https://doi.org/10.26651/allelo.j/2024-62-2-1490 0971-4693/94 Euro 20.00
Allelopathy Journal 62 (2): 115-138 (July, 2024) International Allelopathy Foundation 2024
Table: 5, Figs: -

Role of allelopathy in invasion of invasive species

H. Qureshi* and T. Anwar[1*]
Department of Botany, University of Chakwal, Chakwal-48800, Pakistan
Email: huma.qureshi@uoc.edu.pk; tauseef.anwar@iub.edu.pk

(Received in revised form : June 1, 2024)

CONTENTS

ABSTRACT

Allelopathy, the biochemical interaction between plants through the release of chemicals known as allelochemicals, plays a significant role in the invasion dynamics of many invasive species. This review explores the mechanisms by which allelopathy contributes to the competitive advantage of invasive plants, the types of allelochemicals involved, their modes of action, and the ecological impacts on native plant communities. We discuss the role of allelopathy in invasive species such as *Ailanthus altissima* (tree of heaven), *Eucalyptus* spp., and *Fallopia japonica* (Japanese knotweed), highlighting current research and identifying gaps for future study.

Key Words: Allelopathy, biodiversity threat, habitat destruction, invasive species, weed management.

1. INTRODUCTION

Biological invasion is defined as the ‘dispersal of species to habitats, where it was absent previously followed by its proliferation, spread, persistence and negative effects on biodiversity, health and/or economy’. It is a form of biological pollution, it causes the modifications/deterioration of habitats, competition with and replacement of native species, the spread of pathogens and genetic alteration within a population (6,57). Exotic plants, animals, insects and other living organisms are biological pollutants, among which plants are probably worst, due to their biomass (42,46).

According to the ‘Invasive Species Specialist Group’, out of the 100 worst invasive species in the world, 32 are plants (58). Historically, alien plant species spread through exploration and colonization to new habitats. Today, ‘natural entry’ and ‘introduction’ are dispersal modes of invaders (6) (Table 1).

*Correspondence author, [1]Department of Botany, The Islamia University of Bahawalpur, Bahawalpur-63100, Pakistan.

Table 1. Modes of entry of Alien species into new habitats

Mode of entry	Vectors
1. Natural	Wild animals, water currents, wind
2. Introduced	Humans
a. Intentional	Transport of horticultural, agricultural, pet and study species
b. Unintentional	Packing, commercial goods, ship ballast, interiors and exteriors of vehicles and vessels, clothing, luggage

The pace of spread of invasive plants is increasing with economic activities including trade, travel and technology worldwide (97). Invasive plants contribute to alteration in native flora, human/animal health risks, modification of ecosystem processes (hydrology, soil nutrients composition), reduction in agricultural yield and spread of vector-borne diseases (35,38).

Invasive species pose a significant threat to biodiversity, ecosystem stability, and economic resources worldwide. The ability of invasive plants to establish, spread, and dominate new environments often involves multiple interacting mechanisms, including high reproductive rates, efficient dispersal, and competitive traits. Among these mechanisms, allelopathy stands out as a key factor that can significantly enhance the invasive potential of these species (84,101). Allelopathy refers to the chemical inhibition of one species by another through the release of toxic compounds into the environment. This review examines how allelopathy facilitates the invasion process of certain invasive plant species, focusing on the biochemical mechanisms involved, the impact on native ecosystems, and potential management strategies.

2. ROLE OF ALLELOPATHY IN INVASIVENESS

The term "allelopathy" is coined from the Greek words "allelon," meaning "each other," and "pathos," meaning "suffering," was introduced by Austrian plant physiologist Hans Molisch in 1937. The International Allelopathy Society defines allelopathy as “Biochemical sympathetic (positive) or pathetic (negative) interaction within plants and microorganisms”. However, ecologists consider negative effects of allelopathy (52). In allelopathic interactions, plants produce and release of chemical substances into the environment through root exudation, volatilization, leaching from aboveground parts and by decomposition of plant material (24).

Chemicals involved in this process are called allelopathins, allelochemics, or allelochemicals. Allelochemicals are secondary metabolites with a few exceptions of primary metabolites. Allelochemicals have four precursors: shikimic acid, acetyl coenzyme A, deoxyxylulose phosphate and mevalonic acid synthesized during shikimate or isoprenoid pathway (131). Common types of allelochemicals include phenolic acids and terpenoids (116). These allelochemicals disrupt physiological processes, such as photosynthesis, respiration, water balance and hormonal regulation, in recipient plants by inhibiting enzyme activity (124).

Allelopathy involves the production and release of allelochemicals, which can be secondary metabolites such as phenolics, terpenoids, alkaloids, and flavonoids (Table 2).

Table 2. Allelochemicals isolated from Invasive plants

Plant species	**Isolated Allelochemicals**	**Reference**
Acroptilon repens (L.) DC.	Cnicin, 7,8-benzoflavone	4
Artemisia tridentata Nutt.	Methyl jasmonate	95
Berberis thunbergii DC.	Berberine	21
Carduus nutans L. and *C. acanthoides* L.	Aplotaxene	122
Celastrus orbiculatus Thunb.	Celastrol	21
Centaurea subjacea Hayek	(-)-Catechin	21
Centaurea diffusa Lam.	8-Hydroxyquinoline, Caryophyllene oxide, Linoleic acid	62,98
Centaurea affinis Friv.	(±)-Catechin	62,130
Centrostachys aquatica (R.Br.) Moq.	Loliolide	12
Dysphania ambrosioides (L.) Mosyakin & Clemants	α-terpinene, limonene, ascaridole	54
Cytisus scoparius (L.) Link	Sparteine	21
Elaeagnus angustifolia L.	Harman	21
Euphorbia esula L.	Esulatin	21
Geranium carolinianum L.	Ethyl gallate	44
Pilosella officinarum Vaill.	Umbelliferone	88
Hypericum perforatum L.	Hypericin	21
Hyptis suaveolens (L.) Poit.	Suaveolic Acid	21
Imperata cylindrica (L.) Raeusch.	Tabanone, Hexadecahydro-1-azachrysen-8-yl ester	22,53
Linaria dalmatica (L.) Mill.	Linarioside	21
Lythrum salicaria L.	Gallic acid	21
Melaleuca quinquenervia (Cav.) S.T.Blake	Nerolidol	21
Mikania micrantha Kunth	Deoxymikanolide, dihydromikanolide, 2,3-epoxy-1-hydroxy-4,9-germacradiene-12,8:15,6-diolide	118
Pastinaca sativa L.	Xanthotoxin	21
Phragmites australis (Cav.) Trin. ex Steud.	Gallic acid	108
Rhamnus cathartica L.	Emodin	21
Sporobolus alterniflorus (Loisel.) P.M.Peterson & Saarela	Hexadecanoic acid, Octadecanoic acid, Dibutyl phthalate, Adipic acid	143
Synedrella nodiflora Gaertn.	3-(5-(1-(3-methylpentyloxy) propyl)-tetrahydro-2-oxofuran-3-yl)-dihydrofuran-2(3H)-one	50
Tamarix ramosissima Ledeb.	Tamarixetin	21
Ulex europaeus L.	Maackiain	21
Vincetoxicum rossicum (Kleopow) Barbar.	Antofine	21,51
Xanthium strumarium Lour.	Xanthinosin	117
Neltuma juliflora (Sw.) Raf.	Syringin, (–)-Lariciresinol	89

These compounds can affect the germination, growth, and survival of neighboring plants by inhibiting seed germination and can prevent the germination of seeds of competing species, reducing their chances of establishing in the vicinity of the invasive species; suppressing growth by disrupting root and shoot growth, allelochemicals reduce the competitive ability of native plants and affecting soil microorganisms. Allelochemicals can alter the soil microbial community, affecting nutrients cycling and nutrients availability in ways that favour the invasive species (63).

Phenolic compounds, including simple phenols, phenolic acids, and flavonoids, are extensively studied for their allelopathic effects. These compounds can inhibit seed germination and root elongation, significantly impacting the growth and establishment of competing plants. Terpenoids (monoterpenes, sesquiterpenes, and diterpenes) can volatilize and influence neighbouring plants by inhibiting their growth and altering their metabolic processes. Alkaloids (nitrogen-containing compounds) are highly toxic and can disrupt cellular processes, thereby, affecting the growth and development of competing plants. Saponins, a class of glycosides, impact membrane integrity and nutrients uptake in rival plants, leading to inhibited growth. Lastly, coumarins, known for their ability to inhibit enzyme activities, can also disrupt plant hormone balance, resulting in reduced growth and development in target plants (137).

The modes of action of allelochemicals in plants are diverse and multifaceted. One such mechanism is cell membrane disruption, where certain allelochemicals compromise cell membrane integrity, causing leakage of cellular contents and eventual cell death. Another mode is enzyme inhibition; allelochemicals can inhibit key enzymes involved in metabolic processes, thus disrupting normal physiological functions. Hormonal interference is also a significant mechanism, wherein allelochemicals mimic or inhibit plant hormones, thereby altering growth patterns and development. Additionally, some allelochemicals induce oxidative stress by generating reactive oxygen species, which leads to cellular damage and reduced plant vigour. Lastly, allelochemicals can interfere with nutrients uptake, disrupting the absorption of essential nutrients and causing nutrients deficiencies and impaired growth (141).

Allelopathy plays a crucial role in influencing the invasion of exotic plants (124). Many allelochemicals have anti-microbial, anti-fungal and anti-herbivore effects providing invaders with a competitive advantage in their introduced range (87). These compounds have been observed in many invasive plants and are implicated in their invasion success. Notable invaders like *Centaurea maculosa* Lam. (106), *Alliaria petiolata* (M. Bieb.) Cavara & Grande (18), *Solidago canadensis* L. (2), and *Lantana camara* L. (120) showcase allelopathic effects that contribute to their invasion success.

