertion of genes into crops has generated concern over the risk of producing new invasive species or exacerbating current weed problems. The modern intensive agriculture paved the way for invasive weeds to spread across the globe. Land use changes which is conversion of forests/grasslands into agroecosystem habitat fragmentation as well as increase the level of organic pollutants resulting in the increase level of CO_2/climate change. Global climate changes are directly linked to biological invasions resulting in biodiversity loss (**Figure 2**). Global change stressors like climate change variability and changes in land use are major drivers of ecosystem alterations. Climate is the principal determinant of vegetation distribution from regional to global levels. The global climate is changing; along with measuring temperature and CO_2 level changes are considered major drivers of climate change [15].

Climate conditions exert a significant influence in the spread, population dynamics, life cycle duration, infestation pressure and the overall occurrence of invasive species. Invasive weeds will be influenced by climate change. The direct and indirect consequence of increasing CO_2 or climate change which differentially affects the growth of invasive weeds and crops will alter crop weed competitive interactions. Climate change has a big impact on invasive weed species' distribution, population dynamics, life cycles, pressure from infestations, and overall occurrence [16]. *Parthenium hysterophorus* L. is an invasive weed species worldwide. It is considered as one of the worst weeds in the world due to high fecundity that is ability to produce

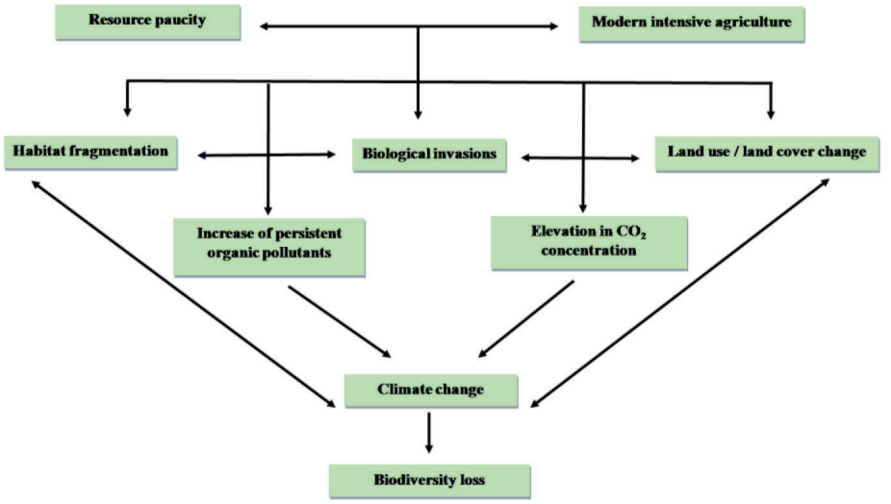

Figure 2.
Paradigm of global inter connected ecological and invasive plant issues.

lot of seeds (20,000 seeds/plants, rapid germination, fast growth rate and threat to crops. The seeds can germinate in a wide range of temperature and cause 40–97 percent yield reduction in crops [17].

