Plant Archives Vol. 26, No. 1, 2026 pp. 909-917 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org

DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2026.v26.no.1.123

FROM NUISANCE TO NATURAL HERBICIDE: A REVIEW ON ALLIGATOR WEED (*ALTERNANTHERA PHILOXEROIDES* MART. GRISEB.)

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(Date of Receiving-08-01-2026; Date of Revision-05-03-2026; Date of Acceptance-19-03-2026)

ABSTRACT

Weed control is one of the major challenges in crop cultivation. The development of natural alternatives to chemical herbicides requires time and research, but it is essential for achieving sustainable and environmentally friendly weed management. Chemical weed control is challenging, due to the recent increase in herbicide-resistant biotypes and to the harmful side effects of herbicides on the environment. Integrated management of weeds including the application of bioherbicides, is an emerging method for weed control in sustainable agriculture. Plant extracts, allelochemicals and some microbes are utilized as bioherbicides to control weed populations. Bioherbicides based on plants and microbes inhibit the germination and growth of weeds. One such plant known to have allelopathy property is [*Alternanthera philoxeroides* Mart.) Griseb.]. It is a worldwide obnoxious and invasive weed, causing irreversibly damage in agricultural production especially in rice and local aquatic ecosystem. Phytotoxic chemicals released by *A. philoxeroides* into irrigation water and/or directly into rice ecosystems have a significant inhibitory influence on germination, growth and yield of field crops, soil properties and nutrient availability, population and community structure and weed invasion. Hence, *A. philoxeroides* can be used as a potential organic alternative to chemical weed-control, due to the higher susceptibility of terrestrial and aquatic weeds to the phytotoxic chemicals released by this weed.

***Key words*:** Allelochemical, allelopathy, bioherbicide, ecology, herbicidal potential, weeds

Introduction

Weed (a plant considered undesirable in a particular situation) populations in agricultural fields are a major cause of crop yield reduction. Adopting manual weed management is in practice, but it is laborious and expensive. Further, the availability of labor at crucial time remains unanswerable. Though herbicides being effective in increasing yield, indiscriminate use of herbicides have resulted in serious ecological implications Further use of herbicides to control aquatic weeds is a challenging and not permitted due to the ill effects on water bodies. Hence, in recent, research attention has been focused on finding out alternative strategies for weed control to reduce the herbicides or emphasis on search for alternative weed management strategies that are cheap, safe and sustainable. Allelopathy is considered as an effective, economical and environment friendly weed management approach (Kamala Bai *et al*., 2022). The individual controlling measures cannot provide the expected outcome of weed control so the integrated weed management by crop rotation, tillage before sowing, mechanical weeding and integrating use of bioherbicides, can reduce weed populations in organic or natural farming (Kong *et al*., 2024; Mandal and Mondal, 2011). Long-term use of chemical herbicides does not effectively control weeds due to the development of resistant weed germplasms (Green and Michael, 2011). Moreover, chemical herbicides also contaminate the water and land, which leads to numerous hazardous effects in living organisms, including humans (Radosevich *et al*., 1997). The increase of herbicide-resistant weeds reduces crop productivity and new environmentally friendly methods are required to control weeds (Duke, 2012). The global interest in organic farming supports alternative methods that do not use chemical herbicides for weed control and prevent herbicide-resistant weed development. Recently, biological agents and allelopathic effects of weeds have been added to integrated weed management strategies. Allelopathy as a tool, can be importantly used to combat the challenges of environmental pollution and herbicide resistance development.

Among weeds, *A. philoxeroides* is an invasive weed native to Argentina and South America having allelopathic effect and drastically retards the growth of many species. An aqueous leachate from the inflorescence, stem root and leaves of *A. philoxeroides* was found to inhibit the germination and seedling growth of Ampelopteris Prolifera (ketz.,). *A philoxeroides* has been reported to be used as leafy vegetable by people in Kerala (India) where it is sold as delicious leafy vegetable in the market by the name of 'Kozhappa'. It was reported to be grown in backyard in almost all the Australian states as leafy vegetable by Sri Lankan community. At Jabalpur (Madhya Pradesh, India), vernacularly called as 'Pullachara' is harvested from the aquatic bodies and sold during summer season to dairy owners who use alligator weed as a substitute of other green fodder like berseem, jowar, maize etc., In parts of Karnataka, the aquatic plant is collected from the aquatic bodies and used as important source of green fodder to livestock (Dhanapal and Ganeshaiah, 2000). It chockes waterways and thus impact boating and sport fishing activities and provide breeding habitat for mosquitoes. This paper aims to review major research findings of potential allelopathy plants other than *A. philoxeroides* and their implications for weed science.