The successful invasion of plants in new habitats is facilitated by various factors, including their ability to colonize disturbed habitats, rapid growth and reproduction, short life cycles, large seed production, vegetative propagation, early flowering and seeding, different phenology from natives, and resistance to pests and diseases. Allelochemicals (secondary metabolites) have recently been recognized to help the ecological dominance of invaders (10). Invasive plants compete more intensely for space, light and nutrients than endemics. They form monotypic stands that eliminate the native flora (131). Allelopathy plays an important role in the distribution and abundance of species within communities, as highlighted by the novel weapons hypothesis (NWH). The NWH proposes that invasive species produce allelopathic compounds to which native plants are not adapted (Table 3). It emphasizes the lack of evolutionary relationships between native and invasive species (17). Support for this hypothesis comes from: (i). Meta-analysis of previous studies (ii). Comparative experiments with native range and invaded species; (iii). Experiments with chemical isolates applied to species from native and invaded ranges (iv). Comparisons of chemicals produced by invasive and native species and (v). Comparisons of allelopathic effects of invasive and native plant species (91).

Table 3. Hypotheses for invasiveness of Alien species

Hypotheses	**Explanation**	**Reference**
Naturalization (DN)	Invasion success is attributed to human interference suitable environmental conditions, high propagule pressure, and favorable community interaction	32
Empty niche (EN)	Invaders use spare resources and occupy unused niches due to the limited Indigenous species pool	82
Dynamic equilibrium model (DEM)	Disturbance and productivity interact to affect invasion. Invaders become dominant in high-productivity systems with high levels of disturbance.	60
Opportunity window (OW)	Similar to EN but niche availability is dynamic. When an opportunity arises, invading species colonize and once naturalized, invade.	68
Evolution of increased competitive ability (EICA)	Release/reduction of enemies that limit population in home range enables invader to allocate resources to enhance its competitive ability in a new range	13
Propagule pressure (PP)	A high supply of plant propagule increases invasion chance due to high genetic diversity and swamping and continual supplementation	81
Increased resource availability (IRA)	An increase in resource level provides an opportunity for invasion as they are required for species colonization and establishment	121
Enemy release (ER)	Invader loses their herbivores and pathogens limiting its population size in the native range	70
Novel weapons (NW)	Invading species release Allelochemicals. Indigenous species are not adapted to these chemical weapons that repress and inhibit potential competitors in the introduced range enhancing invader's competitive ability and success	17
Resource enemy release (R-ER)	Combines ER and IRA, but notes that invasion can be accelerated when both occur	14

The allelopathic effects of invasive species can lead to significant ecological consequences. By suppressing the growth of native plants, invasive species reduce the diversity of plant communities, which can result in the loss of habitat for native wildlife and changes in ecosystem function. Alterations in plant community composition can also impact ecosystem processes such as nutrients cycling, soil structure, and hydrology, with the suppression of understory vegetation leading to increased soil erosion and changes in water availability. Additionally, the environments altered by allelopathic invasive species can become more susceptible to subsequent invasions by other non-native species, creating a positive feedback loop that exacerbates the impact on native ecosystems. Allelochemicals can further alter the composition and function of soil microbial communities, affecting nutrients cycling and plant-microbe interactions, which can have cascading effects on plant growth and ecosystem processes. Moreover, the management and control of allelopathic invasive species can be economically costly, requiring significant resources for mechanical removal, chemical treatments, and restoration efforts (99-101).

3. INVASIVE ALIEN PLANTS (IAP) AND PLANT INVASIONS

Invasive species are those introduced to areas beyond their native range, establishing themselves in the wild and spreading substantially from their point of introduction. They threaten global biodiversity, cause ecological problems, introduce diseases or incur economic costs (65). Due to their potential to outcompete and replace native species, invasive species are the second leading cause of biodiversity loss after habitat destruction (45). There are numerous researches since 1990s on biological invasions. From this perspective, invasion biology is a relatively young discipline (65).

Successful invasions are generally influenced by adequacy of seeds and subsequent ability of dispersal (104), suitability of habitat and ecological niche (115), environmental adaptability (112), ability to escape diseases, parasites and predators (33) and ability to overcome biological, physical and environmental thresholds (83). Hypotheses for success of invasive plants in new habitats.

The rate of plant invasions has rapidly accelerated, attributed to the expansion of disturbed habitats linked with rapid human population growth and various anthropogenic activities (5,15,30,114). The introduction of invasive plants may change the structure and function of the ecosystem by impacting succession, species composition, biomass, net primary production and nutrients cycling at population, community and landscape levels (27). Plant invasions deplete native species diversity, alter community composition and affect ecosystem processes, thus causing ecological imbalance (77). Exotic plants competitively exclude native neighbors in recipient communities. Several studies have provided data on the effects of exotic plants on altering community composition and reducing indigenous diversity. These studies assumed diverse mechanisms that generate significant invasion impacts. These processes include allelopathy, competition and native ecosystem characteristics alteration (92). Direct competition with native flora may result in monocultures of exotic species, as seen with *Psidium cattleianum* in Mauritius and *Parthenium hysterophorus* in Pakistan, Australia and India (35). In various parts of the world, as many as 80 % of endangered species are threatened by alien invasive species (Table 4).

Table 4. Impact of invasive plants on native plants

Invader species	**Site location**	**Assess-ment method**	**Assess-ment tools**	**Effects on Native spp.**	**Ref.**
AFRICA					
Acacia saligna (Labill.) H.L.Wendl.	North Nile Delta, Egypt	a	a	Increased evenness and reduced species richness in invaded plots	1
Lantana camara L.	Nairobi National Park, Kenya	a	a	More diverse and richer shrub-grassland and riverine vegetation in uninvaded areas	123

Lantana camara L.	Sabuk National Park, Kenya	a	a	Lower species diversity but higher plant density in invaded areas	135
Parthenium hysterophorus L.	Jijiga zone, Ethiopia	b	b	Reduced composition and diversity of vegetation in invaded sites	9
P. hysterophorus L.	Gamo Gofa, Ethiopia	c	a	Decrease in diversity indices with a dominance of parthenium	49
Tithonia diversifolia (Hemsl.) A.Gray	IIe-Ife, Southwestern Nigeria	a	a	Reduced diversity in invaded areas	93
ASIA					
Acacia saligna (Labill.) H.L.Wendl.	Northern Jordan	d	a	Reduced native plant species diversity under canopy	92
Chromolaena corymbosa (Aubl.)., *Parthenium hysterophorus* L., *Lantana camara* L.	Shivalik Hills, India	a	c	Decreased diversity, evenness, and richness of native species	34
Chromolaena corymbosa (Aubl.)	Shivalik Hills, India	a	c	Reduced productivity and diversity in invaded areas	36
Alternanthera philoxeroides (Mart.) Griseb.	Nanjing, China	e	e	Altered species composition and decreased species diversity with increased dominance of alligator weed	67
A. philoxeroides (Mart.) Griseb.	Shangrao City, China	a	e	Negative association with native plant communities. Decreased community stability and species count	80
A. philoxeroides (Mart.) Griseb.	China	a	a	Increased diversity with small-scale invasions, decreased diversity with larger invasions	142
Chromolaena odorata (L.)	Guangxi, China	f	f	Adverse effect on biodiversity due to invasion	47
Chromolaena odorata (L.) and *Parthenium hysterophorus* L.	Mysore, India	g	g	More heterogeneous infested sites compared to semi-heterogeneous non-infested sites	111
Chromolaena odorata (L.)	Tropical Sal Forest, Nepal	a	f	Fewer species in invaded plots compared to uninvaded plots	128
Ipomoea cairica (L.) Sweet	Guangdong China	a	f	Reduced plant richness and diversity	59
Lantana camara L.	Vindhyan UP India	h	a	Altered spatial pattern of herbaceous plant species	119
Mikania micrantha Kunth	Chitwan Park, Nepal	a	a	Negative impact on forest stand structure	11
Parthenium hysterophorus L.	Bilaspur, India	a	g	Threat to plant community biodiversity in agril fields	76
P. hysterophorus L., *Lantana camara* L., *Ageratum conyzoides* Sieber ex Sieber ex Steudel	Hilly state of Himachal Pradesh, India	a	g	Sharp decrease in vegetation	73
P. hysterophorus L., *Sesuvium*	Saudi Arabia	a	a	Negative correlation with species dominance	129

portulacastrum (L.) L., *Potamogeton perfoliatus* L., *Opuntia stricta* (Haw.) Haw., *Operculina turpethum* (L.) Silva Manso, *Malvastrum coromandelianum* (L.) Garcke, *Galinsoga parviflora* Cav., *Euphorbia tirucalli* L., *Encelia farinosa* A.Gray ex					
EUROPE					
Acacia leucolobia Sweet	River Miño (Spain)	i	i	Formation of monospecific stands	133
Acacia dentifera Benth.	North and south Portugal	a	a	Decreased canopy cover in lower strata, increased leaf area index, reduced light intensity, and reduced species diversity up to 50 %	102
Ailanthus altissima (Mill.) Swingle	Moldova	j	j	Clustered species occurrence	16
Ailanthus altissima (Mill.) Swingle, *Carpobrotus* N.E.Br., *Oxalis pes-caprae* L.	Mediterranean islands	a	a	Decreased diversity in invaded plots	134
Asclepias syriaca L.	Kiskunsag, Hungary	a	k	Negative impact on species cover	71
Elaeagnus triflora Roxb.	West and central desert Mongolia	a	a	Increased negative impact when escaping from windbreaks into the wild	125
Reynoutria japonica Houtt., *Reynoutria* × *bohemica* Chrtek & Chrtková, *Reynoutria* × *bohemica* Chrtek & Chrtková, *Rumex alpinus* L., *Heracleum mantegazzianum* Sommier & Levier, *Rudbeckia laciniata* L., *Symphyotrichum novi-belgii* (L.) *Helianthus tuberosus* L., *Solidago gigantea* Aiton, *Lupinus polyphyllus* Lindl., *Peucedanum ostruthium* W.D.J.Koch, *Erythranthe guttata* (DC.) G.L.Nesom, *Impatiens glandulifera* Royle	Czech Republic	a	a	Reduced species richness, evenness, and diversity in invaded plots	56