3.1 Consequences due to invasive weeds

Biological invasion has become one of the major causes of economic and environmental damage in most of the countries across the world and its impact have been predicted to increase ever further under future climatic conditions. The Convention on Biological Diversity (1992) emphasized biological invasion as one of the drivers of biodiversity decline. Invasive potential of species enables weeds to be successful invaders and colonizers of the novel environments whether introduced deliberately or accidently. Developing regions are fast witnessing the change across all countries. Losses caused by invasive weeds are thrashing of biodiversity from native ecosystems [18], alteration in ecosystem, decline in abundance and richness of native flora and alteration in community structure. The risk of introduction of alien invasive weeds has enhanced due to global climate change. It is estimated 20–30 percent of all introduced species worldwide cause a problem. The impact of climate change on invasive weeds indicated that weeds on the whole have a large growth in the increase in atmosphere CO_2 concentration relation to plant species and rising CO_2 can be sustainable for invasive noxious species within plant communities [19]. Global efforts are very important to control the invasive weed species. Differences between native and exotic plant species in their mode of resource utilization may cause a change in soil structure, its profile, decomposition, nutrient content of soil and moisture availability. Invasive weed species is a serious hindrance to conservation and sustainable use of biodiversity. The impact of climate change on invasive weeds and indicated that the invasive, noxious weeds on the whole have a larger growth in the projected increases in atmospheric CO_2 concentration in relation to other plant species [20]. Ecological integrity and biodiversity of agriculture ecosystems have been seriously threatened by expansion of invasive weed species across globe. Climate change induced transformations in the invasive weed flora of arable ecosystems. Thermophilic weeds and late emerging invasive weeds have become more abundant in cropping system. Prominent invasive weed species like *Lantana camara*, *Mikania micrantha*, *Chromolaena odorata*, *Eupatorium adenophorum*, *Cytisus scoparius*, *Mimosa invisa*, *Parthenium, hysterophorus* among terrestrial exotics and *Eichhornia crassipes* and *Pistia stratiotis* among aquatic have posed greater threat to the native crop flora [21].

3.2 Invasive alien species/weeds and their distribution

Invasive alien weed species shift is an important aftermath of global climate change in ecosystem that affects weed management strategies and agricultural productivity (**Table 1**). Climate change is viewed as a cause in accelerating the rate of invasion by alien species in addition to the globalization of anthropogenic activities. *Rottboellia cochinchinensis* is an aggressive invasive species native to Asia. The species is known worldwide for invading crops and disturbed habitats in tropical and subtropical regions. The species spread from South America to Asia in 1961 through the seeds accidentally mixed with rice seeds and found to contain in 27 countries [22]. *Imperata cylindrica* (L.) P. Beauv, is one of the ten worst weeds a perennial grass native to South East Asia is a wide spread invader to warmer regions [23, 24]. *Persicaria glabra* is an invasive weed plant native to North America and Eurasia belonging to the family Polygonaceae

Scientific Name	Family	**Origin**	**Distribution**	**Propagation**
Acanthospermum hispidum	Asteraceae	Brazil (South America)	Widespread in the tropics.	Seed
Ageratina adenophora (Spreng.) King & Robinson	Asteraceae	Mexico (Central America)	Tropical and Subtropical region	Seed
Ageratum conyzoides	Asteraceae	Tropical America	Tropical and Subtropical region	Seed
Alternanthera paronychioides A. St.Hil	Amaranthaceae	Colombia (Tropical America)	Asia and Africa	Seed
Alternanthera philoxeroides	Amaranthaceae	South America	China, Australia, Thailand	Vegetative
Alternanthera pungens	Amaranthaceae	Tropical America	Tropical Africa, Asia, and Australia	Seeds, Vegetative
Alternanthera tenella	Amaranthaceae	Tropical America	Tropical Africa and Asia	Seed
Ambrosia artimisiifolia	Asteraceae	North and Central America	Europe, Africa and Asia	Seed
Ambrosiat trifida	Asteraceae	North America	Temperate Europe and Asia	Seed
Ammania baccifera	Lythraceae	Tropical Africa	Tropical Asia, Africa and America	Seed
Argemone Mexicana	Papaveraceae	Tropical and South America	Tropical and Subtropical region	Seed
Asteracantha lonfifolia	Acanthaceae	Tropical Asia	Tropical Africa and America	Seed
Bidens pilosa	Asteraceae	Tropical America	Tropical of regions Africa and Asia	Seed
Blumea eriantha DC.	Asteraceae	Tropical America	Asia and Africa	Seed
Blumea lacera (Burm. f.) DC.	Asteraceae	Tropical America	Asia, tropical Africa and Australia	Seed
Capsella bursa	Brassicaceae	Mediterranean Region	Wide temperate region	Seed
Cassia rotundifolia Pers.	Caesalpiniaceae	Tropical South America	Tropical and Subtropical Africa Asia	Seed
Celosia argentea	Amaranthaceae	Tropical Africa	Tropical and Sub tropical Asia	Seed
Centella asiatica	Apiaceae	Tropical Asia	Widespread in the tropical regions	Seed, Vegetative
Chenopodium album	Amaranthaceae	Europe	Temperate and Subtropical region	Seed
Chloris barbata Sw.	Poaceae	Tropical America	Tropical and Sub tropical Asia	Seed
Chromolaena odorata	Asteraceae	Tropical America	Humid tropical Asia and Africa	Seed

