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Allelopathy, A Potential Approach for Crop, and Weed Management in Special Reference to Family Amaranthaceae

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Abstract

The Amaranthaceae is an ecologically prominent plant family with a global economic impact because of its complex chemical composition. Allelopathic potential exists in many Amaranthaceae plants, with different activities, kinds, and amounts of causative chemicals based on the plant species. The use of allelopathic chemicals in agricultural management might help to minimize pesticide use and environmental degradation. It possesses potent allelopathic action, as evidenced by a) bioassays of aqueous or different solvent extracts and residues, b) finding of causative allelochemicals, and c) field research. Our reviewing key findings are that a) seedling growth is more sensitive than germination, especially root growth b) field soil gathered under the donor greatly inhibited or slightly boosted development of the test plants, and Methanol extracts or fractions, as well as causative phenolic allelochemicals, were used in petri-dish bioassays, which revealed strong phytotoxic activity in a concentration-dependent manner. Further studies need to be carried out to explore the Allelopathic potential of halophytes of the family concerning medicinal plants, crops, and weeds.

***Key words*:** Allelopathy, Allelochemicals, Bioassay, Amaranthaceae

Word allelopathy denominated by Hans Molisch in 1937 from two Greek words “allelon” and “pathy” referring to mutual harm. Allelopathy was described by him as means of biochemical interaction through which one plant hinders surrounding plants' expansion, growth, survival, and procreation. Theophrastus (300 B.C) was the first to document the concept of allelopathy [1]. In 1984 E. L. Rice explained allelopathy as both plus and minus effect of one plant over others in the vicinity via the release of allelochemicals. Allelopathy as a rule is interspecific although, it is called autotoxicity if intraspecific for example at the point when a contributor plant engender allelopathic exacerbates which are unsafe to the advancement of fresh plantlets of similar species. Different parts of the plant are liable for autotoxic conduct, for example, foliage, roots, twigs, pollen, fruits, inflorescence, cotyledons and achenes seeds, seed coat, tuber, leaf litter and plant deposits [2]. Species that exhibit the autotoxic effect is known to direct their populations over a time and space, resist intra-competition, self-perpetuation and better topographical, dissemination though there is no proof that natural selection favors them. By naturally curbing overcrowding, autotoxicity allows established plants to optimize resource use within their local environment, thus maintaining healthier populations. However, there’s no strong evidence that natural selection specifically favors this trait. It may instead be an indirect result of evolutionary pressures favoring defense mechanisms or other survival traits in these plants.

Allelochemicals are secondary metabolites which are non-nutritive substance that don’t take part in growth and development instead play a great role in defense mechanism [3]. Allelochemicals are isolated into 14 synthetic classes [4-5]. Allelochemicals are an appropriate substitute for engineered herbicides since allelochemicals don't have remaining or poisonous impacts, even though effectiveness and specificity of several allelochemicals are limited [6-7]. When used as cover crops, smother crops, mulch, intercrop, or green manure allelopathic plants can counter weed infestation insect pest management effectively [8]. The integration of allelopathic plants could be particularly beneficial in sustainable agriculture, promoting lower dependence on chemical herbicides and improving soil health.

In major crops as rice, wheat, maize loss due to various pest were reported to be 30%, 21.5% and 22.5 % respectively [9]. The effect of weeds is more on crop (34%) in comparison to other pest (18%) and pathogens (16%) [10]. As a result, global food security has become a matter of serious concern particularly in developing countries. Apart from affecting crop productivity weeds are causative of different health issues like allergies, asthma, digestive problem in both human and animals. Alternative solutions to herbicide problem are needed for healthy and green environment, Members of Amaranthacae family have shown great Allelopathic potential and can function as green herbicide. Allelopathic plants, especially those in the Amaranthaceae family, hold promise as natural herbicides due to their ability to release bioactive compounds that suppress the growth of surrounding weed species. Acting as "green herbicides," Amaranthaceae species offer an environmentally safe approach to weed control that minimizes health risks and reduces chemical residues in ecosystems. Their use in cover cropping, mulching, or as green manure could be particularly

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effective for integrated weed management, supporting sustainable and health-conscious agricultural practices.