Impatiens glandulifera Royle	Riparian communities, Czech Republic	l	a	Dominance at the expense of native nitrophilous species	55
Prunus virginiana L.	Compie`gne forest North France	a	a	Trait convergence, community specialization, and reduced local heterogeneity	23
Quercus rubra L.	Poddębice Forest, Poland	a	a	Reduced native species richness and abundance	140
Spartium junceum L.	Manzanares Nature Reserve, Madrid	m	m	Increased nitrogen content and predominance of chamaephytes and therophytes	48
NORTH AMERICA					
Euphorbia esula L., *Cirsium arvense* (L.) Scop.	Rocky Mountain National Park, USA	a	a	Higher plant species richness and relative cover of sedges, herbs, moss, lichen, and fallen litter in non-invasive plots	96
Juniperus communis L.	Modoc, Lassen, Siskiyou Counties California	a	a	Changes in community structure and productivity. Reversal of changes upon removal but increased cheatgrass invasion	29
Lonicera maackii (Rupr.) Maxim.	Oxford, Ohio area	n	a	Decreased species richness, density, and tree seedlings in forests	27
Megathyrsus maximus (Jacq.)	Mona Island, Puerto Rico	a	a	Reduced population growth rates in invaded areas	107
Microstegium vimineum (Trin.) A.Camus	Mixed-hardwood Forest in Tennessee	o	a	Decline in native woody species with M. vimineum cover	94
Triadica sebifera (L.) Small	Neches River, Texas	a	p	Negative correlation with native species density	20
OCEANIA					
Hyparrhenia hirta (L.) Stapf	Travelling route north NSW Australia	a	a	Reduced native species richness	25
Nassella neesiana (Trin. & Rupr.) Barkworth	Yarramundi Beach, Australia	a	q	Decreased native plant diversity	39
N. neesiana (Trin. & Rupr.) Barkworth	Grasslands SE Australia	a	q	Reduced species richness	40
Rubus pedunculosus D.Don	Scalesia forest, Santa Cruz Island, Galapagos	r	r	Lower native species richness and cover	105
SOUTH AMERICA					
Syzigium jambos (L.) Alston	Tropical Forest, Costa Rica	s	s	Negative impact on tree seedling density	8

Codes for Assessment Methods and Tools:

Assessment Methods: a: Invaded and non-invaded areas comparison; **b:** Road transects survey method; **c:** Comparison among sample sites; **d:** Plant species comparison among outside and inside canopy; **e:** Square intercept method in plots; **f:** Communities' comparisons from different habitats to establish sample plots; **g:** Curtis and Mcintosh method of vegetation analysis; **h:** Habitats with different levels of canopy cover analysis; **i:** Visual interpretation; **j:** Direct observation; GPS spotting, Biometric and Statistical processing; **k:** Invaded and non-invaded plots comparison using linear mixed effect models; **l:** Comparison of invaded and uninvaded sites under the same habitat conditions (Space for time substitution), and removal of invader species from experimental plots; **m:** Comparison of invader stands with the native community; **n:** Plot comparison below and away crowns; **o:** Microstegium understory pre- and post-canopy disturbance comparisons; **p:** Paired-plot experimental design; **q:** Invaded and non-invaded patches comparison; **r:** Correlation analysis between cover gradient and species richness, cover and vegetation structure in plots; **s:** Plot analysis

Assessment Tools: a: Simpson diversity index, Shannon-Wiener diversity index, evenness**; b:** Evenness index (E), Jaccard's coefficient of similarity (JCS)**; c:** Density, abundance, frequency, Basal area, dominance, Margalef's index of richness, index of similarity and dissimilarity**; d:** Total number of species, Simpson's diversity index, Shannon's diversity index and Margalef's diversity index**; e:** Abundance, frequency, cover, importance value**; f:** Plant species richness**; g:** Frequency, density, abundance**; h:** Tree canopy cover (%), Lantana cover (%), Total herb cover (%), Shannon-Weiner index**; i:** Aerial photograph interpretation and analysis**; j:** Measurement of trunk with forest die, tree height with dendrometric pendulum and locating species by GPS**; k:** Species cover using linear mixed effect models**; l:** Number of species, evenness, Shannon diversity index and importance values**; m:** Soil properties, standing vegetation, temporal soil seed bank contents and net primary production (NPP) of annual grasslands**; n:** Species richness, cover, tree seedlings with canopy potential, seed1bud bank**; o:** Species richness of native woody species. Simpsons and Shannon's diversity indices**; p:** Density, basal area, quadratic mean diameter, stand density index and relative density**; q:** Foliar cover and species diversity**; r:** Vegetation height and species cover, plant species richness**; s:** Relative abundance and density of tree seedlings

4. INVASIVE SPECIES USING ALLELOPATHY

4.1. Invasive Weeds

4.1.1. *Lantana camara*: *Lantana camara*, commonly known as lantana, is a perennial shrub native to the tropical regions of Central and South America. This invasive plant produces various allelopathic compounds, including phenolic acids and terpenoids, which inhibits the germination and growth of native plant species. Research indicated that these compounds can alter soil chemistry, making it difficult for native plants to thrive. The dense thickets formed by *L. camara* outcompete and displace indigenous flora, leading to significant ecological imbalances. Phenolic acids and terpenoids from *L. camara* interfere with the normal physiological processes of surrounding plants by disrupting cellular functions and inhibiting enzyme activities. These allelochemicals can also alter soil pH and nutrients availability, further hindering the growth of native species. Additionally, the dense canopy of *L. camara* reduces light penetration to the understory, exacerbating the competitive disadvantage for native plants. The allelopathic effects of *L. camara* results in a marked reduction in native plant diversity and changes in plant community composition. This displacement of native species can lead to the loss of habitat for native wildlife and disruptions in ecosystem services such as nutrients cycling and water regulation. The ability of *L. camara* to dominate landscapes and its production of potent allelochemicals make it a highly problematic invasive species in many parts of the world (46,119,123).

4.1.2. *Parthenium hysterophorus* : *Parthenium hysterophorus*, commonly known as parthenium weed, is an annual herb native to the tropical Americas. It produces allelopathic compounds such as Parthenin, which are highly toxic to many plant species. Studies have shown that these compounds can inhibit seed germination and growth of native plants, leading to significant declines in biodiversity. The aggressive spread of *P. hysterophorus* and its allelopathic effects make it a major invasive species in tropical and subtropical regions. Parthenin and other allelochemicals produced by *P. hysterophorus* interfere with various physiological processes in target plants. These compounds can disrupt cell membrane integrity, inhibit photosynthesis, and reduce nutrients uptake, leading to stunted growth and reduced reproductive success. By altering soil microbial communities, Parthenin also affects soil health and nutrients cycling, creating conditions unfavourable for native plant species. The allelopathic effects of *P. hysterophorus* decreased the native plant diversity and altered plant community structures. This displacement of native species can lead to the loss of habitats for dependent fauna and changes in ecosystem functions such as nutrients cycling and soil stability. The rapid spread and strong allelopathic properties of *Parthenium hysterophorus* make it a serious threat to biodiversity and ecosystem health in invaded regions (9,76).

4.1.3. *Microstegium vimineum* : *Microstegium vimineum*, commonly known as Japanese stiltgrass, is an annual grass native to Asia. It produces allelopathic chemicals that inhibits the growth of native plant species. Studies have shown that these compounds can alter soil microbial communities and nutrients availability, further disadvantaging native plants. The rapid spread and dense growth of *M. vimineum* make it a formidable invasive species in North American forests. Allelopathic chemicals produced by *M. vimineum* affect native plants by disrupting cellular functions and inhibiting nutrients uptake. These compounds can also alter soil microbial communities, reducing the availability of essential nutrients for native plants. The dense mats formed by *M. vimineum* further suppress the native vegetation by limiting light availability and physical space. The allelopathic effects of *M. vimineum* lead to decreased native plant diversity and changes in forest understory composition. The suppression of native plants can result in altered ecosystem processes such as nutrients cycling and soil erosion. The ability of *Microstegium vimineum* to rapidly colonize disturbed areas and produce allelopathic compounds makes it a significant invasive species in many parts of North America (94).

4.1.4. *Phragmites australis* : *Phragmites australis*, commonly known as the common reed, is a perennial grass native to Eurasia. It produces allelopathic compounds, including gallic acid, which inhibits the growth of native plant species. Research has shown that these compounds can reduce seed germination and seedling growth in native plants, leading to the formation of dense monocultures of Phragmites. The aggressive growth and allelopathic effects of *P. australis* contribute to its success as an invasive species in wetlands. Gallic acid and other allelopathic compounds produced by *P. australis* disrupt cellular processes in target plants, leading to reduced germination and growth. These compounds can also alter soil chemistry, making it less favorable for the establishment of native plant species. The dense growth of Phragmites further suppresses native vegetation by limiting light and space. The allelopathic effects of *P. australis* lead to reduced native plant diversity and changes in wetland ecosystem structure. The displacement of native plants can result in the loss of habitat for native wildlife and alterations in wetland functions such as water filtration and nutrients cycling. The ability of *P. australis* to form dense stands and produce potent allelochemicals makes it a major ecological threat in invaded wetlands (108,132).

4.1.5. *Tamarix* spp. : *Tamarix* spp., commonly known as saltcedar, is a group of invasive shrubs and small trees native to Eurasia and Africa. They produce allelopathic compounds, including phenolics and flavonoids, which inhibits the growth of native plant species. Studies have shown that these compounds can alter soil chemistry and water availability, further disadvantaging native vegetation. The ability of *Tamarix* spp. to dominate riparian habitats and produce allelopathic compounds contributes to their invasive success. Phenolics and flavonoids produced by *Tamarix* spp. interfere with the normal physiological processes of surrounding plants by disrupting enzyme activities and cellular functions. These compounds can also alter soil chemistry by increasing salinity and affecting nutrients availability. The extensive root systems of *Tamarix* spp. further deplete water resources, creating conditions unfavorable for native plants. The allelopathic effects of *Tamarix* spp. lead to reduced native plant diversity and changes in riparian ecosystem structure. The displacement of native vegetation can result in the loss of habitat for wildlife and disruptions in ecosystem functions such as water regulation and nutrients cycling. The aggressive growth and allelopathic properties of *Tamarix* spp. make them a significant ecological threat in many riparian areas (21).