Taxonomy and ecology

A. Philoxeroides commonly known as alligator weed belongs to family Amaranthaceae. Leaves and stems vary greatly in size and shape. Fleshy, succulent stems can grow horizontally and float on the surface of the water, forming rafts, or form matted clumps which grow on to banks. The horizontal stems (called stolons) may reach a length of 10 m. The leaves are opposite in pairs or whorls, with a distinctive midrib, and range in size from 5-10 cm. Fibrous roots arising at the stem nodes may hang free in water or penetrate into the sediment /soil. Flowers, which appear from September to December, are thin and clover-like in shape. The white flowers grow on stalks and are approximately 1.25 to7.6 cm in length and 13 mm in diameter. Alligator weed occurs in a range of habitats ranging from dry terrestrial to aquatic. Alligator weed is a perennial emergent, semi aquatic species that rarely sets seeds. To facilitate buoyancy, plants growing in aquatic habitats tend to have stems that are hollow and larger than those of plants growing on land (Julien *et al*., 1992).

Table 1: Moisture and dry matter content in different forms of alligator weed.

Parameter	Aquatic Plant	Terrestrial Plant
Moisture (%)		
Whole plant	91.18± 0.48	85.23±0.34
Leaf	87.66±0.30	84. 18±0.40
Stem	94.06±0.85	86.26±0.33
Dry matter (%)		
Whole plant	8.82±0.48	14.77±0.34
Leaf	12.34±0.30	18.82±0.40
Stem	5.94±0.85	13.74±0.33

Invasiveness

The ability of *A. Philoxeroides* to persist in terrestrial, semi aquatic and aquatic environments, the ability to rapidly take root along water way banks and ability to propagate *via.*, vegetative fragmentation and water borne dispersal of vegetative propagules all contribute to its success as an invasive species. From its invasive point of view, it is next to *Parthenium hysterophorus*. Alligator weed now occurs as an invasive exotic in subtropical to temperate regions of the America, Asia, Australia, New Zealand and a number of Pacific Island nations. The samples of *A. philoxeroides* were analysed and it was reported that in terrestrial form, moisture was less (85.2 ± 0.35%) than aquatic form (91.18 ± 0.5%). The moisture percent was higher in stem than leaf (Table 1). It was observed that the crude protein content increased with reduction in crude fibre content. Crude protein and crude fibre in alligator weed was 15 and 16 per cent, respectively. This weed is a good source of protein, carbohydrate, calcium, magnesium and other nutritional requirements of animals; this may be the reason that the dairy owners use it as a green fodder substitute. However, it will be pertinent to mention that water bodies, particularly in urban areas, is a great source of accumulation of heavy metals due to draining of waste water from nearby houses, factories, etc. which may be absorbed by the alligator weed and may reach in the food chain through milk of dairy animals (Dhanapal and Ganeshaiah, 2000). It contains 85 and 94 % water in aquatic and terrestrial systems, respectively (Table 1).

Mechanical removal of *A. philoxeroides* mats is costly and often results in the dispersal of large numbers of vegetative fragments that can exacerbate the infestation. Although biocontrol by means of the alligator weed flea beetle (*Agasicleshy hgrophila*) and other control agents has greatly attenuated the threat of this plant, the cost associated with carefully studying, planning and managing the release of biocontrol agents is substantial (Mandal and Mondal, 2011).

Allelopathic effects of potential selected plants against weeds

The definition of allelopathy was first used by Molisch in 1937 to indicate all the effects that directly and indirectly result from biochemical substances transferred from one plant to another. The term was refined by Rice in 1984 to define "any direct or indirect harmful or beneficial effect by one plant (including micro- organisms) on another through production of chemical compounds that escape into the environment. In 1996, the International Allelopathy Society broadened its definition of allelopathy to refer to any process involving secondary metabolites produced by plants, microorganism, viruses and fungi that influences the growth and development of agricultural and biological systems.