Scientific Name	Family	**Origin**	**Distribution**	**Propagation**
Cirsium arvense	Asteraceae	South eastern Europe	Subtropical and temperate region	Seed, Vegetative
Cleome gynandra L.	Cleomaceae	Tropical America	Tropical and Subtropical worldwide	Seed
Cleome rutidosperma DC.	Cleomaceae	Tropical America	Tropical Africa Asia and Australia	Seed
Cleome viscosa L.	Cleomaceae	Tropical America	Tropical and Subtropical region	Seed
Commelina benghalensis	Commelinaceae	Tropical Asia	Tropical Africa and Subtropical Asia	Seed, Vegetative
Cuscuta chinensis	Cuscutaceae	Mediterranean	Distributed worldwide	Seed
Cuscuta reflexa	Cuscutaceae	Tropical Asia	Distributed worldwide	Seed
Cyanotisaxillaris	Commelinaceae	Indian sub-continent	South East Asia and Australia	Seed, Vegetative
Cyperus difformis	Cyperaceae	Tropical America	Distributed worldwide	Seed
Cyperus iria	Cyperaceae	Tropical America	Distributed worldwide	Seed
Cytisus scoporius	Fabaceae	Central and Southern Europe	Temperate and sub-tropical region	Seed
Dactylactenum aegyptium	Poaceae	Tropical Africa	Tropical, Subtropical and warm temperate	Seed
Datura innoxia	Solanaceae	Tropical America	Tropical and Subtropical Asia & Africa	Seed
Datura metel	Solanaceae	Tropical America	Tropics and Subtropics worldwide	Seed
Digera muricata (L.) Mart.	Amaranthaceae	Southwest Asia	Tropical Africa and Malesia	Seed
Digitaria sanguinalis	Poaceae	Eurasia	Temperate warm region of world	Seed
Dinebra retroflexa (Vahl) Panz.	Poaceae	Tropical America	Through tropical and South Africa	Seed
Echinochloa colona	Poaceae	Tropical South America	Worldwide Tropics and Subtropics	Seed
Echinochloa crusgalli	Poaceae	Tropical South America	Worldwide Tropics and Subtropics	Seed
Eclipta prostrata	Asteraceae	Tropical America	Tropical, Subtropical and warm temperate	Seed
Eichhornia crassipes	Pontederiaceae	Tropical America	Distributed worldwide	Vegetative
Eleusine indica	Poaceae	Eurasia	Distributed worldwide	Seed
Elytrigia repens	Poaceae	Europe	Distributed to temperate region	Seed