4.1.6. *Imperata cylindrica* : *Imperata cylindrica*, commonly known as cogongrass, is a perennial grass native to Southeast Asia. It produces allelopathic compounds, including ferulic and p-coumaric acids, which inhibits the growth of surrounding plant species. Research indicates that these compounds can reduce seed germination and seedling growth, allowing cogongrass to form dense monocultures. The rapid spread and allelopathic effects of *I. cylindrica* make it a highly invasive species in tropical and subtropical regions. Ferulic and p-coumaric acids produced by *I. cylindrica* disrupt cellular functions and inhibit enzyme activities in target plants. These allelochemicals can also alter soil microbial communities, reducing the availability of essential nutrients for native plants. The dense growth of cogongrass suppresses the native vegetation by limiting light and space. The allelopathic effects of *Imperata cylindrica* result in reduced native plant diversity and altered plant community dynamics. The displacement of native species can lead to the loss of habitats for native wildlife and disruptions in ecosystem processes such as soil stabilization and nutrients cycling. The ability of cogongrass to rapidly spread and produce potent allelopathic compounds makes it a significant ecological threat in invaded regions (22,53).

4.2. Invasive Trees

4.2.1. *Ailanthus altissima* : *Ailanthus altissima*, (heaven tree), is a rapidly growing deciduous tree native to China. It produces ailanthone, a quassinoid compound, which has been shown to inhibit seed germination and growth of various native plants. Studies have demonstrated that ailanthone can reduce the biomass of competing plants by affecting their root development and nutrients uptake. The allelopathic effects of *A. altissima* are evident in its ability to create monospecific stands, outcompeting native vegetation and altering ecosystem dynamics. Ailanthone disrupts cell membrane integrity and inhibits key metabolic enzymes, leading to cellular damage and reduced growth. It also affects the hormonal balance of target plants, inhibiting root elongation and shoot development. By altering soil microbial communities, ailanthone can further impact nutrients cycling and availability, creating an environment less favorable for native species. The allelopathic effects of *A. altissima* lead to a reduction in native plant diversity and changes in community structure. The displacement of native species can result in the loss of habitat for dependent wildlife and alterations in ecosystem processes such as nutrients cycling and hydrology. The ability of *A. altissima* to rapidly colonize disturbed areas and its production of allelopathic compounds make it a formidable invasive species (16,126).

4.2.2. ***Eucalyptus spp.:*** *Eucalyptus* species, native to Australia, are widely planted around the world for their fast growth and valuable timber. However, their allelopathic properties have contributed to their invasive success in many regions. *Eucalyptus* trees release volatile oils and phenolic compounds into the soil, which have allelopathic effects on surrounding vegetation. These compounds can inhibit the growth of understory plants and alter the composition of plant communities, giving *Eucalyptus* an advantage in colonizing new areas. The volatile oils released by *Eucalyptus* trees can volatilize and affect nearby plants through the air, while phenolic compounds are leached into the soil. These allelochemicals disrupt cell membrane integrity, inhibit enzyme activity and interfere with nutrients uptake. The cumulative effect is reduced germination and growth of competing plants, leading to a decline in plant diversity and changes in community composition. The allelopathic effects of *Eucalyptus* species can lead to the formation of dense monocultures, reducing biodiversity and altering ecosystem processes. The suppression of understory vegetation can affect soil erosion rates, water availability and nutrients cycling. The impact on native plant communities can also have cascading effects on wildlife that depend on these plants for habitat and food (127).

4.2.3. ***Schinus terebinthifolia*** **:** *Schinus terebinthifolia*, commonly known as Brazilian pepper tree, is an evergreen shrub or small tree native to South America. It produces allelopathic compounds, including phenolic acids and flavonoids, which inhibit the germination and growth of native plant species. Studies have shown that these compounds can alter soil chemistry and microbial communities, further disadvantaging native vegetation. The aggressive spread and allelopathic effects of *Schinus terebinthifolia* contribute to its success as an invasive species in subtropical and tropical regions. Phenolic acids and flavonoids produced by *S. terebinthifolia* interfere with the normal physiological processes of surrounding plants by disrupting enzyme activities and cellular functions. These compounds can also alter soil chemistry, making it less favorable for the establishment of native plant species. The dense growth of Brazilian pepper trees further suppresses native vegetation by limiting light and space. The allelopathic effects of *S. terebinthifolia* lead to reduced native plant diversity and changes in ecosystem structure. The displacement of native species can result in the loss of habitats for native wildlife and alterations in ecosystem functions such as nutrients cycling and soil stabilization. The ability of Brazilian pepper tree to form dense stands and produce potent allelopathic compounds makes it a major ecological threat in invaded regions (37).

5. INVASIVE PLANTS EFFECTS ON CROPS

Invasive plants have significant negative effects on crops and the environment (Table 5). These plants, often introduced to new regions unintentionally or intentionally for ornamental purposes, can outcompete native vegetation and disrupt ecosystems. Some of the major impacts of invasive plants on crops and are listed in Table 5. Invasive plants often outcompete native crops for essential resources such as water, nutrients, and sunlight, this competition reduces crop yields (86). Invasive plants can alter or destroy native habitats, reducing biodiversity by displacing native flora and fauna, this severely affects the ecosystem functions and services (74,140). Invasive plants may alter nutrients cycling in soils, impacting the availability of essential nutrients for both crops and native plants. This can lead to imbalances in soil fertility (3,41). Some invasive plants are highly water-demanding, leading to increased water consumption in invaded areas, potentially affecting water availability for crops and other vegetation (78,110). These poses risks to both agril lands and natural ecosystems, impacting crop production and native species (85).

Table 5. Invasive plant species affect crops and the environment

Invasive Plant	**Effects on Crops**	**Effects on Environment**	**References**
Ailanthus altissima (Mill.) Swingle	Competes with native vegetation	Alters forest ecosystems, reducing biodiversity	126
Argemone mexicana L.	Competes with crops for resources	Alters natural habitats affect native plant species	90
Phragmites australis (Cav.) Trin. ex Steud.	Competes for water resources	Alters riparian ecosystems, increasing the risk of wildfires	132
Berberis thunbergii DC.	Facilitates tick-borne diseases	Alters forest understory, impacting wildlife	136
Bromus tectorum L.	Increases the risk of wildfires	Alters grassland ecosystems, disrupting native plants	43
Broussonetia papyrifera (L.) Vent.	Displaces native vegetation	Alters forest ecosystems, affecting biodiversity	100
Carduus acanthoides L.	Competes with crops for resources	Alters grassland ecosystems, displacing native species	103
Casuarina equisetifolia L.	Suppresses native vegetation	Alters coastal ecosystems, impacting biodiversity	144
Centaurea solstitialis L.	Reduces forage for livestock	Alters grassland ecosystems, impacting wildlife	66
Cuscuta spp.	Parasitizes, weakens host plants	Reduce crop yields.	113
Cyperus rotundus L.	Competes with crops for nutrients	Thrives in wetland areas, impacting natural vegetation	61
Pontederia crassipes Mart.	Blocks sunlight and nutrients, impacts aquatic crops, hinders irrigation	Alters aquatic ecosystems reduce water quality and biodiversity	26

Elaeagnus angustifolia L.	Alters soil composition	Displaces native riparian vegetation, impacting waterways	125
Eucalyptus spp.	Consumes large amounts of water	Alters local ecosystems impact biodiversity	127
Reynoutria japonica Houtt.	Suppresses native plant growth	Disrupts riverbank stability and promotes erosion	56
Heracleum mantegazzianum	Competes with native plants for resources	Contains toxic sap that causes skin burns and photosensitivity	72
Impatiens glandulifera Royle	Displaces native vegetation	Increases soil erosion along riverbanks	55
Imperata cylindrica (L.) Raeusch.	Outcompetes crops for resources	Alters fire regimes, increasing the risk of wildfires	22
Lamium galeobdolon (L.) L.	Suppresses native plant species	Spreads rapidly in woodlands, impacting biodiversity	109
Lantana camara L.	Suppresses native plant growth	Forms dense thickets impact forest ecosystems	119, 123
Lythrum salicaria L.	Crowds out native wetland plants	Alters wetland ecosystems and reduces habitat for wildlife	21
Microstegium vimineum (Trin)	Outcompetes native vegetation	Alters forest understory, impacting native species	94
Olea europaea subsp. cuspidata (Wall. & G.Don) Cif.	Displaces native vegetation	Alters soil composition and disrupts natural ecosystems	31
Parthenium hysterophorus L.	Competes with crops for nutrients	Reduces biodiversity, affects soil health	9, 76
Polygonum perfoliatum L.	Rapidly spreads and covers vegetation	Displaces native plants impacts forest ecosystems	75
Neltuma juliflora (Sw.) Raf.	Reduces forage for livestock	Alter ecosystems, impact water availability	89
Pueraria montana (Lour.) Merr.	Smothers crops by fast growth and covering them	Alters ecosystems by displacing native vegetation	69
Rhaponticum repens (L.) Hidalgo	Competes with crops for resources	Alters grasslands, impacting native plant species	19
Robinia pseudoacacia L.	Alters soil composition	Forms dense stands, impacting forest ecosystems	79
Schinus terebinthifolia Raddi	Inhibits the growth of native vegetation	Alters ecosystems in coastal areas, impacting biodiversity	37
Silybum marianum (L.) Gaertn.	Can outcompete native plants	Alters grassland ecosystems, impacting local biodiversity	101
Tamarix spp.	Consumes excessive water	Alters river ecosystems reduce water availability	21
Tithonia diversifolia (Hemsl.) A.Gray	Can inhibit the growth of other plants	Alter soil composition impacts local ecosystems	93
Triadica sebifera (L.) Small	Inhibits native plant growth	Alters wetland ecosystems, affecting water flow	20
Ulex europaeus L.	Competes with native vegetation	Alters heathland and grassland ecosystems	28
Xanthium strumarium Lour.	Competes with crops for resources	Can dominate disturbed areas, impacting native plant species	99

Invasive plants can serve as hosts for diseases that affect crops, potentially acting as vectors that spread diseases to agricultural fields (138). Invasive plants can modify natural ecosystems, affecting the structure and composition of habitats and displacement of native species (64). Some invasive plants may affect carbon sequestration and contribute to climate change impacts (7). It's crucial to address invasive species to mitigate their negative impacts on agriculture and ecosystems. Efforts to control and manage invasive plants involve a combination of prevention, early detection, and eradication measures. It's crucial to address the spread of invasive species to mitigate their wide-ranging impacts on agriculture, ecosystems, and human well-being.