Geographical distribution and climatic requirements

Amaranthaceae, is a broad and cosmopolitan family which includes about 180 genera and more than 2500 species [11]. The Amaranthaceae family has as of late been reached out to incorporate the Chenopodiaceae family dependent on morphological and phylogenetic examination. The family is endemic to tropical America and Africa, with members living in a variety of climates ranging from the tropics and subtropics to more moderate climates. The family is said to have originated in the United States' southwestern area, Central America, or Africa [12]. The family's wide ecological range allows it to occupy diverse habitats, which has likely contributed to the development of unique adaptive traits, including allelopathic potential. This adaptability also makes Amaranthaceae species valuable in sustainable agriculture, where their natural herbicidal properties can be leveraged for eco-friendly weed management, enhancing soil health and reducing the need for synthetic inputs.

Around 18 separate genera and more than 50 species wa s reported from India [13]. Many species of Amaranthaceae are found in xerophytic climate many are weeds; others live in harsh environments like sandy, calcareous, saline, gypseous, or serpentine soils; some thrive in undisturbed tropical forests; and a few survive in maritime, aquatic, or semiaquatic environments. South of the Sahara Desert, Africa, southwestern America, Central and South America are inhabited by the most diverse members of the family [14]. This wide distribution showcases the family's resilience and ecological versatility, which may be partly responsible for its allelopathic capabilities, allowing certain Amaranthaceae species to function as natural weed suppressants. This adaptability also underlines the family's potential as a resource in sustainable agricultural practices, especially in challenging soil conditions.

Amaranthaceae genera with allelopathic effect

Weeds are undesirable plants that thrive in conjunction with agricultural crops and dramatically decline their yield due to competition for nutrients, space, energy, daylight etc. [15]. Amaranthaceae is included in one of the 12 families that possess the world's worst weed problem. It accounts for 3.5% of world's weed out of twelve vital weed families that constitute 68% of the 200 species [16]. Weeds have significant effects on the growth and germinate of certain crops by allelopathy, as well as several allelochemicals that interact with various ways by either blocking or promoting the germination of plants that and production receive them [10]. Weeds impact crop growth not only through resource competition but also via allelopathy. Many weeds release allelochemicals that influence the growth and germination of neighboring plants by either promoting or inhibiting their development. These allelopathic interactions can affect crop productivity, posing both challenges and opportunities in agricultural weed management. By understanding and managing allelopathic effects, such as those exhibited by Amaranthaceae weeds, farmers can leverage certain allelopathic plants as natural herbicides, potentially reducing the need for synthetic chemicals in crop production.

Extensive studies on allelopathy in weeds using laboratory assays and statistical methods have been carried out, many of which involve amaranthacea family plants such as amaranthus species, Beta species, Chenopodium species and Celosia species. In field studies, residues of *Amaranthus retroflexus* decreased *Zea mays* productivity by 15 to 20%, while allelochemicals found in plant residues meddled with photosynthesis, leaf biomass accumulation, and grain productivity established that methanol leaf extract of *Suaeda fruticosa* L. a halophyte in the family Amaranthaceae remarkably reduced the frequency of germination, radicle and plumule growth of *Abelmoschus esculentus* and *Brassica oleracea* in a concentration dependent manner [17-18].

In a concentration dependent manner, essential oil from aerial portions of *Bassia muricata* had a remarkable phytotoxic effect on *Chenopodium murale*, germination of seeds and seedling growth [19]. Thapar and Singh (2005) investigated the influence of *Amaranthus spinosus* L. leaf residue *parthenium hysterophorus* L. lipid composition, germination, growth parameters, sugar and chlorophyll, content in *Parthenium hysterophorus* .Amranthaceae was represented by three weed species in research undertaken by Dangwal *et al.*, in Nowshera tehsil of Rajauri district (Jammu and Kashmir) namely i.e., *Achyranthus aspera* L, *Amaranthus spinosus* L, *Amaranthus virdis* L.