Allelopathy is a common biological phenomenon by which one organism produces biochemicals that influence the growth, survival, development, and reproduction of other organisms. These biochemicals are known as allelochemicals and have beneficial or detrimental effects on target organisms. Plant allelopathy is one of the modes of interaction between receptor and donor plants and may exert either positive effects (e.g., for agricultural management, such as weed control, crop protection, or crop re-establishment) or negative effects (e.g., autotoxicity, soil sickness, or biological invasion). To ensure sustainable agricultural development, it is important to exploit cultivation systems that take advantage of the stimulatory/inhibitory influence of allelopathic plants to regulate plant growth and development and to avoid allelopathic autotoxicity. Allelochemicals can potentially be used as growth regulators, herbicides, insecticides, and antimicrobial crop protection products. Here, we review the plant allelopathy management practices applied in agriculture and the underlying allelopathic mechanisms (Fang and Zhihui, 2015).

Natural compounds can be screened as potential ecological herbicides (cost effective, efficacious, selective and environmentally safe). Experiments were conducted on selected weeds *(Rumex dentatus*, *Euphorbia helioscopia*, *Chenopodium album*, *Avena fatua*, *Phalaris minor*) to study allelopathic potential of *Rhazya stricta*. Experiments were performed using a medium of 0.75 % (w / v) agar, filter paper and soil. Results showed that seed germination of *R. dentatus, P. minor and C. album* is inhibited by *R. stricta* allelochemicals. Minimum germination for *C. album* was noted whereas non-significant effect on the germination of E. *helioscopia, T. aestivum and A. fatua* was observed. Results have indicated that even though radicle length and germination of *T. aestivum* is not affected by leaf extract of *R. stricta*, the plumule length was substantially decreased. The retarding effect of growth on wheat seedlings indicates that *R. stricta* might not be an acceptable candidate for weed control under field conditions (Anwar *et al*., 2023) studies on herbicide and pesticide ability of *Coronopus didymus* (L.) Sm. and *Nasturtium officinale* W.T. Aiton was evaluated (Khan *et al*., 2021). Aqueous extracts of both plants were also used to determine the effects on crop growth in seedlings (wheat and maize). The inhibition effect for wheat and maize was of insignificant. Micro-spectrophotometric technique was used for fungicidal assessment. Both plant extracts (3.125 mg/mL) demonstrated substantial pesticide activity against pathogenic strains *Pyricularia oryzae* Cavara and *Fusarium fujikuroi* Nirenberg. *C. didymus* reported maximum total phenolic content (214.6983 μg GAE/g dry sample) and *N. officinale* (124.181 μg GAE/g dry sample). Identification of new active compounds can aid in weed and pest management (Kong *et al*., 2024).

Allelopathic ability of *Lantana camara* (sage-plant) flowers was assessed against weeds *viz. Avena fatua* (wild oat), *Euphorbia helioscopia* (sunspurge), *Chenopodium album* (goosefoot), *Phalaris minor* (canary-grass), and *Rumex dentatus* (knotweed). Bioassay analysis of three methanolic fractions of the combiûash from *L. camara* was performed at 50, 75 and 100 per cent concentration using germination percentage parameters, inhibition of plumule and radicle size. The fraction II of combiûash strongly suppressed all weeds with negligible effect on *T. aestivum*. Gas chromatography-mass spectroscopy was conducted for the fraction, and isolated compounds were used to perform bioassays. From fraction II GC–MS detected four methyl esters of allelopathic fatty acid *viz*., methyl oleate, methyl palmitate, methyl stearate and methyl linoleate. The evaluation of physiological effects of the bioassay revealed substantial suppression of chlorophyll, antioxidant enzymes (superoxide, dismutase peroxidase) and protein material in all weeds by methyl palmitate. Bioassay activity and study of physiological parameters revealed that the effective bio-herbicidal compound in Lantana camara ûowers isomethyl palmitate. This is the ûrst time that methyl palmitate (a fatty acid methyl ester) has been related to herbicidal activity in *L. camara* ûowers (Anwar *et al*., 2019d).