FUTURE RESEARCH DIRECTIONS

While significant progress has been made to understand the role of allelopathy in plant invasions, following areas require further research:

(i) **Identification of Allelochemicals**: More comprehensive identification and characterization of the allelochemicals involved in plant invasions are needed. Advanced analytical techniques such as mass spectrometry and nuclear magnetic resonance (NMR) spectroscopy can identify these compounds.

(ii) **Mechanistic Studies**: Detailed studies on the modes of action of these chemicals at the physiological and molecular levels will enhance our understanding of their impacts. This includes investigating how allelochemicals affect plant hormone balance, enzyme activity, and cellular processes.

(iii) **Field Studies**: Many allelopathic interactions have been studied under controlled conditions. Field studies are necessary to confirm these effects in natural settings. This includes examining the spatial and temporal dynamics of allelochemical release and its impact on native plant communities.

(iv) **Management Strategies**: Developing effective management strategies to mitigate the impacts of allelopathic invasive species is crucial for preserving native biodiversity. This includes exploring the use of native plants resistant to allelochemicals and developing restoration techniques to enhance the recovery of native plant communities.

(v) **Climate Change Interactions**: Investigating how climate change may interact with allelopathy to influence invasion dynamics is important. Changes in temperature, precipitation, and atmospheric CO2 levels could affect the production and release of allelochemicals, as well as the susceptibility of native plants to these compounds.

(vi) **Socioeconomic Impacts**: Understanding the socioeconomic impacts of allelopathic invasive species, including their effects on agriculture, forestry, and human health, is important for developing comprehensive management strategies. This includes assessing the costs of control and the benefits of preserving native ecosystems.

CONCLUSIONS

Allelopathy is a critical mechanism that contributes to the success of many invasive plant species. By releasing allelochemicals into the environment, these species can suppress native vegetation, alter ecosystems, and facilitate their own dominance. Understanding the role of allelopathy in plant invasions provides valuable insights into the dynamics of invasions and helps in developing effective management and control strategies. Further research in this field will continue to uncover the complexities of these interactions and aid in protecting native ecosystems from the adverse effects of invasive species.

ACKNOWLEDGMENTS

NA

CONFLICT OF INTEREST

The authors announce that they have no conflicts of interest.

DECLARATION

We declare that all authors of this manuscript have made substantial contributions. We have not excluded any author who substantially contributed to this manuscript. We have followed the ethical norms established by our respective institutions.

ETHICAL APPROVAL

The authors declare that the study was carried out following scientific ethics and conduct.

REFERENCES

1. Abd-El-Gawad, A.M. and El-Amier, Y.A. (2015). Allelopathy and potential impact of invasive *Acacia saligna* (Labill.) Wendl. on plant diversity in the Nile Delta Coast of Egypt. *International Journal of Environmental Research* **9**: 923-932.
2. Abhilasha, D., Quintana, N., Vivanco, J. and Joshi, J. (2008). Do allelopathic compounds in invasive *Solidago canadensis* s.l. restrain the native European flora? *Journal of Ecology* **96**: 993-1001.
3. Afzal, M.R., Naz, M., Ashraf, W. and Du, D. (2023). The Legacy of Plant Invasion: Impacts on Soil Nitrification and Management Implications. *Plants* **12**: 2980.
4. Alford, E.R., Perry, L.G., Qin, B., Vivanco, J.M. and Paschke, M.W. (2007). A putative allelopathic agent of Russian knapweed occurs in invaded soils. *Soil Biology and Biochemistry* **39**: 1812-1815.
5. Aliani, S., Berta, M., Borghini, M., Carlson, D., Conversi, A., Corgnati, L., Griffa, A., Magaldi, M.G., Mantovani, C., Marini, S., Mazzei, L., Suaria, G. and Vetrano, A. (2015). Biodiversity conservation: an example of a multidisciplinary approach to marine dispersal. *Rendiconti Lincei. Scienze Fisiche e Naturali* **26**: 37-48.
6. Alpert, P. (2006). The advantages and disadvantages of being introduced. *Biological Invasions* **8**: 1523-1534.
7. Anonymous. (2004). Invasive species and climate change fact sheet. Invasive species council. http: //www.invasives.org.au/ Accessed on Mach 03, 2024
8. Avalos, G., Hoell, K., Gardner, J., Anderson, S. and Lee, C. (2006). Impact of the invasive plant *Syzigium jambos* (Myrtaceae) on patterns of understory seedling abundance in a Tropical Premontane Forest, Costa Rica. *International Journal of Tropical Biology* **54**: 415-421.
9. Ayele, S., Nigatu, L., Tana, T. and Adkins, S.W. (2013). Impact of parthenium weed (*Parthenium hysterophorus* L.) on the above-ground and soil seed bank communities of rangelands in Southeast Ethiopia. *International Research Journal of Agricultural Science and Soil Science* **3**: 262-274.
10. Balezentiene, L. (2015). Immediate allelopathic effect of two invasive *Heracleum* species on acceptor-germination. *Acta Biological and Universal Daugava* **51**: 17-26.
11. Basnet, S., Chand, D.B., Chand, D.B., Wagle, B.H., Wagle, B.H., Rayamajhi, B. and Rayamajhi, B. (2016). Plant diversity and stand structure comparison of *Mikania micrantha* invaded and non-invaded tropical *Shorea robusta* forest. *Bankong Janakari* **26**: 78-81.

12. Bich, T.T.N. and Kato-Noguchi, H. (2014). Isolation and identification of a phytotoxic substance from the emergent macrophyte *Centrostachys aquatic Botanical Study* **55**: 59.
13. Blossey, B. and Notzgold, R. (1995). Evolution of increased competitive ability in invasive non-indigenous plants: A hypothesis. *Journal of Ecology* **83**: 887-889.
14. Blumenthal, D.M. (2006). Interactions between resource availability and enemy release in plant invasion. *Ecology Letters* **9***:* 887-895.
15. Bonari, G., Acosta, A.T.R. and Angiolini, C. (2018). EU priority habitats: Rethinking Mediterranean coastal pine forests. *Rendiconti Lincei. Scienze Fisiche e Naturali* **29**: 295–307.
16. Bostan, C., Borlea, F., Mihoc, C. and Beceneaga, A.M. (2014). Spread species *Ailanthus altissima* in new areal and impacts on biodiversity. *Research Journal of Agricultural Science* 46: 104-108.
17. Callaway, R.M. and Aschehoug, E.T. (2000). Invasive plants versus their new and old neighbors: A mechanism for exotic invasion. *Science* **290**: 521-523.
18. Callaway, R.M., Cipollini, D., Barto, K., Thele, G.C., Hallett, S.G., Prati, D., Stinson, K.A. and Klironomos, J.N. (2008). Novel weapons: Invasive plant suppresses fungal mutualists in America but not in its native Europe. *Ecology* **89**: 1043-1055.
19. Callaway, R.M., Schaffner, U. and Thelen, G.C. (2012). Impact of Acroptilon repens on co-occurring native plants is greater in the invader’s non-native range. *Biological Invasions* **14**: 1143-1155.
20. Camarillo, S.A., Stovall, J.P. and Sunda, C.J. (2015). The impact of Chinese tallow (*Triadica sebifera*) on stand dynamics in bottomland hardwood forests. *Forest Ecological Management* **344**: 10-19.
21. Cappuccino, N. and Arnason, J.T. (2006). Novel chemistry of invasive exotic plants. *Biology Letters* **2**: 189-193.
22. Cerdeira, A.L., Cantrell, C.L., Dayan, F.E., Byrd, J.D. and Duke, S.O. (2012). Tabanone, a new phytotoxic constituent of cogongrass (*Imperata cylindrica*). *Weed Sciences* **60**: 212-218.
23. Chabrerie, O., Loinard, J., Perrin, S., Saguez, R. and Decocq, G. (2010). Impact of *Prunus serotina* invasion on understory functional diversity in a European temperate forest. *Biology Invasions* **12**: 1891-1907.
24. Cheema, Z.A., Farooq, M. and Wahid, A. (2013). Allelopathy: Current trends and future applications. *Springer*-Verlag Berlin Heidelberg, ISBN: 978-3-642-30594-8.
25. Chejara, V.K., Nadolny, C., Kristiansen, P., Whalley, R.B.D. and Sindel, B.M. (2006). Impacts of *Hyparrhenia hirta* (L.) Stapf (Coolatai grass) on native vegetation in a travelling stock route in northern New South Wales. 15th Australian Weeds Conference, Papers and Proceedings, Adelaide, South Australia, 24-28 September 2006. *Managing Weeds in a Changing Climate.* 207-210.
26. Coetzee, J.A., Jones, R.W. and Hill, M.P. (2014). Water hyacinth, *Eichhornia crassipes* (Pontederiaceae), reduces benthic macroinvertebrate diversity in a protected subtropical lake in South Africa. Biodivers Conserv **23**: 1319-1330.
27. Collier, M.H., Vankat, J.L. and Hughes, M.R. (2002). Diminished plant richness and abundance below *Lonicera maackii*, an invasive shrub. *Middle Naturals* **147**: 60-71.
28. Cordero, R.L., Torchelsen, F.P. and Overbeck, G.E. (2016). Invasive gorse (Ulex europaeus, Fabaceae) changes plant community structure in subtropical forest–grassland mosaics of southern Brazil. *Biological Invasions* **18**: 1629-1643.
29. Coultrap, D.E., Fulgham, K.O., Lancaster, D.L., Gustafson, J., Lile, D.F. and George, M.R. (2008). Relationships between Western Juniper (*Juniperus occidentalis*) and understory vegetation. *Invasive Plant Sciences Management* **1**: 3-11.
30. Croce, A., Stinca, A., Santangelo, A. and Esposito, A. (2019). Exploring vascular flora diversity of two protected sandy coastal areas in southern Italy. *Rendiconti Lincei. Scienze Fisiche e Naturali* **30**: 323-336.
31. Cuneo, P., and Leishman, M.R. (2013). Ecological impacts of invasive African olive (*Olea europaea ssp. cuspidata*) in Cumberland Plain Woodland, Sydney, Australia. *Austral Ecology* **38**: 103-110.
32. Darwin, C. (1859). On the origin of species by means of natural selection or the preservation of favoured races in the struggle for life. John Murray, London.
33. Davis, M.A., Grime, J.P. and Thompson, K. (2000). Fluctuating resources in plant communities: A general theory of invisibility. *Journal of Ecology* **88**: 528-534.
34. Dogra, K.S., Kohli, R.K. and Sood, S.K. (2009). An assessment and impact of three invasive species in the Shivalik hills of Himachal Pradesh, India. *International Journal of Biodiversity and Conservation* **1**: 004-010.
35. Dogra, K.S., Sood, S.K., Dobhal, P.K. and Sharma, S. (2010). Alien plant invasion and their impact on indigenous species diversity at global scale: A review. *Journal of Ecology and Natural Environment* **2**: 175-186.