Amaranthus species

The genus Amaranthus comprises of about 60 species w idespread in tropical, subtropical, and temperate regions [20-22]. The vast majority of Amaranthus species are fast growing annual weeds and are regularly alluded to as pigweeds. Some of the species are sources of food and nutrition while others are weeds interfering with the productivity of major crops. *Amaranthus hybridus, A. spinosus, A. blitoides, A. veridis, A. gracilis, A. palmeri*and *A. retroflexus*, are among the species with high allelopathic potential. A. *retroflexus* is the most studied one. J R Qasem (1994, 1995) in a sequence of laboratory and field experiment investigation allelopathic impact of *Amaranthus blitoides, Amaranthus retroflexus* L., *Amaranthus gracilis* on wheat and found that fresh shoot or root extract of the same diminishes the germination, root length, root dry weight and coleoptiles length. The inhibitory potential of different Amaranthus species is richly cited in literature [23-29].

Van Volkenburg (2020) investigated the allelopathic potential of A. hybridus against five cover crops and found that the aqueous extract of A. hybridus significantly reduced the growth and germination of all five cover crops. Trifolium pratense had massive reductions in root weight in both the extract (52%) and dried (72%) treatments, but only a 48 percent reduction in shoot weight in the dried treatment. The shoot weight of Medicago sativa was reduced by 52% in the 20g fresh treatment, whereas the root weight decreased by 62% in the dried treatment. Raphanus sativus shoot weight increased (32%) at mid-extract concentrations, while root weight only increased (33%) with dried treatment; nevertheless, both shoot and root weight dropped (>40%) with fresh treatment. Only the shoot weight of Lolium multiflorum increased 41% in 75% extract and 55% in dried treatment. Both Cichorium intybus shoot and root weights decreased (~50%) in fresh treatment. Crops reactions to A. hybridus are diverse and material and species dependent. Carvalho et al., (2019) performed phytochemical analysis of ethanolic extracts on five species of Amaranthus and observed that steroids, organic acid, and carotenoids were present in all [30].

Azulenes and saponin are present in *A. spinosus* and *A. retroflexus* whereas *A. spinosus*, *A. viridis* and *A. deflexus* exhibited positive result regarding depsides, coumarin derivatives are present in the species *A. retroflexus, A. spinosus* and *A. hybridus* polysaccharides are absent in all four species except *A. spinosus* proteins and amino acids are present in all four species with an exception of *A. hybridus* also further concluded that these secondary metabolites are responsible for germination inhibition and cytogenotoxicity in *Lactuca sativa* (Table 1). These secondary metabolites play a role in inhibiting seed germination and exhibit cytogenotoxic effects, as observed in studies on *Lactuca sativa* (lettuce). Such allelopathic impacts highlight these species' potential as natural inhibitors of competing vegetation, offering insights into weed management strategies and the ecological influence of Amaranthus species on surrounding plant communities.

Table 1 Secondary metabolites present in ethanolic extracts of *Amaranthus* spp [30]

Chemical class	*A. spinosus*	*A. hybridus*	*A. viridis*	*A. deflexus*	*A. retroflexus*
Organic acid	Present	Present	Presesnt	Present	Present
Reducing sugar	-	-	-	-	-
Polysaccharides	Present	-	-	-	-
Amino acid	Present	-	Present	Present	Present
Protein	-	-	-	-	-
Tannins	-	-	-	-	-
Catechins	-	-	-	-	-
Flavonoids	-	-	-	-	-
Cardiac glycosides	-	-	-	-	-
Sesquiterpene lactone and other lactone	-	-	-	-	-
Azulenes	Present	-	-	-	Present
Carotenoids	-	Present	Present	Present	Present
Steroids	Present	Present	Present	Present	Present
Depsides	Present	-	Present	Present	-
Coumarinsand Derivatives	Present	Present	-	-	Present
Saponins	Present	-	-	-	Present
Alkaloids	-	-	-	-	-
Purines	-	-	-	-	-
Anthraquinones	-	-	-	-	-