Exploring the new allelopathic plants potential is found to be an alternative to avoid resistance build-up in weed. The research was conducted to investigate allelopathic effects of *Carica papaya* L. leaf powder and aqueous extract on seeds as well as pre-germinated seeds of *Avena fatua L*., *Helianthus annuus L*., *Rumex dentatus*

L., Zea mays L. and Triticum aestivum L. on filter paper and soil. Germination percentage (%), radicle length (cm) and plumule length (cm) were parameters observed for 'Plant leaf powder bioassay' and 'aqueous extract method'. Most significant growth inhibition was observed in *A. fatua* seedlings in filter paper method. A. fatua radicle length was reduced by *C. papaya* aqueous extract (80%) and leaf powder (89%) bioassays. Plumule length was reduced under the influence of aqueous extract (57-73%) and powdered material (59-77%). The inhibitory effects on other test species were in sequence of *H. annuus* followed by *Z. mays* and *R. dentatus*. The aqueous extract showed non-significant effect on wheat seed germination, radicle and plumule growth. It is suggested that *C. papaya* aqueous extract can be used as source of weed management in wheat crop (Anwar *et al*., 2019).

Huge amounts of synthetic chemical herbicides are sprayed to manage weeds. Heavy doses of synthetic chemicals for weed control are encouraging herbicidal resistance in weeds, risking human health and environment. Natural compounds, known as "bio herbicides" are environmentally safe herbicides, based on compounds produced by living organisms. The study was aimed to evaluate allelopathic activity of leaf powder of *Rhazya stricta, Pinus roxburghii, Carica papaya and Lantana camara* against selected weeds *viz., Phalaris minor, Avena fatua, Chenopodium album, Euphorbia helioscopia and Rumex dentatus* on 0.75 (w/v) agar, soil and filter paper at concentration of 10 and 50 mg leaf powder. Germination percentage (%), radicle length (cm) and plumule length (cm) were parameters to assess allelopathic potential. It was concluded that selected plants possess potential inhibitory effects. The germination and growth inhibition effects were found in order *L. camara>P. roxburghii>R. stricta>C. papaya.* (Anwar *et al*., 2021; Anwar *et al*., 2019a, Anwar *et al*., 2019b and Anwar *et al*., 2019c)

Bioassay studies performed on the allelopathic effect of dried leaf powder of *C. papaya, P. hysterophorus, E. helioscopia* and *R. dentatus* on intact and pre-germinated seeds of *R. dentatus, A. fatua, H. annuus, Z. mays and T. aestivum*. Experiments were designed in CRD with five replications accounting parameters of germination percentage, radicle length (cm) and plumule length (cm). *C. papaya and P. hysterophorus* decreased the emergence of *R. dentatus and A. fatua* on agar similarly, all treatments inhibited the germination of *R. dentatus and A. fatua*. In direct seeding, radicle growth of R. dentatus and *A. fatua* was decreased by all treatments. In same experiments, plumule of *A. fatua* was significantly repressed by *E. helioscopia* treatments. In direct seeding, *E. Helioscopia* reduced the radicle length of *R. dentatus and A. fatua. R. dentatus* radicle growth was also significantly inhibited by *P. hysterophorus.* All treatments inhibited radicle as well as the plumule of all test species. *P. hysterophorus* and *E. helioscopia* treatments were evaluated as good weed suppressants. Weed suppressive effects of these treatments are attributed to their secondary metabolites needed to be explored (Anwar *et al*., 2018).

Fig. 1: *A. philoxeroides* in aquatic system.

Fig. 2. *A. philoxeroides* single plant.