36. Dogra, S., Kohli, R.K., Sood, S.K. and Dobhal, P.K. (2009). Impact of *Ageratum conyzoides* L. on the diversity and composition of vegetation in the Shivalik hills of Himachal Pradesh (Northwestern Himalaya) India Kuldip. *International Journal of Biodiversity and Conservation* **1**: 135-145.
37. Eorgan C.M. and Overholt, W.A. (2005). Potential allelopathic effects of Brazilian pepper (*Schinus terebinthifolius* Raddi, Anacardiaceae) aqueous extract on germination and growth of selected Florida native plants. *The Journal of the Torrey Botanical Society* **132**: 11-15.
38. Etana, B. (2013). Distribution and challenges of an invasive exotic species, *Prosopis juliflora* (Sw.) DC. (Fabaceae) in Ethiopia, East Africa. *International Journal of Green Herbal Chemistry* **2**: 110-120.
39. Faithfull, I., Hocking, C. and McLaren, D. (2008). A preliminary assessment of the composition and cover of vascular plants associated with patches of *Nassella neesiana* (Trin. & Rupr.) Barkworth (Poaceae) in an Australian native grassland. *Proceedings of the 16th Australian Weeds Conference,* Cairns Convention Centre, North Queensland, Australia, 18-22 May, 2008 pp. 206-208.
40. Faithfull, I.G., Hocking, C. and McLaren, D.A. (2010). Chilean needle grass (*Nassella neesiana*) in the native grasslands of south-eastern Australia: biodiversity effects, invasion drivers and impact mechanisms. 17th Australasian weeds conference. *New frontiers in New Zealand: Together we can beat the weeds.* Christchurch, New Zealand, 26-30 September 2010 pp. 431-434.
41. Feng Sun, Zeng L., Cai M., Chauvat M., Forey E., Tariq A., Graciano C., Zhang Z., Gu Y., Zeng F., Gong Y., Wang F. and Wang M. (2022). An invasive and native plant differ in their effects on the soil food-web and plant-soil phosphorus cycle, *Geoderma*, **410**: 115672.
42. Florece, L.M. and Baguinon, N.T. (2011). Bioinvasion: Concepts, criteria and rating system for determining the invasiveness of alien plant species. *Global Journal of Environmental Science Management* **14**: 77-87.
43. Freeman, E. D., Sharp, T. R., Larsen, R. T., Knight, R. N., Slater, S. J. and McMillan, B. R. (2014). Negative effects of an exotic grass invasion on small-mammal communities. *PloS One* **9**: e108843.
44. Fujii, Y., Kamo, T., Hiradate, S., Shindo, M. and Shishido, K. (2011). Isolation and identification of novel allelochemicals and utilization of allelopathic cover plants for sustainable agriculture. *23rd Asian-Pacific Weed Science Society Conference.* 26-29 September 2011.
45. Gaertner, M., Breeyen, A.D, Hui, C. and Richardson, D.M. (2009). Impacts of alien plant invasions on species richness in Mediterranean-type ecosystems: A meta-analysis. *Progress in Physical Geography* **33**: 319-338.
46. Gantayet. P.K., Lenka, K.C. and Padhy, B. (2011). Vegetative growth and yield response of Niger (*Guizotia abyssinica*) to leaf- litter dust of *Lantana camara*. *The Bioscan* **6**: 07-210.
47. GaoZhong, P., SaiChun, T., YuMei, P., ChunQiang, W. and MingChao, L. (2012). *Chromolaena odorata* community structure and its effects on species richness of native vegetation community under different habitats in karst area of Guangxi. *Prataculture Science* **29**: 447-452.
48. Gavilan, R.G., Sanchez-Mata, D., Gaudencio, M., Gutierrez-Giron, A. and Vilches, B. (2015). Impact of the non-indigenous shrub species *Spartium junceum* (Fabaceae) on native vegetation in central Spain. *Journal of Plant Ecology* **9**: 132-143.
49. Gebrehiwot, N. and Berhanu, L. (2015). Impact of *Parthenium* on species diversity in Gamo Gofa, Ethiopia. *Scholarly Journal of Agricultural Science* **5**: 226-231.
50. Ghayal, N.A., Dhumal, K.N., Deshpande, N.R., Ruikar, A.D. and Phalgune, U.D. (2011). Phytotoxic effects of leaf leachates of an invasive weed *Cassia uniflora* and characterization of its allelochemical. *Research Journal Pharmaceutical Biological Chem**istry** Science* **2**: 524-534
51. Gibson, D.M., Krasnoff, S.B., Biazzo, J. and Milbrath, L. (2011). Phytotoxicity of antofine from invasive Swallow- Worts. *Journal Chemistry Ecology* **37**: 871–879.
52. Gross, E. (1999). Allelopathy in benthic and littoral areas case studies on allelochemicals from benthic cyanobacteria and submerged macrophytes. In: *Principles and Practices in Plant Ecology Allelochemical Interactions* (Eds., Inderjit KM, Dakshini M, Foy CL.) pp. 179-199. CRC Press, Boca Raton.
53. Hagan, D.L., Jose, S. and Lin, C. (2013). Allelopathic exudates of cogongrass (*Imperata cylindrica*): Implications for the performance of native pine savanna plant species in the Southeastern US. *Journal Chemistry Ecology* **39**: 312-22.
54. Hegazy, A.K. and Farrag, H.F. (2007). Allelopathic potential of *Chenopodium ambrosioides* on germination and seedling growth of some cultivated and weed plants. *Global Journal of Biochemistry and Biotechnology* **2**: 1-9.
55. Hejda, M. and Pysek, P. (2006). What is the impact of *Impatiens glandulifera* on species diversity of invaded riparian vegetation? *Biology Conservation* **132**: 143-152.
56. Hejda, M., Pysek, P. and Jarosik, V. (2009). Impact of invasive plants on the species richness, diversity and composition of invaded communities. *Journal Ecology* **97**: 393-403.