Celosia species

Celosia is a tiny genus of Amaranthaceae edible and ornamental plants that are indigenous to the highlands of East Africa. Common garden ornamental plants include *C. argentea* and *C. cristata*. It has been shown that the weed *Celosia argentea* lowers the yields of pulse legumes, maize, and pearl millet in agricultural fields growing legumes. Thus, it was assumed that the competition was not the sole factor causing these crops' yields to decline. But also, by allelopathic inhibition of crop plant [31]. Patil and Khad [32] labelled *Celosia argentea* L. (Cocks Comb) as one of the most allelopathic plant. Saswade and Dhumal [33] carried out an experiment to find out how *Celosia argentea* affected the germination and early seedling growth of the crop plants chickpea, sorghum, and mung bean. Investigations were conducted into the ability of aqueous leaf extracts to inhibit seed germination and seedling growth in a variety of crops. Low concentrations (1:4%) of the stimulus were noticed, but larger concentrations (1:1%) were the most inhibiting to test crops. Higher extract concentrations were found to be linked to both seed germination and seedling development. Saritha *et al.* [34] investigated the sociability of *Celosia argentea* to establish a relationship between its Allelopathic effect and microorganism. In another study conducted by Saritha and Sreeramulu exhibited phytotoxic effect of aqueous extract from leaves of *Celosia argentea* on radical and plumule growth of *Arachis hypogaea*, *Sorghum bicolor*, *Dolichos lab*, *Phaseolous aureus*, and *Vigna unguiculata* a result of the allelochemicals present like, betanin hyaluronic acid, isocelosianin and celosianin.

The photosynthetic pigment in *Trigonella foenumgraecum* and *Vigna aconitifolia* L. and *Trigonella* was reduced by aqueous extract of *Celosia argentea*, according to Patil and Khade [32]. Kengar and Patil [35] discovered a strong correlation between *Celosia argentea* L. aqueous leachate concentrations and *Lens Culanaris* Medic. (lentil) amylase activity. Results obtained with phenolic extracts of *Celosia argentea* that could halt the development of *Lepidium sativum*. Perveen *et al.* [36] suggested that *Celosia argentea* might be used instead of pesticides to manage some weeds that threaten crops such as *Lepidium sativum*. *Celosia argentea* exhibits notable allelopathic effects on various plants, impacting growth and enzymatic activity. These findings support *C. argentea*'s potential as an eco-friendly tool for integrated weed control.

Chenopodium species

The genus Chenopodium, commonly referred to as goosefoot includes 250 species and is cosmopolitan distribution. Almost 25 species of chenopodium are pernicious weeds reported to occur in the cultivated fields, of them *Chenopodium murale* L. and *Chenopodium album* L. are most notorious [37]. Due to highly competitive and acclimatization ability chenopodium species infest many crops and vegetables which include wheat, barley, pea among others. *Chenopodium album* L. displays its inhibitory effect on cucumber (*Cucumis sativus* L.) growth by 68 percent, onion (*Allium cepa* L.) by 85 percent, tomato (*Lycopersicon esculentum* L.) by 47 percent, and sunflower (*Helianthus annuus* L.) by 51 percent [38]. Extracts of *C. murale* parts (both fresh and dry) in a concentration dependent fashion, reduced wheat, and barley germination, shoot and root length, coleoptile length, shoot, and root dry weight [23]. Studies conducted by Batish *et al.*, (2007) and others [39] concluded that residue incorporation of *Chenopodium murale* L. in soil has greatly affected the nodulation and also reduced the total chlorophyll content, amount of protein and carbohydrate along with leghemoglobin in *Cicer arietinum* L. (chickpea) and *Pisum sativum* L. (pea).

Alternanthera species

In the Amaranthaceae family, Alternanthera is a genus of over 200 herbaceous plants [40]. Alternanthera with five species notably *A. paronychioides* St. Hill (smooth joyweed), *A. philoxeroides* (Mart) Griseb, *A. pungens* Humb. Bonpl and Kunth (khaki weed), The genera with the most foreign invasive species include *A. sessilis* (L.) DC. and *A. tenella* Colla (Joyweed). *A. philoxeroides* represents the most popular and extensively studied member of the Alternanthera genus [40]. *A. sessilis* in combination with other weeds is reported to reduce the grain yield of soyabean [41] and of rice by 25.9%. In an examination led by Yongjie Huang *et al.* [42] proposed that over all allelopathic impact of *A. philoxeroides* on the growth and antioxidant enzyme activities on *Zoysia matrella* went from marginally stimulatory concentrations (≤10 g L-1) to profoundly inhibitory (≥40 g L-1). Joshi and Joshi reported that aqueous extracts of 6 weed species including *Alternanthera sessilis* significantly reduced growth of plumule, radicle length, affected seedling weight, seed vigor index, total protein content of *Triticum aestivum* [43].