Allelopathic potential of *A. philoxeroides* and *A. sessilis*

The allelopathic potential of *A. Philoxeroides* in its successful invasion of new areas has been reported on mustard and rice and lettuce (Zuo *et al*., 2012). Results from experiments conducted by Mohney *et al*., 2014 reported that water extracts of *A. philoxeroides* and *A. sessilis* caused significant reduction in rice germination, shoot and root length, and seedling vigor index. Leaf extracts from *A. philoxeroide*s and *A. sessilis* at 5 per centconcentration caused up to 100 per cent and 49 per cent reduction in rice seed germination, respectively. Water extracts (2.5 and 5 w/v %) of five aquatic weeds such as *A. philoxeroides, A. sessilis, C. stricta, P. Barbatum* and *E. crus-galli* were tested on rice and wheat. It was evaluated that all tested weeds caused significant germination and seedling growth inhibition in rice and wheat (Abbas, 2015 and Abbas, 2014). Inhibitory effects were more significant on the root growth of E. crus-galli and grew by increasing the dose of *A. philoxeroides*. (Quazi and Khan, 2010). The suppressive effect was due to the allelochemicals commonly found in Alternanthera species (Kamala Bai *et al.*, 2023 and Wang *et al*., 2007)

A. phioxeroides and *A. sessilis* both ecotypes of alligator weed showed significant growth inhibition of *M. aeruginosa*. However, the allelopathic patterns of algal suppression differed. The extract of the aquatic ecotype stimulated the growth of *M. aeruginosa* in the first 5 days, after which allelochemicals were produced that inhibited algal growth in the subsequent 20 days. The level of inhibition became more pronounced with the time of extract exposure. Phyto-inhibitory effects of water extracts were more severe than residues. The algal growth was inhibited at the logarithmic, stationary and decline phases and the peak level of allelopathic inhibition was 85.7 per cent. In contrast, the extracts from the terrestrial ecotype had immediate allelopathic growth inhibition effects on *M. aeruginosa*. However, the intensity of the allelopathic inhibition was relatively weak, with a mean algal inhibition of 43.5per cent. The algal inhibition potential declined with time. The studies revealed that two invasive weeds *A. sessilis* and *A. philoxeroides* have more inhibitory effects on rice compared with conventional weed including *C. stricta, P. barbatum and E. crusgalli*. Their higher phytotoxic interference will be a threat to rice crop in Pakistan and may play havoc with rice yields in conventional wet land rice ecosystem (Abbas *et al*., 2016).

The inhibition of harmful algal growth by alligator weed depends on its nutritional status. Aqueous extracts of *A. philoxeroides* exhibited the strongest inhibition of the algae in oligotrophic conditions, moderate inhibition in mesotrophic conditions, and the lowest inhibition in eutrophic conditions. The forecast equation showed that *A. philoxeroides* exhibited the greatest inhibition of harmful algae during the lag phase in co-culture, with a 25 mg mL^{-1} concentration (inhibition rate = 85.59%) (Zeng *et al*., 2001).

Lettuce germination was influenced by ethyl acetate fraction obtained from leaves of *A. philoxeroides* at the highest concentrations; however, the germination speed and the radicle growth were significantly affected by all the extracts starting at 1mg mL^{-1} concentration. Those results demonstrate allopathic effect of different extracts of this plant, although they have not interfered with the strains growth used in this experiment of allelochemicals and mesotrophic conditions (Kleinowski *et al.*, 2016).

Study conducted to control water hyacinth, the most serious aquatic weed in water body using extracts of *A. philoxeroides*. indicated reduction in plant height (32 to 61 %), number of leaves (13 to 38 %), number of branches (20 to 43%) and fresh weight (63 to 73 %). *E. crassipes* plants dried in cisterns treated with *A. philoxeroides* (Kamala Bai *et al*., 2021). The allelopathic leachate of *A. philoxeroides* caused maximum decrease in growth of *E. crassipes*, due to presence of alkaloids and phenols. In control, there were no detrimental effects on growth of *E. crassipes*.