57. Holm, L.G., Plucknett, D.L., Pancho, J.V. and Herberger, J.P. (1991). *The world's worst weeds: Distribution and biology*. Krieger Publishing Company, Florida.
58. Holzmueller, E.J. and Jose, S. (2009). Invasive plant conundrum: What makes the aliens so successful? *Journal Tropical Agriculture* **47**: 18-29.
59. Hui, Z. and Shuang, T.W. (2012). Impacts of invasion of *Ipomoea cairica* on plant community and soil fertility. *Journal Ecology Rural Environment* **28**: 505-510.
60. Huston, M.A. (1979). A general hypothesis of species diversity. The American Naturalist **113**: 81-101.
61. Imron, M.F., Hestianingsi, W.O.A., Putranto, T.W.C., Citrasari, N., Abdullah, S.R.S., Hasan, H.A. and Kurniawan, S.B. (2024). Effect of the number of *Cyperus rotundus* and medium height on the performance of batch-constructed wetland in treating aquaculture effluent. *Chemosphere* **353**: 141595.
62. Inderjit, R. Callaway, R.M. and Vivanco J.M. (2006) Can plant biochemistry contribute to understanding of invasion ecology? *Trends Plant Science*. **11**: 574-580.
63. Islam, A.K.M.M., Ohno, O., Suenaga, K. and Kato-Noguchi, H. (2014). Suaveolic Acid: A potent phytotoxic substance of *Hyptis suaveolens. The Scientific World* **2014**: 425942.
64. Jamil, M.D., Waheed, M., Akhtar, S., Bangash, N., Chaudhari, S.K., Majeed, M., Hussain, M., Ali, K. and Jones, D.A. 2022. Invasive Plants Diversity, Ecological Status, and Distribution Pattern in Relation to Edaphic Factors in Different Habitat Types of District Mandi Bahauddin, Punjab, Pakistan. *Sustainability* **14**: 13312.
65. Jeschke, J.M., Aparicio, L.G., Haider, S., Heger, T., Lortie, C.J., Pysek, P. and Strayer, D.L. (2012). Support for major hypotheses in invasion biology is uneven and declining. *NeoBiota* **14**: 1-20.
66. Jia, T., Qi, Y., Zhao, H., Xian, X., Li, J., Huang, H., Yu, W. and Liu, W. (2023). Estimation of climate-induced increased risk of *Centaurea solstitialis* L. invasion in China: An integrated study based on biomod2. *Frontiers in Ecology and Evolution* **11**: 1113474.
67. Jin-Cheng, L. and Sheng, Q. (2006). Influence of *Alternanthera philoxeroides* on the species composition and diversity of weed community in spring in Nanjig. *China Journal Plant Ecology* **30**: 585-592.
68. Johnstone, I.M. (1986). Plant invasion windows: A time-based classification of invasion potential. *Biological Reviews* **61**: 369-394.
69. Kato-Noguchi, H (2023). The Impact and Invasive Mechanisms of *Pueraria montana* var. lobata, One of the World's Worst Alien Species. *Plants* **12**: 3066.
70. Keane, R.M. and Crawley, M.J. (2002). Exotic plant invasions and the enemy release hypothesis. *Trends in Ecology and Evolution* **17**: 164-170.
71. Kelemen, A., Valko, O., Kroel-Dulay, G., Deak, B., Torok, P., Toth, K., Miglecz, T. and Tothmeresz, B. (2016). The invasion of common milkweed (*Asclepias syriaca*) in sandy old-fields-Is it a threat to the native flora? *Applied Vegetation Science* **19**: 218-224.
72. Klimaszyk, P., Klimaszyk, D., Piotrowiak, M. and Popiołek, A. (2014). Unusual complications after occupational exposure to giant hogweed (*Heracleum mantegazzianum*): A case report. *International Journal of Occupational Medicine and Environmental Health* **27**: 141-144.
73. Kohli, R.K., Dogra, K.S., Batish, D.R. and Singh, H.P. (2004). Impact of Invasive plants on the structure and composition of natural vegetation of Northwestern Indian Himalayas. *Weed Technology* **18**: 1296-1300.
74. Kumar R. P. and Singh J.S. (2020). Invasive alien plant species: Their impact on environment, ecosystem services and human health. *Ecological Indicators* **111**: 106020.
75. Kumar, V. and Ditommaso A. (2017). Mile-a-Minute (*Polygonum perfoliatum*): An Increasingly Problematic Invasive Species. *Weed Technology* **19**: 1071-1077
76. Kumari, P., Sahu, P.K., Soni, M.Y. and Awasthi, P. (2014). Impact of *Parthenium hysterophorus* L. invasion on species diversity of cultivated fields of Bilaspur (C.G.) India. *Agricultural Science* **5**: 754-764.
77. Kunzi, Y., Prati, D., Fischer, M. and Boch, S. (2015). Reduction of native diversity by invasive plants depends on habitat conditions. *American Journal Plant Sciences* **6**: 2718-2733.
78. Le Maitre, D.C. (2020). Impacts of Plant Invasions on Terrestrial Water Flows in South Africa. In: *Biological Invasions in South Africa* (Eds., van Wilgen, B., Measey, J., Richardson, D., Wilson, J., Zengeya, T.). Invading Nature - Springer Series in Invasion Ecology. Springer, Cham. https: //doi.org/10.1007/978-3-030-32394-3_15
79. Li, K., Han, X. and Ni, R. (2021). Impact of Robinia pseudoacacia stand conversion on soil properties and bacterial community composition in Mount Tai, China. *Forest Ecosystem* **8**: 19.
80. Lian-Jin, G. and Tao, W. (2009). Impact of invasion of exotic plant *Alternanthera philoxeroides* on inter-species association and stability of native plant community. *China Journal Eco-Agriculture* **17**: 851-856.
81. Lonsdale, W.M. (1999). Global patterns of plant invasions and the concept of invasibility. *Ecology* **80**: 1522-1536.

82. MacArthur, R.H. (1970). Species packing and competitive equilibrium for many species. *Theoretical Population Biology* **1**: 1-11.
83. Malik, R.N. and Husain, S.Z. (2007). *Broussonetia papyrifera* (L.) L'Hér. ex Vent.: An environmental constraint on the Himalayan foothills vegetation. *Pakistan Journal of Botany* **39**: 1045-1053.
84. Marwat, K.B., Hashim, S. and Ali, H. (2010). Weed management: A case study from North-West Pakistan. *Pakistan Journal Botany* **42**: 341-353.
85. Matthew, L.B., D'Antonio, C.M., Richardson, D.M., Grace, J.B., Keeley, J.E., DiTomaso, J.M., Hobbs, R.J., Pellant, M. and Pyke, D. (2004). Effects of Invasive Alien Plants on Fire Regimes. *BioScience* **7**: 677-688.
86. Mayfield, A.E. (2021). Impacts of invasive species in terrestrial and aquatic systems in the United States. In: *Invasive Species in Forests and Rangelands of the United States* (Eds., Poland, T.M., Patel-Weynand, T., Finch, D.M., Miniat, C.F., Hayes, D.C., Lopez, V.M.). Springer, Cham. https: //doi.org/10.1007/978-3-030-45367-1_2
87. Meiners, S.J., Kong, C.H., Ladwig, L.M., Pisula, N.L. and Lang, K.A. (2012). Developing an ecological context for allelopathy. *Plant Ecology* **213**: 1221-1227.
88. Morikawa, C.I.O., Miyaura, R., Kamo, T., Hiradate, S., Perez, J.A.C. and Fujii, Y. (2011). Isolation of umbelliferone as a principal allelochemical from the Peruvian medicinal plant *Diplostephium foliosissimum* (Asteraceae). *Revista Soc Quím Perú* **77**: 285-291.
89. Nakano, H., Fujii, Y., Yamada, K., Kosemura, S., Yamamura, S., Hasegawa, K. and Suzuki, T. (2002). Isolation and identification of plant growth inhibitors as candidate(s) for allelopathic substance(s), from aqueous leachate from mesquite (*Prosopis juliflora* (Sw.) DC.) leaves. *Plant Growth Regulation* **37**: 113–117.
90. Namkeleja, H., Tarimo, M. and Ndakidemi, P. (2014). Allelopathic Effects of *Argemone mexicana* to Growth of Native Plant Species. *American Journal of Plant Sciences* **5**: 1336-1344.
91. Ni, G.Y., Zhao, P., Huang, Q.Q., Hou, Y.P., Zhou, C.M., Cao, Q.P. and Peng, S.L. (2012). Exploring the novel weapons hypothesis with invasive plant species in China. *Allelopathy Jouarnal* **29**: 199-214.
92. Odat, N., Al-Khateeb, W., Muhaidat, R., Al-U'datt, M. and Irshiad, L. (2011). The effect of exotic *Acacia saligna* tree on plant biodiversity of Northern Jordan. *International Journal Agriculture Biology* **13**: 823-826.
93. Oludare, A. and Muoghalu, J.I. (2014). Impact of *Tithonia diversifolia* (Hemsly) A. Gray on the soil, species diversity and composition of vegetation in lle-lfe (Southwestern Nigeria), Nigeria. *International Journal of Biodiversity and Conservation* **6**: 555-562.
94. Oswalt, C.M., Oswalt, S.N. and Clatterbuck, W.K. (2007). Effects of *Microstegium Vimineum* (Trin.) A. Camus on native woody species density and diversity in a productive mixed-hardwood forest in Tennessee. *For Ecology Manage* **242**: 727-732.
95. Preston, C.A., Betts, H. and Baldwin, I.T. (2002). Methyl jasmonate as an allelopathic agent: sagebrush inhibits germination of a neighboring tobacco, *Nicotiana attenuata*. *Journal Chemistry Ecology* **28**: 2343-2369.
96. Pritekel, C., Whittemore-Olson, A., Snow, N. and Moore, J.C. (2006) Impacts from invasive plant species and their control on the plant community and belowground ecosystem at Rocky Mountain National Park, USA. *Appllication Soil Ecology* **32**: 132-141.
97. Pysek, P. and Hulme, P.E. (2005). Spatio-temporal dynamics of plant invasions: linking pattern to process. *Ecoscience* **12**: 302-315.
98. Quintana, N., El Kassis, E.G., Stermitz, F.R. and Vivanco, J.M. (2009). Phytotoxic compounds from roots of *Centaurea diffusa* Lam. *Plant Signaling Behav* **4**: 9-14.
99. Qureshi, H., Anwar, T., Arshad, M., Osunkoya, O.O. and Adkins, S.W. (2019). Impacts of *Xanthium strumarium* L. invasion on vascular plant diversity in Pothwar region (Pakistan). *Annali Di Botanica* **9**: 73-82.
100. Qureshi, H., Anwar, T., Fatima, S., Akhtar, S., Khan, S. and Azeem, M. (2020). Invasion Impact Analysis of *Broussonetia papyrifera* in Pakistan. *Polish Journal of Environmental Studies* **29**: 2825-2831.
101. Qureshi, H., Arshad, M. and Bibi, Y. (2014). Invasive flora of Pakistan: A critical analysis. *International Journal of Bioscience* **4**: 407-424.
102. Rascher, K.G., Große-Stoltenberg, A., Maguas, C., Meira-Neto, J.A.A. and Werner, C. (2011). *Acacia longifolia* invasion impacts vegetation structure and regeneration dynamics in open dunes and pine forests. *Biological Invasions* **13**: 1099-1113.
103. Rauschert, E.S., Shea, K. and Goslee, S. (2015). Plant community associations of two invasive thistles. *AoB Plants* **7**: plv065.