Allelochemicals in amaranthaceae genera

Allelochemicals that cause allelopathic effects interact with physiological functions of neighboring plants and other species e.g., water balance, respiration, stomatal function, stem conductance of water, photosynthesis, xylem element flux, cell division/development enzyme activity alteration, membrane permeability, protein synthesis, and so on [44]. Many of these compounds are non-nutritive, secondary metabolites or microbial breakdown products. The plant that produces allelochemicals is called a donor plant, and the plant that is impacted by the discharge of allelochemicals is called a target plant or a receiver plant [45-46] root exudation, volatilization from above ground parts residual breakdown of dead and leaching plant parts are some of the ways allelochemicals enter the environment [47-49]. Using similarities in chemical composition, allelochemicals are grouped into 14 classes [5], long-chain fatty acids Simple unsaturated lactones; and polyacetylenes; benzoquinone, complex quinones and anthraquinone, and ; simple phenols, benzoic acid; water-soluble organic acids, straight-chain alcohols, aliphatic aldehydes, and ketones; simple unsaturated lactones; long-chain fatty acids and polyacetylenes; benzoquinone, anthraquinone, amino acids and peptides; alkaloids and cyanohydrins; sulphide and glucosinolates; purines and nucleosides; simple phenols, benzoic acid and its derivatives; cinnamic acid and its derivatives; coumarin; flavonoids; terpenoids tannins and steroids; amino acids and peptides; alkaloids and cyanohydrins; sulphide ethylene Salicylic acid,and gibberellic acid, are examples of allelochemicals, which are all plant growth regulators [6]. Allelochemicals belonging to different species in the same genera and family are summarized (Table 2).

Table 2 Allelochemical in Amaranthacea species

Species	Allelochemicals	References
Amaranthus cruentus L.	Vanillic, *p*-hydroxybenzoic, and ferulic acids, caffeic acid, sinapic and cinnamic acids, Gallic acid, rutin	[60]
Amaranthus. retroflexus L.	Flavonoids (rutin),	
Achyranthes aspera L.	4-hydroxy-3-methoxy benzoic acid vanillic acid, p-coumaric acid, Caffeic acid,m-coumaric acid, Gallic acid, Chromatotropic acid, syringic acid and ferulic acid	[40], [59]
Aerva lanata Juss.	10-methoxy-canthin-6-one,10-β-D-glucopyranosyloxycanthin-6-one 10-hydroxycanthin-6-one, β-carboline-1 -propionic acid, ervolanine, propionic acid, quercetin, flavanone glucoside persinol, kaempferol, persinosides A and B	[40]
Alternanthera ficoidea L. P. Beauv.	tannins, saponins, quinone, anthraquinone, steroids, glycosides, terpenoids, triterpenoids, flavonoids, alkaloids, coumarins, phenolic compounds	[61]
Alternanthera philoxeroides (Mart.) Griseb	Ethyl propionate	[42]
Amaranhus spinosus L.	p–hydrobenzoic, ferulic,sinapic, salicylic, chlorogenic gentisicvanillic.syringic acid, quinolizidine, sesquiterpen lactone	[28]
*Amaranthus palmeri*s. Wats.	2-heptanone, 2-nonanone, 3-methyl-1-butanol, 3-methyl-2- butanone, 3-hydroxy-2-butanone	[62], [35]
Amaranthus tricolor L.	Limonene, odorine, methyl linoleate, linoleic acid, xanthoxyline, vanillin and vanillic acid	
Bassia muricata L.	Hexahydrofarnesyl acetone, *endo*-borneol, 6-methoxy-1-acetonaphthone, methyl-*α*-ionone and *n*-tricosane	[63]
Chenopodium murale L.	Caffeic, vanillic, protocatechuic acids and p-coumaric acids, p-hydroxybenzoic cinnamic and ferulic acid	
Celosia argentea L.	4-hydroxycinnamic acid (p-coumaric acid), 3,5-dihydroxybenzoic acid, 4-hydroxybenzoic acid, protocatechuic acid, caffeic acid, gallic acid, 4-hydroxybenzaldehyde, m-hydroxybenzaldehyde, m-coumaric acid 2,4-dihydroxybenzoic acid, pyrogallol, genetic acid	
Chenopodium album L.	N-trans-feruloyl 3' -O-methyldopamine, N-trans-feruloyl tyramine and N-trans-4'-O-methylferuloyl 3',0 ,4' -O-dimethyldopamine, N-trans-feruloyl tryptamine, N-trans-4-O-methylferuloyl 4-O-methyldopamine, *N-trans*-feruloyl 4'- *O* –methyldopamine. N-trans-4-O-Methylcaffeoyl 3' -O-methyldopamine	[64]
Chenopodium quinoa wild	Flavonoids (quercetin, acacetin, apigenin, kampferol) phytoecdysteroids 20-hydroxyecdysone, makisterone A, 24-epi-makisterone A and 24(28)-dehydromakisterone A]; phenolic acids (ferulic, vanillic and p-coumaric) phytosterols (β-sitosterol, campestrol, brassicasterol and stigmasterol	[65-66]
Haloxylonpersicum Bunge	Phenolics, flavonoids, flavonols, anthocyanins, tannins, saponins	
Kochia	Saponins, alkaloids, oxalates, and nitrates	[67]
Salicornia herbacea L.	Ferulic acid, procatechuic acid, isorhamnetin, caffeic acid, and quercetin, β–sitosterol, stigmasterol, uracil, quercetin 3-O-β-D-glucopyranoside, and isorhamnetin 3-O-β-Dglucopyranoside,	
Salsola kali L	Caffeic, ferulic, chlorogenic, isochlorogenic, and neochlorogenic acids, and quercetin	[68]