A laboratory study was conducted to investigate the allelopathic effect of aqueous extracts of plant parts of *A. philoxeroides* and *A. sessilis* and soil incorporated residues on germination and seedling growth of rice (*Oryza sativa*). Aqueous extracts prepared from different plant parts of *Alternanthera* species delayed rice germination. *A. philoxeroides* and *A. sessilis* inhibited rice germination by 9-100 per cent and 4-49 per cent, respectively. Germination of rice seeds was reduced with increasing concentration of aqueous leaf extracts of both weed species. Early seedling growth (root and shoot lengths) and seedling vigor index were significantly reduced by 5 per cent aqueous leaf extract compared with distilled water treated control. Germination, root and shoot lengths, root and shoot dry weights and seedling vigour index of rice were drastically reduced by 3 and 4 per cent in residue infested soil compared with residue free soil. The inhibitory effect of *A. philoxeroides* in terms of germination and seedling growth of rice was greater than that of *A. sessilis*. Five percent aqueous leaf extract and 4 per cent residue infested soil of *A.*

philoxeroides caused complete failure of rice seed germination. *A. philoxeroides* contained water soluble phenolics, namely 4 hydroxy-3-methoxy benzoic acid (16.19 mg L^{-1}) and m-coumaric acid (1.48 mg L^{-1}), whereas *A. sessilis* was rich in chlorogenic acid (17.85 mg L^{-1}), gallic acid (11.03 mg L^{-1}) and vanillic acid (9.88 mg L^{-1}). The study indicates that the allelopathic potential of *Alternanthera* species may play an important role in enhancing the invasiveness of these species and may suppress rice plants in the vicinity (Mohney *et al*., 2009).

Allelochemicals in *A. philoxeroides*

Allelochemicals (non-nutritive substances) are mainly produced as plant secondary metabolites or decomposition products or microbes are the active media of allelopathy. Allelochemicals consist of various chemical families and based on the chemical similarity are classified in 14 categories: water-soluble organic acids, straight-chain alcohols, aliphatic aldehydes and ketones, simple unsaturated lactones, long-chain fatty acids and polyacetylenes benzoquinone, anthraquinone and complex quinones; simple phenols, benzoic acid and its derivatives, cinnamic acid and its derivatives, coumarin, flavonoids, tannins, terpenoids/teroids, aminoacids /peptides, alkaloids /cyanohydrins, sulphide and glucosinolates and purines and nucleosides (Rice, 1974). Plant growth regulators, including salicylic acid, gibberellic acid and ethylene, are also considered as allelochemicals.

Chemicals with allelopathic potential are present in almost all plants and in many tissues, such as leaves, stems, inflorescence, fruits, seeds, roots. These chemicals under specific conditions are released into the environment and can positively or negatively effect on growth and development of vegetation (Peng *et al*., 2004). Allelopathic inhibition is complex and can involve in the interaction of different classes of chemicals like phenolic compounds, flavonoids, terpenoids, alkaloids, steroids, carbohydrates and amino acids with mixtures of different compounds sometimes having a greater allelopathic effect than individual compounds alone.

Allelopathic compounds influence physiological processes such as cellular expansion, cell wall contraction, phytohormonal balance activity of specific enzymes like indole lactic acid oxidase, pollens, spores and seeds germination mineral uptake, stomatal movement, pigment synthesis, photosynthesis, respiration, protein synthesis, leghaemoglobin biosynthesis, Nitrogen fixation, plant water relations, DNA and RNA modification and activation of cellular antioxidative (Tanveer *et al*., 2013 and Zuo *et al*., 2011). The highest suppressive action of *A. philoxeroides* and *A. sessilis* seem not only due to their higher total phenolic contents (116 and 106 mg L^{-1}) but complex interaction of potent phenolic compounds namely 4-hydroxy-3-methoxybenzoic acid, chlorogenic acid, ferulic acid, gallic acid, m-coumaric acid, p-coumaric acid and vanillic acid as shown by their HPLC analysis. It can be concluded that these two invasive weed species are bigger threat to local wet land rice ecosystems and may result in greater yield losses of rice crop in the country (Zeng *et al*., 2001).

The GC–MS analysis conducted by Ashwini (2021) on the aqueous and ethanol extracts of different plant parts of *A. philoxeroides* revealed the presence of several bioactive phytochemical compounds. Among that 9-compounds are present in all the parts of the plant. This includes Eucalyptol, 1,2,3-Propanetriol, 1-acetate, (+)-2-Bornanone, 1-Tridecene, 1-Tetradecene, 1-Heptadecene, 1-Nonadecene, n-Hexadecanoic acid and Phytol. The aqueous extract of the whole plant recorded a higher number of phytoconstituents compared to the extracts of other plant parts. In the root extracts, eight chemical compounds were found to be common in both aqueous and ethanol extracts. Similarly, five chemical compounds were commonly identified in both extracts of the leaf and whole plant. However, no common compounds were detected between the aqueous and ethanol extracts of the stem.