Scientific Name	Family	**Origin**	**Distribution**	**Propagation**
Equisetum arvense	Equisetaceae	Europe	Distributed Europe and Asia	Seeds and Rhizomes
Euphorbia cyathophora Murray	Euphorbiaceae	South America	Subtropical areas worldwide	Seed
Euphorbia hirta	Euphorbiaceae	Tropical America	Widespread Tropical and Subtropical	Seed
Evolvulus nummularius (L.)	Convolvulaceae	South America	Tropical and Subtropical regions	Seed
Fimbristyllus dichotoma	Cyperaceae	Tropical America	Distributed worldwide	Seed
Flaveria trinervia (Spreng.) C. Mohr.	Asteraceae	Tropical Central America	Tropical regions	Seed
Glechoma hederacea	Laminaceae	Europe	North America, Australia and New Zealand	Vegetative and Seed
Gnaphalium pensylvanicum Willd.	Asteraceae	Tropical America	Distributed worldwide	Seed
Gnaphalium polycaulon Pers.	Asteraceae	Tropical America	South America, Tropical Asia and Africa	Seed
Gomphrena serrata L.	Amaranthaceae	Tropical America	Distributed worldwide	Seed
Impatiens capensis	Balsiminaceae	North America	Temperate region	Seed
Imperata cylindrica	Poaceae	Tropical America	Tropical and Warm Temperate region	Seeds
Ipomoea carnea	Convolvulaceae	South America	Tropical and Subtropical region.	Seed
Kyllinga nemorallis	Cyperaceae	South East Asia	Distributed worldwide	Seedsand Rhizomes
Lagascea mollis Cav.	Asteraceae	Tropical Central America	Tropical and Subtropical regions	Seed
Lantana camara	Verbenaceae	Tropical America	Tropical and Subtropical regions	Seed
Leersia oryzoides	Poaceae	Central America	Tropical and Subtropical regions	Seed
Leontodon taraxacum	Asteraceae	Europe	Distributed worldwide temperate region	Seed
Leptochloa chinensis (L.)	Poaceae	Tropical Asia	Africa, Central and South America	Seed and Vegetative
Leptochloa uninervia (J. Presl) Hitchc. & Chase	Poaceae	Central America	Distributed worldwide	Seed and Vegetative
Ludwigia adscendens (L.) Hara	Onagraceae	Tropical America	South East Asia and Malesia	Seed

Scientific Name	Family	**Origin**	**Distribution**	**Propagation**
Ludwigia octovalvis (Jacq.) Raven	Onagraceae	Tropical Africa	Throughout the Tropical world	Seed
Ludwigia perennis	Onagraceae	Tropical Africa	Throughout the Tropical world	Seed
Marselia quadrifolia	Marsileaceae	Southern and Central Europe	North America and Asia	Rhizomes
Merremia aegyptia (L.) Urban.	Convolvulaceae	Tropical America	Worldwide Tropical and Subtropical	Seed
Mikania micrantha Kunth	Asteraceae	Tropical America	Tropical area Africa and Asia	Seed
Mimosa pudica	Mimosaceae	South and Central America	Tropical regions of the World	Seed
Mimosa invisa	Mimosaceae	South and Central America	Tropical regions of the World	Seed
Mirabilis jalapa L.	Nyctaginaceae	Peru	Warmer parts across World	Seed
Monochoria vaginalis (Burm.f.) C. Presl.	Pontederiaceae	Tropical America	Tropical and Subtropical wet areas	Seed
Nastridium indicum	Tropaeolaceae	South America	Distributed worldwide	Seed
Nicotiana plumbaginifolia Viv	Solanaceae	Tropical America	Tropical regions of the World	Seed
Panicum repens	Poaceae	Africa	Tropics and Subtropics	Seed and rhizomes
Parthenium hysterophorus	Asteraceae	Tropical and North America	Throughout the World	Seed
Papspalum dilatum	Poaceae	South America	Humid Tropics and Subtropics	Seed
Paspalaum distichum	Poaceae	Tropical and Subtropical America	Tropical and Subtropical region	Seed
Paspalum hydrophyllum	Poaceae	South America	Tropical Asia, Africa and Australia	Seed
Passiflora foetida L.	Passifloraceae	Tropical and South America	Tropical region of Asia and Africa	Seed
Pennisetum purpureum	Poaceae	Tropical America	Tropical and Subtropical region	Seed
Phyla nodiflora	Verbenaceae	South America	Tropical and Subtropical region	Seed
Phyllanthus tenellus	Euphorbiaceae	Mascarene Islands	Africa, Southern Europe and Asia	Seed
Physalis angulata L.	Solanaceae	Tropical America	Asia and Africa	Seed
Pistia stratiotes L.	Araceae	Tropical America	Tropical and Subtropical region	Vegetative

