Review Article

ALLELOPATHIC POTENTIAL OF MEDICINAL PLANTS SERVES AS A VALUABLE SOURCE FOR SUSTAINABLE WEED MANAGEMENT

Abstract

Weeds are noxious plants that cause major problems for crop cultivation by interfering with crop growth and development. Due to weed infestation, about 50% of crop yields are reduced. In fact, weed causes more damage than pests and diseases in crop production. In modern agriculture, weeds are managed by using synthetic chemical herbicides. However, in organic farming, weed management is only possible through conventional methods such as manual and mechanical weeding, which are uneconomical and labor-intensive processes. Nowadays, labor shortage is the major problem in agriculture for performing various intercultural operations, especially weed management. In addition, continuous usage of synthetic herbicides can cause contamination to the surroundings thereby resulting in environmental pollution and the evolution of several herbicide-resistant weed species. To address these drawbacks allelopathic potential and allelochemicals can be utilized for weed management. Medicinal plants are rich sources of secondary metabolites with allelopathic potential, which helps to manage weeds by using plants extracts and natural herbicides. Allelochemicals of medicinal plants have the greatest potential for biological weed management by utilizing plant extracts and extracted allelochemicals as natural herbicides. Naturally extracted allelochemicals have almost the same effect as that of using synthetic herbicides in weed management without causing hazards to the environment. Thus, natural herbicides play a vital role in maintaining eco-friendly agriculture and sustainability in soil health. This review will help to create a general view about the allelopathic potential of medicinal plants and also helps to identify future research areas for weed management in organic farming with the help of allelochemicals.

Keywords: Allelopathic potential, Medicinal plants, Natural herbicides, Secondary metabolites, Weeds

Introduction:

Weeds are considered as the most important deleterious pest, and they rank first in causing yield loss ranging from 33-55% in the crop production (Siddiqui *et al.,* 2010;Maurya *et al.,* 2022 ; Benjamin *et al.,* 2024). In a global context, this results in significant economic losses estimated at around USD 32 billion annually, primarily due to the impact of weeds (Kubaik *et al.,* 2022). In organic farming, farmers are facing major problems with economical and efficient weed management practices (Soni *et al.,* 2020). Organic farmers generally follow conventional methods viz., manual and mechanical weed management practices. But the major drawbacks of conventional weed management practices are uneconomical, labour-intensive and time-consuming process (Hozayn *et al.,* 2011. Further in this decade wage rate has been drastically increased and the availability of labor has been drastically reduced (Duary and Mukherjee, 2013 Ray *et al.,* 2022). In modern agriculture, synthetic chemical herbicides are utilized for the effective weed management: in fact, farmers of this decade use tones of synthetic chemical herbicides for weed management (Mesnage *et al.,* 2021). Moreover, the uncontrolled use of chemical herbicides causes environmental pollution and has harmful effects on soil, water, animals and humans; (Wilson and Tisdell, 2001; Duary, 2008; Aktar *et al.,* 2009). The prolonged usage of chemical herbicides results in the emergence of new herbicide-resistant weed species. In fact, persistence in herbicide usage paves the way for development of 310 weed species as herbicide-resistant biotypes (Sharma *et al.,* 2022). By adopting sustainable agriculture principles and practices are the only way to overcome all these difficulties and challenges in weed management, Sustainable agriculture mainly focuses on eco-friendly farming with the reduction in the usage of chemical pesticides and herbicides (Velten *et al.,* 2015). So, recently researchers have been focusing on the development of eco-friendly new natural herbicides (Akbar *et al.,* 2014; Islam *et al.,* 2018). These natural herbicides are developed from the microorganisms (Bashir *et al.,* 2018; Javaid *et al.,* 2022) and plant (Akbar *et al.,* 2022; Erida *et al.,* 2023) originated allelochemicals. Allelochemicals are known for causing negative or positive interactions one on another organism known as allelopathy (Chon *et al.,* 2006). So, use of the allelopathic potential of medicinal plants is effective in weed management without causing any environmental issues (Hong *et al.,* 2003; Javaid *et al.,* 2020). Further, usage of the plant extracted allelochemical in weed management helps to overcome labour shortages in weed management issues and environmental pollution (Muhammad *et al.,* 2019). According to Ray *et* *al.* (2022) allelopathic potential and allelochemicals are the innovative and novel solutions for sustainable weed management practices either directly or indirectly. This review will discuss the various importance and properties of allelochemical compounds in medicinal plants.