Spinacia oleracea L.	Flavonoids; quercetin, myricetin, apigenin, luteolin, patulein, spinacetin, jaceidin, 4- glucuronide, 5,3,4-trihydroxy-3-methoxy-6,7-ethylenedioxyflavone-4-glucuronide, 5,4- dihydroxy-3,3-dimethoxy-6,7methylene-dioxy-flavone, 3,5,7,3,4-pentahydroxy-6-ethoxyflavone and the Polyphenols; para-coumaric acid, ferulic acid, orthocoumaric acid	[69]
Suaeda monoica	Saponin, flavonoids, phenol, 2 ,4 bis (1,1-dimethylethyl) 2- methoxy -4-vinylphenol, diphenylether	

Although the effectiveness and specificity of many allelochemicals are restricted, they do not have any residual or harmful consequences [7]. Allelochemicals can be used to suppress other competitors, herbivores, and pathogens via both constitutive and inducible defensive mechanism. Using allelopathic effects to improve agricultural output, decrease of chemical pesticide input and subsequent environmental damage, and supply of effective technique are the major goals of allelopathy research [50-51]. Allelopathic species with their targeted species are summarized (Table 3).

Table 3 Allelopathic species and their target species

Allelopathic species	Target species	References
Achyranthes aspera	*Triticum aestivum Cenchrus pennisetiformis, C. setigerus , Chloris barbata*	[70]
Aerva lanata	Lettuce	[71]
Alternanthera ficoidea	Jowar and mung	
Alternanthera philoxeroides	*Zoysia matrella. Oryza sativa, Lactuca sativa*, radish and lettuce	[42],
Alternanthera sessilis	*Oryza sativa*	[72]
Amaranthus cruentus	*Solanum lycopersicum, Brassica oleracea, Conyza bonariensis*	[73]
Amaranthus palmeri	*Brassica oleracea* var. *Capitata* L. *Daucus carota* L. var. *sativa, Glycine max*	[74-75]
Amaranthus retroflexus L.	*Triticum durum* L., *Glycine max*, Maize	
Amaranthus spinosus	*Oryza sativa* L., *Brassica campestris* L. *Parthenium hysterophorus* L.	
Amaranthus viridis	*Vigna radiate, Lolium rigidum* L., *Raphanus sativus* L. *Phaseolus vulgaris* L. *Vigna sinensis* L. Walp., *Cajanus cajan* L. Millsp. and *Medicago sativa* L.	[76-78]
Arthrocnemum macrostachyum	*Eruca sativa*	[79]
Artiplex. codonocarpa.	*Lactuca sativa* L. *Enchylaena tomentosa R. Br Maireana georgei*	[80]
Atriplex cana	*Amaranthus retroflexus* L. and *Poa annua* L.	[81]
Bassia muricata	*Chenopodium murale L.*	[19]
Bassia scoparia	Oil flax	[51]
Beta vulgaris	*Portulaca oleracea*, *Vigna umbellate*, Zea mays	[82]
Beta vulgaris	*Phalaris minor* and *Malva parviflora*	[83]
Celosia argentea	*Vigna mungo Sorghum bicolor*, *Phaseolous aureus*, *Arachis hypogaea*, *Dolichos lab lab* and *Vigna unguiculata*. *Lens culinaris* Medic, *Vigna aconitifolia*L. and *Trigonella foenum graecum* L.	[32], [34]
Chenopodium album L.	*Zea mays* L *Camelina sativa* L., *Helianthus annuus* L. *Triticum aestivum* L. *Solanum lycopersicum* L	[84-87]
Chenopodium murale	*Hordeum vulgar*, *Trifolium alexandrinum*, *Triticum aestivum*, *Melilotus indicus*, *lycopersicum esculentum* and *Cucumus sativus Cicer arietinum* L. and *Pisum sativum* L	[23], [39], [88]
Enchylaena tomentosa R. Br	*Lactuca sativa* L. var. Cos	[80]
Haloxylon persicum	Wheat and Black Mustard	[89]
Salicornia europaea	*Skeletone macostatum*.	[90]
Salicornia bigelovii	*Skeletone macostatum*	[91]
Salicornia herbacea	*Hyssopus officinalis* and *Nigella sativa*, *Taraxacum officinale* and *Amaranthus retroflexus*	[92]