Whereas, the GC-MS analysis of ethanolic extract of different plant parts of *A. philoxerodies* showed the presence of many phytoconstituents. There were eleven compounds identified in all the parts of the plant and this includes Neophytadiene, 2-Pentadecanone, 6,10,14-trimethyl-Hexadecanoic acid, methyl ester, Dibutyl phthalate, n-Hexadecanoic acid, 9,12-Octadecadienoic acid (Z,Z)-, methyl ester, Hexadecenoic acid, ethyl ester, 8-Octadecenoic acid, methyl ester, 12(Z)-Conjugated linoleic acid, (Z)-9-Octadecenoic acid, methyl ester10(E)-, Phthalic acid, and butyl 2-pentyl ester. The ethanolic leaf extract of *A. philoxeroides* recorded highest phytoconstituents than other plant parts.

Allelochemicals induce series of plant physiological and biochemical processes and changes in plants, changes in the micro and Ultra structure of cells, Inhibition of cell division and elongation, imbalances in the antioxidant system, increase in cell membrane permeability. These also effects the plant growth, functions and performance of enzymes, respiration, photosynthesis and nutrients and water uptake, protein and nucleic acid synthesis and metabolism etc., (Gniazdowska and Bogatek, 2005). Furthermore, microbes also play an important role in the activation of allelochemicals, e.g., through the release of non-toxic glycosides followed by microbial degradation to release the active allelochemicals.

An allelochemical released into the environment is not a single substance and the number of allelochemicals released under different conditions vary. Interactions such as synergy, antagonism and incremental effects between different allelochemicals should be evaluated because one allelochemical may or may not show allelopathic activity as a single component in a certain situation or may increase allelopathy in association with other allelochemicals (Albuquerque *et al*., 2011).

The type and amount of allelochemicals released into the environment depend on the combined effects of the plant itself (Plant factors- which include the species, variety, growth stage and different tissues) and environmental factors (include both abiotic factors e.g., irradiation, temperature, nutrient limitation, moisture, pH) and biotic factors (e.g., plant competition, disease, insects, animal invasion, receptor feedback regulation (Anaya, 2003). Plants from the same environment or with close taxonomic proximity do not necessarily display production of similar secondary metabolites and may not secrete the same quantity and quality of allelochemicals or have similar allelopathic effects (Chon and Nelson, 2010; Hagan *et al*., 2013 and Imatomi *et al*., 2013). The stress environment can increase the release of allelochemicals from allelopathic plants (Albuquerque *et al*., 2011). Allelochemicals can be degraded after their release into the soil, the half-life of allelochemicals varies from a few hours to a few months (Barto and Cipollini, 2009; Bertin *et al*., 2009; Demuner *et al*., 2005; Mandal and Mondal, 2011 and Weidenhamer, 2005), it depends on the allelochemical concentration, soil type, soil enzymes, soil microbial population and community structure (Gu *et al*., 2009 and Macias *et al*., 2005). Previous studies indicated that some allelochemicals had tremendous spatial and temporal heterogeneity (Dayan *et al*., 2009; Molisch, 1937; Weidenhamer *et al*., 2009 and Weston, 1996).

Conclusion

The selectivity of receiver plants to allelochemicals released by *A. philoxeroides* changes the population and community structure of an ecosystem. The strong allelopathic potential of *A. philoxeroides* aquatic weed allelopathy can be used as an organic, sustainable, environment-friendly and cheap source to control arable weeds in field crops. Research efforts should be focussed on screening more allelopathic plants like *A. philoxeroides* to evaluate their potential to control arable weeds in an agroecosystem. Understanding how to use *A. philoxeroides* allelopathy to achieve sustainability in crop yields, sustainable weed control and reduced weed invasions.

Conflict of interest: The authors declare no conflict of interest. All authors agree to publish it.

Declaration

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

Ethical statement

This is to inform you that in this study, we have not been involved in any animal and human studies.

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