Allelopathy and Allelochemicals:

The harmful or beneficial effects of one plant on another due to the production of allelochemicals are referred to as "allelopathy" (Molisch, 1937; Islam and Kato-Noguchi, 2013b). It is also defined as plant-to-plant chemical interaction that may either promote or interfere with the growth and development of plants present in the surroundings (Fernandez *et al.*, 2016). Allelopathy effects are caused by some chemical compounds, particularly secondary metabolites, which are known as allelochemicals and these chemicals have the ability to produce both positive and negative interactions in the surrounding environment (Del Fabbro *et al.*, 2014). Generally, these allelochemicals are non- nutritive and naturally originated from living organisms especially microorganisms, plants and animals (Lim *et al.*, 2017) .

Yankova-Tsvetkova *et al.* (2020) identified that the allelochemical compounds mainly consist of secondary metabolites such as alkaloids, coumarins, fatty acids, flavonoids, ketones, phenolics, purines, quinine, terpenoids, and aldehydes. Further, these allelochemicals are divided into 14 different groups by considering their similarities. The 14 groups namely Aliphatic aldehydes, alkaloids, amino acids, and peptides; anthraquinone, benzoic acid and its derivatives, benzoquinone, cinnamic acids and its derivatives, complex quinones, coumarins, cyanohydrins, flavonoids, glucosinolates, ketones, long-chain fatty acids, nucleoside, polyacetylenes, purines, purines, simple phenols, simple unsaturated lactones, steroids, straight-chain alcohols, sulfide, tannins, terpenoids, water-soluble organic acids (Cheng and Cheng, 2015). For example, in *Eucalyptus* species 1,8-cineol is a volatile terpene compound released and acts as allelochemicals that inhibits the germination, growth and the development of weed common amaranth (*Amaranthus retroflexus* L.) (Azizi and Fuji, 2005).

The plant parts such as leaves, fruits, seeds, flowers, stems, bark, and roots are responsible for the release of allelochemicals at different concentrations into the environment (Bertin *et al.*, 2003; Tesio *et al.*, 2010; Motmainna *et al.*, 2023) and differ in their pathway of interaction and release into the environment (Sathishkumar *et al.*, 2017). The following ways are responsible release of allelochemicals 1) through root exudation of chemical compounds 2) the release of allelochemicals from the decomposition of plant tissues and residues 4) releasing of volatile allelochemicals from living tissues of plants (Chon *et al.,* 2006)

Scope for utilization of allelochemicals in weed management:

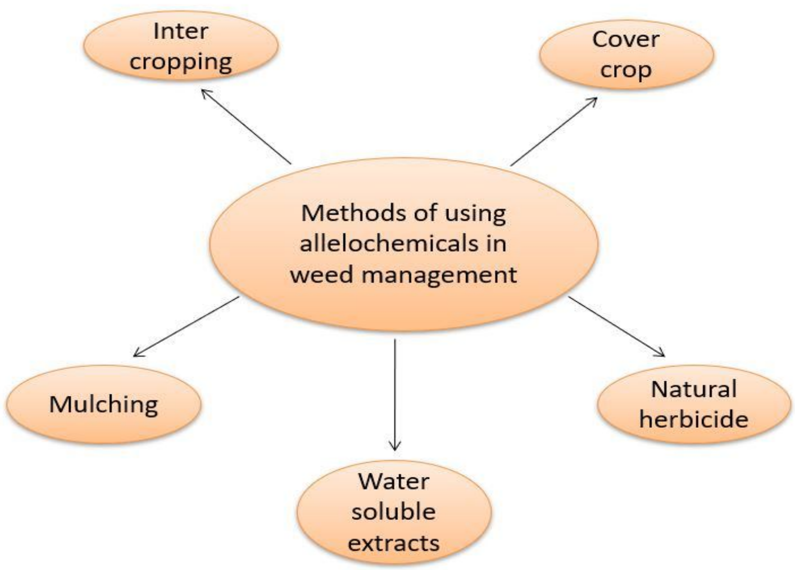
There are several methods for utilization of allelochemicals in weed management practices such as intercropping, cover crops, mulching, crop rotation, plant extracts and natural herbicides as shown in Fig.1 (Farooq *et al.,* 2013). Intercropping with allelopathic potential species can prevent weed growth and the development by releasing allelochemicals into the soil (Baumann *et al.,* 2002; Khamare *et al.,* 2022;). According to Saudy and Science (2015) weed growth has been reduced while using cowpea as an intercrop with maize due to competition and soil-released allelochemicals.