Salsola imbricata	*Portulaca oleracea* and *Chenopodium murale*	[93]
Salsola kali L.	*Kochia*, *sweet clover*	[68]
Spinacia oleracea L.	*Vigna radiata* L.	[94]
Sueda fruticose L.	*Abelmoschus esculentus* and *Brassica oleracea*	[17]
Urena lobata	Lettuce	[71]

Techniques applied in allelopathic research

Bioassays in Petri-dishes

Petri plates bioassays are the most popular approach in early stages. A bioassay is a test that determines how plant extracts (aqueous, hydroalcoholic, fractions from different solvents, etc.), volatile essential oils, and isolated or marketed chemicals affect the germination and early growth of a target plant, because receptor plants are subjected to multiple interacting environmental influences, evaluating seed germination and seedling growth in the field may be challenging. Bioassays in the lab allow for precise control of growth conditions while eliminating a variety of possible sources of interference (e.g., resources competition, etc.) Allelopathic potential exists in almost every plant part, including leaves [52], pollen [53], trichomes [54], roots [55], bark, seeds, and fruits [56], In a laboratory testing, it was found that aqueous extract of above ground pigweed (*Amaranthus viridis* L.), parts significantly decreased seed germination of the tested poaceous crop.

Residue incorporation in soil

In general, seedling inhibition by residue was exacerbated when crop residue was absorbed prior to sowing, but significantly decreased when residue remained on the surface. The allelopathic material was either a water-soluble molecule leached from residue, or a compound generated during plant residue microbial breakdown [56-57]. Plant residues may be both stimulatory and inhibitory when incorporated into soil, and the findings show that changes in allelopathic potential were dependent on the plant type, volume, and condition of residues [58]. According to a study, introducing powdered above ground parts of *Amaranthus viridis* L. in the soil at rates of 1, 2, 3, 4, and 5% (w/w) significantly inhibited seedling development. Furthermore, as the amount of powder in the soil grew, so did the reduction in seedling development. Another study indicated that soil-incorporated *Achyranthus aspera* plant residues lowered the emergence index of the weed species tested in a concentration-dependent manner at all concentration The emergence index (75.9%), emergence percentage (61.9%), mean emergence time (41.6 days), and emergence energy (38.6%), of weeds have all decreased [59].

CONCLUSION

As previously indicated, the majority of the Amaranthaceae species give the possibility for biological weed control by releasing allelochemicals from various plant parts. This discussion is also evident that Allelopathic effect of some Amaranthaceae plants are well studied for weeds, crops and medicinal plants having significant content of secondary metabolites while halophytes of the family are not quite explored in terms of allelopathy and allelochemicals. Furthermore, there is also a need for extensive research on plants with more herbicidal potential, for these genetic and molecular studies could be employed for advanced research.

Conflict of interests

The authors declared no conflicts of interest.

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