Scientific Name	Family	**Origin**	**Distribution**	**Propagation**
Plantigo lanceolata	Plantaginaceae	Eurasia	South Asia, Australia and North America	Seed
Portulaca oleracea	Portulacaceae	Tropical Central America	Tropical and Subtropical region	Seeds
Portulaca quadrifida	Portulacaceae	Tropical South America	Africa and Tropical Asia	Seed
Prosopis juliflora (Sw.) DC.	Mimosaceae	Mexico	Tropical and Subtropical region	Seed
Rotala densiflora	Lythraceae	Tropical Asia	Tropical Africa America and Australia	spores
Ruellia tuberosa L.	Acanthaceae	Tropical America	South East Asia and Tropical Africa	Seed
Salvinia molesta	Salviniaceae	South Eastern Brazil	Wide spread across tropical world	Vegetative
Sida acuta Burm.f.	Malvaceae	Tropical America	Pacific and South East Asia	Seed
Solanum seaforthianum Andre	Solanaceae	Brazil	Worldwide distribution	Seed
Solanum viarum Dunal	Solanaceae	Tropical America	Tropical and Subtropical region	Seed
Sonchus oleraceus L.	Asteraceae	Mediterranean	Tropical and Subtropical region	Seed
Sonchus asper Hill	Asteraceae	Mediterranean	Tropical and Subtropical region	Seed
Stylosanthes hamata (L.) Taub.	Papilionaceae	Tropical America	Tropical Africa and Asia	Seed
Stachytarpheta jamaicensis (L.) Vahl	Verbenaceae	Tropical America	Subtropical Asia Africa and Oceania	Seed
Stachytarpheta urticaefolia (Salisb.) Sims	Verbenaceae	Tropical America	Tropical Africa, Asia and Pacific region	Seed
Stellaria media	Caryophyllaceae	Europe	Throughout the world	Seed
Synadenium grantii Hook. F.	Euphorbiaceae	Tropical Africa	Tropical region of America and Asia	Seed
Synedrella nodiflora (L.) Gaertn.	Asteraceae	West Indies	Warmer region of the world	Seed
Taraxacum officinale	Asteraceae	Europe	Temperate region of the world	Seed
Tribulus terrestris	Zygophyllaceae	Tropical America	Warm Temperate region of Eurasia, Africa	Seed
Tridax procumbens	Asteraceae	Tropical Central America	Warm Temperate and Tropical region	Seed
Turnera subulata J.E. Smith	Turneraceae	Tropical America	Tropical region of Asia and Africa	Seed

Scientific Name	Family	**Origin**	**Distribution**	**Propagation**
Turnera ulmifolia L.	Turneraceae	Tropical America	Africa, South East Asia and Tropical Island	Seed
Typha angustata	Typhaceae	Tropical America	Asia, North Africa and South Europe	Seed
Ulex europaeus L.	Papilionaceae	Western Europe	Tropical Africa and Asia and Australia, NZ	Seed
Urena lobata L.	Malvaceae	Tropical Africa	Tropical Africa and South East Asia	Seed
Waltheria indica L.	Sterculiaceae	Tropical America	Tropical region of world	Seed
Xanthium strumarium	Asteraceae	Tropical America	Africa and Temperate and South East Asia	Seed
Youngia japonica (L.) DC.	Asteraceae	Tropical Asia	Worldwide	Seed

Table 1.
Invasive alien weed species world wide.