Crop rotation can significantly suppress the weed growth and disease-causing pathogens and pest incidence. Allelochemicals released from the crop rotation by roots and decomposition of crop residues helps in controlling weed seed germination (Peters *et al.,* 2003). Jabran and Chauhan (2018) recorded that weed infestation was reduced in the wheat crop, when the wheat crop was grown following the sorghum crop as a result of allelochemicals released from sorghum. Cover crops are also utilized in sustainable weed management as they possess allelopathic effects and causes competition for light, nutrients, water, and sunlight for weed growth. This result suppresses the weed population (Khamare *et al.,* 2022). An allelochemical L-DOPA (L-3, 4-dihydroxyphenylalanine) was produced and identified in the field when velvet beans were grown as a cover crop (Fujii *et al.,* 1992). Mulching with the residue of allelopathic potential plants is an effective source for sustainable weed management (Tiquia *et al.*, 2002). Using crop residue as mulches can suppress weed growth through allelochemicals released from crop residue (White *et al.,* 1989 Batish *et al.,* 2001; Shafique *et al.,* 2013). According to Molina *et al.* (1991) releasing of allelochemicals from Eucalyptus litter restrict the growth of many weeds. Most of the allelochemicals are secondary metabolites these compounds can be water soluble and water act as a medium of extraction for most of allelochemicals (Farooq *et al.,* 2013). The Aqueous extracts of Datura consist of allelochemicals Scopolamine, hyoscyamine and atropine has the ability to inhibit the growth of *Parthenium hysterophorus* (Javaid *et al.,* 2010; Elisante and Ndakidemi, 2014). In recent days the allelopathic potential of plants extracts can be utilized for the discovery of new natural herbicides (Nornasuha and Ismail, 2017). A list of commercially developed natural herbicides with their natural allelopathic components of medicinal plants are given in "**Table 1**". This natural herbicide can reduce the usage of synthetic herbicides (Motmainna *et al.*, 2021a; Motmainna *et al.*, 2021b). There are two ways of extracting allelochemicals from plant tissue 1) identification and isolation of active chemical compounds and 2) Aqueous extract or organic extracts can be used directly for preparation of natural herbicides (Yang and Tang, 1988).

Table 1: List of commercial developed natural herbicides and their responsible allelopathic components of medicinal plants (Cornes, 2005; Kato□Noguchi *et al.*, 2016; Dayan *et al.*,2009).

Allelopathic components of medicinal plants	**Natural herbicide products**
Citrus oil (70%)	Weed Zap™
Citronella grass oil (50%) and	GreenMatch EX ™
Wintergreen oil and clove oil (46%)	Matran II ™
Cinnamon oil (30%)	Weed Zap™
Chinese perfume plant (*Aglaia odorata)* leaf extracts	PORGANIC™

Fig 1: Methods of using allelochemicals in weed management



Allelopathic potential of medicinal plants and herbs in weed management:

In the world about 52,885 flowering plants are identified and evaluated as medicinal plants (Wakdikar, 2004). Generally, the chemical compounds produced from medicinal plants are used as healing agents and preparation of tablets, tonics, syrups (Kamboj, 2000 ; S. Verma and Singh, 2008 ; Mukherjee *et al.,* 2010). From the total medicinal plants, only 6 percent of plants are examined for their biological and phytochemical properties (Appiah *et al.,* 2017). From the examined medicinal plants about 40000 secondary metabolites were identified but only some secondary metabolites have been selected for their effective herbicidal activities (Einhellig and Leather, 1988). Some medicinal plants with their phytotoxic effects against weeds are listed in "**Table 2".**