104. Rejmanek, M. and Richardson, D.M. (1996). What attributes make some plant species more invasive? *Ecology* **77**: 1655-1661.
105. Renteria, J.L., Gardener, M.R., Panetta, F.D., Atkinson, R. and Crawley, M. J. (2012). Possible impacts of the invasive plant *Rubus niveus* on the native vegetation of the Scalesia Forest in the Galapagos Islands. *PLoS ONE* **7**: e48106.
106. Ridenour, W.M. and Callaway, R.M. (2001). The relative importance of allelopathy in interference: The effects of an invasive weed on native bunch grass. *Oecologia* **126**: 444-450.
107. Rojas-Sandoval, J., Meléndez-Ackerman, E.J. and Anglés-Alcázar, D. (2016). Assessing the impact of grass invasion on the population dynamics of a threatened Caribbean dry forest cactus. *Biological Conservation* **196**: 156-164.
108. Rudrappa, T., Bonsall, J., Gallagher, J.L., Seliskar, D.M. and Bais, H.P. (2007). Root-secreted allelochemical in the noxious weed *Phragmites australis* deploys a reactive oxygen species response and microtubule assembly disruption to execute rhizotoxicity. *Journal of Chemical Ecology* **33**: 1898–1918.
109. Rusterholz, H.P., Huber, K. and Baur, B. (2023). Invasion of a Horticultural Plant into Forests: *Lamium galeobdolon argentatum* Affects Native Above-Ground Vegetation and Soil Properties. *Plants* **12**: 1527.
110. Sachin, K., Rana, S.S., Sharma, N., Iqbal, R.K., Qureshi, H., Anwar, T., Syed, A., Elgorban, A.M. and Eswaramoorthy, R. (2023). Weed phyto-sociology and diversity in relation to conservation agriculture and weed management strategies in Northwestern Himalayas of India. *Journal of King Saud University - Science* **35**: 102728.
111. Sagar, K.K., Rajanna, M.D. and Rao, R.R. (2015). Impact of invasive alien weeds on native flora-A study from Mysore, 25th Asian-Pacific weed science society conference on "*Weed science for sustainable agriculture, environment and biodiversity*", Hyderabad, India during 13-16 October, 2015.
112. Sage, R.F. (2004). The evolution of C4 photosynthesis. *New Phytologist* **161**: 341-370.
113. Sandler, H.A. (2010). Managing *Cuscuta gronovii* (Swamp Dodder) in Cranberry Requires an Integrated Approach. *Sustainability* **2**: 660-683.
114. Sarmati, S., Bonari, G. and Angiolini, C. (2019). Conservation status of Mediterranean coastal dune habitats: anthropogenic disturbance may hamper habitat assignment. *Rendiconti Lincei. Scienze Fisiche e Naturali* **30**: 623-636.
115. Sax, D.F. and Brown, J.H. (2000). The paradox of invasion. *Global Ecology and Biogeography* **9**: 363-371.
116. Shankar, S.R.M., Girish, R., Karthik, N., Rajendran, R. and Mahendran, V.S. (2009). Allelopathic effects of phenolics and terpenoids extracted from *Gmelina arborea* on germination of Black gram (*Vigna mungo*) and Green gram (*Vigna radiata*). *Allelopathy Journal* **23**: 323-332.
117. Shao, H., Huang, X., Wei, X. and Zhang, C. (2012). Phytotoxic Effects and a Phytotoxin from the Invasive Plant *Xanthium italicum* Moretti. *Molecules* **17**: 4037-4046.
118. Shao, H., Peng, S., Wei, X., Zhang, D. and Zhang, C. (2005). Potential allelochemicals from an invasive weed *Mikania micrantha* H.B.K. *Journal of Chemical Ecology* **31**: 1657-1668.
119. Sharma, G.P. and Raghubanshi, A.S. (2011). *Lantana camara* L. invasion and impact on herb layer diversity and soil properties in a dry deciduous forest of India. *Applied Ecology and Environmental Research* **9**: 253-264.
120. Sharma, G.P., Raghubanshi, A.S. and Singh, J.S. (2005). *Lantana* invasion: An overview. *Weed Biological Management* **5**: 157-167.
121. Sher, A.A. and Hyatt, L.A. (1999). The disturbed resource-flux invasion matrix: A new framework for patterns of plant invasion. *Biological Invasions* **6**: 107-114.
122. Silva, F.M., Donega, M.A., Cerdeira, A.L., Corniani, N., Velini, E.D., Cantrell, C.L., Dayan, F.E., Coelho, M.N., Shea, K., and Duke, S.O. (2014). Roots of the invasive species *Carduus nutans* L. and *C. acanthoides* L. produce large amounts of aplotaxene, a possible allelochemical. *Journal of Chemical Ecology* **40**: 276-284.
123. Simba, Y.R., Kamweya, A.M., Mwangi, P.N. and Ochora, J.M. (2013). Impact of the exotic weed, *Lantana camara* L. on abundance of native plants in Nairobi National Park, Kenya: Implications for the conservation of wildlife. *International Journal of Scientific Research* **2**: 294-300.
124. Soltys, D., Krasuska, U., Bogatek, R. and Gniazdowska, A. (2013). Allelochemicals as Bioherbicides-Present and perspectives. In: *Herbicides-Current Research and case studies in use* (Eds., Price AJ, Kelton JA.). InTech Publishers (pp. 517-542).
125. Sudnik-Wójcikowska, B., Moysiyenko, I., Slim, P.A. and Moraczewski, I.R. (2009). Impact of the invasive species *Elaeagnus angustifolia* L. on vegetation in Pontic desert steppe zone southern Ukraine. *Polish Journal of Ecology* **57**: 269-281.

126. Terzi, M., Fontaneto, D. and Casella, F. (2021). Effects of Ailanthus altissima Invasion and Removal on High-Biodiversity Mediterranean Grasslands. *Environmental Management* **68**: 914-927.
127. Tesfaw, A., Teferi, E., Senbeta, F. and Alemu, D. (2023). The spatial distribution and expansion of Eucalyptus in its hotspots: Implications on agricultural landscapes. *Heliyon* **9**: e14393.
128. Thapa, L.B., Kaewchumnong, K., Sinkkonen, A. and Sridith, K. (2016). Impacts of invasive *Chromolaena odorata* on species richness, composition and seedling recruitment of *Shorea robusta* in a tropical Sal forest, Nepal. *Songklanakarin Journal of Scientific Technology* **38**: 683-689.
129. Thomas, J., El-Sheikh, M.A., Alfarhan, A.H., Alatar, A.A., Sivadasan, M., Basahi, M., Al-Obaid, S. and Rajakrishnan, R. (2016). Impact of alien invasive species on habitats and species richness in Saudi Arabia. *Journal of Arid Environments* **127**: 53-65.
130. Thorpe, A.S., Thelen, G.C., Diaconu, A. and Callaway, R.M. (2009). Root exudate is allelopathic in invaded community but not in native community: field evidence for the novel weapons hypothesis. *Journal of Ecology* **97**: 641-645.
131. Tilman, D. (1997). Community invasibility, recruitment limitation and grassland biodiversity. *Ecology* **78**: 81-92.
132. Uddin, M.N. and Robinson, R.W. (2017). Changes associated with Phragmites australis invasion in plant community and soil properties: A study on three invaded communities in a wetland, Victoria, Australia. *Limnologica* **66**: 24 - 30.
133. Vazquez-de-la-Cueva, A. (2014). Case studies of the expansion of *Acacia dealbata* in the valley of the river Miño (Galicia, Spain). *Forest Systems* **23**: 3-14.
134. Vila, M., Tessier, M. and Gimeno, I. (2004). Impacts of plant invasion on species diversity in Mediterranean islands. *Proceedings, 10th MEDECOS Conference*. pp. 1-7.
135. Wambua, J.K. (2010). The distribution, abundance and ecological impacts of invasive plant species at Ol-Donyo Sabuk National Park, Kenya. M. Sc. *Thesis submitted to University of Nairobi*.
136. Ward, J.S., Williams, S.C. and Worthley, T.E. (2013). Comparing Effectiveness and Impacts of Japanese Barberry (Berberis thunbergii) Control Treatments and Herbivory on Plant Communities. *Invasive Plant Science and Management* **6**: 459-469.
137. Wei, C.Y., Wang, J.K., Shih, H.C., Wang, H.C. and Kuo, C.C. 2020. Invasive plants facilitated by socioeconomic change harbor vectors of scrub typhus and spotted fever. *PLOS Neglected Tropical Diseases* **14**: e0007519.
138. Weidlich, E.W., Florido, F.G., Sorrini, T.B. and Brancalion, P.H. (2020). Controlling invasive plant species in ecological restoration: A global review. *Journal of Applied Ecology* **57**(9): https: //doi.org/10.1111/1365-2664.13656
139. Weir, L.T., Park, W.S. and Vivanco, J.M. (2004). Biochemical and physiological mechanisms mediated by allelochemicals. *Current Opinion in Plant Biology* **7**: 472-479.
140. Woziwoda, B., Kopeć, D. and Witkowski. J. (2014). The negative impact of intentionally introduced *Quercus rubra* L. on a forest community. *Acta Societatis Botanicorum Poloniae* **83**: 39-49.
141. Writuparna, D, Basuthakur, P. and Ray, P. 2021. Gardening the menace! *Environmental and Sustainability Indicators* **12**: 100148.
142. Wu, H., Carrillo, J. and Ding, J. (2016). Invasion by alligator weed, *Alternanthera philoxeroides*, is associated with decreased species diversity across the latitudinal gradient in China. *Journal of Plant Ecology* **9**: 311-319.
143. Zheng, H., He, C., Xu, Q.Y., Yang, J.N., Zhan, Y.W. and Lei, Y. (2011). Inference of Allelopathy about Spartina Alterniflora to Scirpus Mariqueter by Effects of Activated Carbon on Soil. *Procedia Environmental Sciences* **10**: 1835-1840.
144. Zimmermann, T.G., Andrade, A.C. and Richardson, D.M. (2016). Experimental assessment of factors mediating the naturalization of a globally invasive tree on sandy coastal plains: a case study from Brazil. *AoB Plants* **8**: plw042.