and spread to subtropical region of Asia, South America, Africa, Australia and Pacific Islands [25]. *Rubus fruticosus* L. (Family: Rosaceae) which is invasive weed is expected to retreat to subtropical and temperature regions and to higher altitude because sensitive to higher temperature and drought conditions [26]. *Nassella neesiana* (Trin and Rupr) Barkworth (Family: Poaceae) spread to new regions as it is highly invasive and drought resistant [27]. *Ulex europaens* L. (Family: Fabaceae) spread to high rainfall areas and cooler regions since the weed is drought sensitive. It is a weed in fifteen countries of the world from temperate to tropical areas and from coastal areas to mountains along a wide latitudinal and altitudinal gradient [28]. *Prosophis glandulosa* Torr. which belong to family Mimosaceae invade to warmer dry parts/lower rainfall areas because the weed is drought tolerant [29]. *Nassella trichtonia* (Nees) Hack. ex Arechav. weed belongs to family Poaceae spread to subtropical and temperate region and to higher altitude due to sensitive to temperature. It has diminished the agricultural carrying capacity of crops in south-eastern Australia, New Zealand and South Africa, and emerging populations have now been identified in Europe and the United States [30]. The changes in the distributions of globally noxious alien species (*Aegratina adenophora*, *Ageratum conyzoides*, *C. odorata*, *L. camara*, *M. micrantha*, and *P. hysterophorus*) in Bhutan, to provide evidence that even a mountain environment is under the threat of invasion given the change in climatic conditions which is a native of Central and South America [31]. *Ageratina adenophora* (Sprengel) R. King and H. Robinson (Asteraceae), is one of the most noxious invasive weeds in many parts of Asia, Oceania, and Africa. It has had serious ecological impacts on native biodiversity and caused enormous economic [32]. *Tagetes minuta* is a fast-growing annual weed that grows in moist and dry areas, from sea level to reasonable altitudes in the tropics and subtropics, and in soil pH ranging from 4.3 to 6.6. *Echium plantagineum*, an annual weed of the family Boraginaceae, is native to the western Mediterranean regions of Portugal, Spain and northern Africa, but is an introduced weed in the arid and temperate zones of Australia. *E. plantagineum* weed is a prolific seeder, producing up to 10,000 seeds per plant [33]. *P. hysterophorus* is a noxious weed in America, Asia, Africa and Australia and has now become one of the world's seven most devastating and hazardous weeds. P*arthenium*. *hysterophorus* alien weed is believed to

have been introduced into India as contaminants in PL 480 wheat. P*arthenium*. *hysterophorus*, one of the most troublesome weeds in India and has also significantly expanded to Nepal. In Africa, there are about 35 invasive alien species were identified. Foremost among these are *P. hysterophorus* L., *E. crassipes* (Mart.) Solms, *Prosopis juliflora* (Sw.) DC., *L. camara* L., *Argemone ochroleuca* Sweet, *Xanthium strumarium* L., *A. conyzoides* L., *Datura stramonium* L., *Nicotiana glauca* Graham, *Senna didymobotrya* (Fresen.) Irwin & Barneby and *Senna occidentalis* (L.) which has spread from tropical and subtropical regions of South America. *A. ochroleuca* is flowering plants in the family Papaveraceae commonly known as prickly poppies and native to the West Indies and Central America; now a cosmopolitan tropical and subtropical weed. *S. didymobotrya* is a species of flowering plant in the Fabaceae (Leguminosae) which is native to Africa and found across the continents in several types of habitat [34]. *M. micrantha* has the largest distribution area (increase by 61–120%), while *adenophora* expand by 7–33%, *A. philoxeroides* by 12–74%, and *Ambrosia artemisiifolia* by 8–27%, respectively across globe. *A. adenophora*, Alternanthera philoxeroides, *A. artemisiifolia* and *M. micrantha* were invasive alien species to South East Asia native of Brazil. Invasive weed species, *L. camara*, A. adenophora, *P. hysterophorus* and *A. conyzoides* have reached 2900 m, which is higher than its reported elevation range (300–2800 m) across globe [35]. The distribution of invasive weed plants *A. adenophora*, *A. philoxeroides*, *A. artemisiifolia* and *M. micrantha* spreads towards the northern/southern ranges and higher elevation region worldwide due to susceptible to high temperature. Invasive weed species in family Poaceae (27 species), Asteraceae (23 species), Brassicaceae (18 species), Laminaceae (15 species), Fabaceae (11 species) and Caryophyllaceae (9 species) were recorded in the upper reaches of India [36].