Table 2. List of medicinal plants with their phytotoxic effects against weeds

Common name	**Scientific name**	**Plant Parts**	**Targeted weed species**	**Effects on growth and the development**	**Reference**
Common barberry	*Berberis vulgari*	Whole plant extracts	Lettuce weed	80 percent suppression in growth	(Mardani *et al.*, 2014)
Saffron crocus	*Crocus sativus*	stigma and style	Lettuce weed	Strong inhibitory effects against seedlings	(Amini *et al.*, 2016)
Golden apple	*Aegle marmelos*	Whole plant extracts	*Raphanus sativus*	100 percent inhibits the growth	(A. M. Islam *et al.*, 2018)
Camelthorn	*Alhagi maurorum*	Aqueous extract	*Amaranthus retroflexus, Chenopodium murale*	Prevents the germination and growth of seedlings in laboratory experiment	(Qasem, 2002)
Black Jack	*Bidens Pilosa*	Litter and residue incorporation @2tons ha^{-1}	Rice ecosystem weeds	Reduce weeds growth up to 80% in rice and increase yield up to 20 percent.	(Hong *et al.*, 2004)
Chinese Perfume Plant	*Aglaia odorata*	Leaves powder applicati	*Digitaria adscendens, Trianthema portulacastrum and Amaranthus gracilis*	Inhibited the emergence and growth	(Laosinwattana *et al.*, 2012)

		on @ 1ton ha^{-1}			
White Weed Black Jack Milk peas	*Ageratum conyzoides, Bidens pilos, Galactia pendula.*	Residue incorporation @ 1-2 tons ha^{-1}	*Rotala indica*	Inhibits the emergence	(Xuan *et al.*, 2005)

Medicinal plant consists of large amounts of secondary metabolites; these secondary metabolites are responsible for performing various biological activities such as plant defense against biotic and abiotic stress and the production of allelopathic potential compounds (Wink, 2018 ; Qasem, 2002 ; Rice, 1984). According to A. Islam and Kato-Noguchi (2014), the phytotoxic potential can be easily identified in medicinal plants which contain numerous bioactive and secondary metabolites than any other plant groups. (Fujii and Appiah, 2018) started detailed studies on the allelopathic potential of medicinal plants and identified that the screened compounds possess growth inhibition of some weed species. A list of identified medicinal allelopathic plants with their potential allelochemicals against the growth and development of weeds are given in **"Table 3"**. Azizi *et al.* (2009) analyzed the allelopathic potential of 56 aromatic medicinal plants species in Iran and the study exposed that the 51 aromatic medicinal plants species possess inhibitory activity against the seedling growth of lettuce. The allelopathic potential of aromatic medicinal such as *Ocimum* spp, *Mentha* spp, *Leucas* spp, *Datura* spp and *Eucalyptus* spp are elaborately discussed.

Table 3. List of identified medicinal allelopathic plants with their potential allelochemicals against growth and development of weeds

Common name	**Scientific name**	**Family**	**Allelochemical Compound isolated**	**Phytotoxicity effects on targeted**	**Targeted weed species plants**	**References**

				plants		
Pignut	*Hyptis suaveolens*	Lamiaceae	suaveolic acid (14α-hydroxy-13β-abiet-8-en-18-oic acid)	Inhibition of growth and development	Italian grass, barnyard grass, garden cress	(A. Islam *et al.*, 2014)
Neem	*Azadirachta indica*	Meliaceae	Nimbolide B and Nimbic acid B.	Root and shoot growth reduction	Barnyard grass (*Echinochloa sp)*	(Kato-Noguchi *et al.*, 2014)
Neem	*Azadirachta indica*	Meliaceae	Nimbolide B and Nimbic acid B.	Inhibits germination	*Lepidium sativum, Latuca sativa*	(Salam & Kato-Noguchi, 2010)
Garden asparagus	*Asparagus officinalis*	Asparagaceae	trans-Cinnamic acid, p-Coumaric acid and iso-Agatharesinol	Inhibits the root and shoot growth	Rye grass	(Kato-Noguchi *et al.*, 2017)
Prickly ash	*Zanthoxylum limonella*	Rutaceae	Brevifolin	Inhibits the seed germination and growth	Chinese amaranthus	(Charoenying *et al.*, 2010)
Thorn-Apple	*Datura metel*	**Solanaceae**	hyoscyamine, atropine	Reduce emergence and growth	*Parthenium sp*	(Javaid *et al.*, 2010)
River Red Gum tree	*Eucalyptus camaldulensis*	**Myrtaceae**	p-coumaric, gallic, gentisic,p-hydroxybenzoic, syringic acid, catechol and	Suppression of germination and growth	*Portulaca oleracea*	(Sasikumar *et al.*, 2002); (Dadkhah