3.3 Effect on crops by invasive alien weed species

Wide adaptability and faster growth of invaded weeds lead to dominance of weed in crop habitat Invasive weeds are responsible for 34% of agricultural losses [37] with the magnitude of impact varying between countries or location as 10% yield loss has been attributed to weeds in less developed countries and 25% in the least developed countries [38]. *Rottboellia cochinchinensis* is rated among the worst weeds in the world and is considered a serious problem in soybean (*Glycine max* (L.) Merr.), maize, cotton (Gossypium hirsutum L.), groundnut (*Arachis hypogaea* L.) and upland rice (*Oryza saliva* L.) in tropical regions of the world [39]. In tropical region it is a major weed problem in sugarcane (*Saccharum* spp.) and soybean. Invasive weed *Asphodelus fistulosus* a native of North America, South Europe and West Asia has been found in onion crop. The weed could make the land infertile if it is not controlled in a timely manner. *Imperata cylindrical* (L.) P. Beauv is one of the top invasive worst weed in the world and causes severe damage to the date palm and sugarcane fields of Iran [40].

Rice crop is infested with different invaded weed flora consisting of aquatic, semi-aquatic and terrestrial weeds (**Figure 3**). The invaded weed species *Alternanthera philoxeroides*, *Cyperus rotundus*, *Echinocloa crusgalli*, *Echinochloa stagnina*, *Eicchornia crassipes*, *Eragrostis stagnina*, *Commelina diffusa*, *Ludwigia liniflolia*, *Ageratum houstonianum*, *Alternanthera phiexeroides*, *Borrera articularis*, *Cynodon dactylon*, *Aeschynomene indica*, *Polygonum glabrum* Willd, *Melochia corchorifolia*, *Paspalam scrobiculatum*, and *Eleocharis acutangula* causes yield losses to the tune of 28–89 percent in transplanted and direct seeded lowland rice and 48–100 percent in upland

Echinochloa colona

Panicum repens

Eleusine indica

Echinochloa crusgalli

Paspalum distichum

Leersia oryzoides

Digitaria sanguinalis

Dactyactenium aeayptium

Dinebra retroflexa

Leptochloa uninervia

Cyperus rotundus

Cyperus iria

Fimbristylis dichotoma

Fimbristylus. meliacea

Scirpus microcarpus

Alternanthera echinata

Figure 3.
Invasive weed species in paddy lands.

ecosystem [41]. *Solidago gigantia* Aiton. had pronounced alleloapathic effect on germination and initial growth of carrot, barley and coriander. Reduction in emergence percent, shoot length and fresh weight of carrot and barley was also observed [42]. *Ageratum conyzoides*, *A. houstonianum* and *Erigeron karvinskianus* are primarily invading agroecosystem. *Avena fatua*, *Phalaris minor* and *Lolium temulentum* are the grassy weeds, which have now become a threat in wheat crop and affected yield [43].

Invaded weed species *P. minor* Retz, *Chenopodium album* L., *A. fatua* L., *Cichorium in*tybus, *Celosia argentia* and *Medicago denticulata* affect the yields in wheat [44]. *Echinochloa co*lona, *Trianthema portulacastrum*, *Euphorbia geniculata*, *Commelina communis* and *Physalis minima* invaded weed species affected soybean crop [45]. *Convolvulus arvensis* L., *Chicorium intybus* and *Lathyrus aphaca* invaded weed species affected chickpea crop. *Cynotis axillaris*, *Melochia conchorifolia* L., *Blainvillea acmella* (L.) Philipson (Asteraceae) and *Cyperus iria* native of Tropical America affected maize crop across globe [46]. *Tagetes minuta* is widely distributed across the tropics and subtropics and computing light, nutrients, and water with many economically important crops such as maize, rice, and beans. *Parthenium hysterophorus*, *Lantana camara*, *A. adenophora* and *A. conyzoides* are widely distributed and more rapidly proliferating alien plant weed species after crop yield [47]. Eighteen invasive weed species namely, *A. conyzoides*, *Cassia alata*, *Catharanthus pusillus*, *Celosia argentea*, *C. album*, *Eichhornia crassipes*, *Impatiens balsamina*, *Ipomoea eriocarpa*, *Ipomoea quamoclit*, *L. camara*, *Leucaena latisiliqua*, *Leucaena leucocephala*, *Melilotus alba*, *Mirabilis*

jalapa, *Passifora foetida*, *Pennisetum purpureum*, *Portulaca oleracea* and *Prosopis julifora* have been introduced from South America affecting crops like rice, wheat, sorghum, oilseed and pulse crops in India [48]. *Echinochloa crus-galli*, *Setaria viridis* and *Digitaria sanguinalis* populations were high and *Sorghum halepens*, *Bidens* pilosa, *Acalypha wilkesiana*, *Galinsoga parviflora*, *Amaranthus retroflexus*, *Solanum physalifolium*, *C. album*, *Polygonum lapathifolium*, *Xanthium italicum Datura stramonium* and *Sicyos angulatus* affected maize, wheat, sunflower, sorghum, sugarbeet and soyabean crops [49]. Invasive weed species *Trifolium repens*, *Eryngium billardieri*, *Lemna minor* and *Sorgum halepense* are the major invasive weeds in hilly tracts of India affecting the yield of paddy, mustard, wheat and oats crops [50]. *Typha augustata* which belongs to the family Typhaceae is found across wetland ecosystem throughout the world affecting the yield of rice crop [51].

3.4 Measures to control invasive weed

Understanding invasive weed species ecology, morphology, reproductive biology, physiology, and biochemistry is essential for effective management and prevention management and control through a full range of factors regulating their density, growth and competitive ability. The weed management strategies could be adapted to minimize prevalence of the invasive species for reducing to minimize the undesired effects and optimizing land use by combining prevention and control practices [52]. Invasion by alien species in agroecosystem can be best controlled by measures like crop rotation, balanced fertilization, maintenance of cover crops, intercropping diversification, and alteration in soil physical chemical and biological properties.

Enforcement of strong legislation could prevent introduction of invasive alien weed species in the country for conserving the rich biodiversity and increase crop production. Prevention, early detection and eradication of invasive alien weed species is the most economical and effective means of management. It is important to ensure new weed species of vegetative reproductive weed parts are not introduced in new areas. Mechanical, physical, biological, and chemical (herbicide) have to be used for the control of invasive weed species across the world. Mechanical control usually refers to the mowing or mechanical cutting of an invasive plant infestation to limit seed production. Manual invasive plant control usually refers to hand-pulling or digging. Cultural control and competition including re-vegetating, irrigating or fertilizing to encourage the establishment of a healthy ground or crop cover to resist invasive plants. Biological control involves using living organisms to reduce seed production and vigor of an invasive plant species. Biological control agents are not available for many invasive plant species [53].

4. Conclusion

The twenty first century threat of invasive alien weed species is extensive and distributed globally. An invasion by alien weed species is a global problem and forms one of the major drivers of global change. Invasive weeds species are one of the major problems in crop production. The threat by invasive alien plant species has been with rapid growth of globalization. The species affect crop production and biodiversity. Apart from threat to biodiversity and ecological distribution invasive alien species have significant socio-economic impact. The weeds compete with crop plants for light, moisture, nutrients and space. The mechanism of plant weed invasions has been

change in climatic condition, disturbance in natural ecosystem (soil, canopy cover, habitat fragmentation, fast growing potential of alien species and chemical interference by litter of alien weed species). The high seed production capacity spread, adaptation to wide climatic and soil condition are challenges to the management across worldwide for sustainable agricultural production.

Conflict of interest

The authors declare no conflict of interest.

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