			vanillic acid,			& Science, 2013)
Bluegum eucalyptus	*Eucalyptus globulus*	**Myrtaceae**	Hyperoside, kaempferol 3-O-glucoside, shikimic-succinic acids	Inhibit germination and physiological growth.	*Agrostis stolonifera*	(Puig *et al.*, 2018)
Long Pepper	*Piper longum*	**Piperaceae**	Sarmentine	Inhibits growth	*Convolvulus arvensis* *Conyza canadensis* *Sinapis arvensis*	(Hasan *et al.*, 2021)
Aleo vera	*Aloe barbadensis*	Liliaceae	Anthraquinones	Inhibits the germination and seedling growth	Dandelion *Taraxicum officinalis*)	Jaime *et al.*, 2013

***Ocimum* spp.:**

Generally, the *Ocimum* genus has been classified into 65 different species (Paton and Putievsky, 1996) and is widely distributed in tropical and subtropical of Asia (S. K. Verma *et al.*, 2012 ; Bączek *et al.*, 2019). Most popular species such as *Ocimum tenuiflorum* L., *Ocimum sanctum* L, *Ocimum gratissimum* L., *Ocimum. Americanum* L. *(O. canum S.), Ocimum basilicum* L., *Ocimum kilimandscharicum* G. and *Ocimum micranthum* W. are grown for their incredible medicinal properties. In *ocimum* majority of allelopathic bioactive compounds are grouped as terpeniods in the composition of Terpene alcohol (linalool); Acyclic monoterpenes (alloocimene, p-cymene, citronellal, cis-β-ocimene); Sesquiterpenes (β-carophyllene); Monoterpene bicyclic ether (1,8-cineole); Cyclic monoterpenes (limonene); Bicyclic monoterpenes (camphene, α-pinene); Terpenic hydrocarbons, and fewer diterpenes. (Prakash *et al.,* 2005). *Ocimum basilicum* L. commonly known as sweet basil is the most vital aromatic herbs composed of a variety of secondary metabolites such as Flavonoids, alkaloids, terpenoids, essential oil, tannin, phenols, steroids, saponins, aldehydes, and glyphosids. (Walton and Uses, 2021). Basil (*O. sanctum* L) is a widely grown medicinal plant also Grown for their religious belief in India. It is classified under the Lamiaceae family; many secondary metabolites such as steroid ursolic acid and n-triacontanol are extracted from the basil leaves. The potential allelopathic compounds such as Methyl ether (4.8%), Eugenol (70.5%), Apinene (3.5%), Caryophyllene (7.5%), Terpinen–4-(0.4%), Nerol (6.4%), Terpinen–4-(0.4%), Selenine (0.4%), Pinene (0.4%), and Decyl aldehyde (Purohit and Pandya, 2013); (Prakash *et al.,* 2005). Lawrence (1988) identified that the *O. tenuiflorum* plant extracts consist of phytotoxic substances such as methyl chavicol, linalool, methyl eugenol and methyl cinnamate in addition to some subtypes of oils. (Kamel *et al.,* 2022) identified some allelopathic bioactive compounds with GC-MS analysis in *Ocimum Sp,* which contains m-Camphorene (5.45%), Phenol, 2-methoxy-3-(2-propenyl)- (9.79%), Ethyl-3-hydroxyandrostan-17-one (4.62%), Geranyl-à-terpinene (6.87%), Retinol, acetate (6.77%), 1,3,6,10-Cyclotetradecatetraene, 14-Isopropyl-3,7,11-Trimethyl(+)- (8.69%), Eugenol (9.79%), 2-(7-Heptadecynyloxy)tetrahydro-2h-pyran(4.62%), 1,3,6,10 Cyclotetradecatetraene, 14-Isopropyl-3,7,11-Trimethyl(+)- and p-Camphorene (5.45%) are the compounds identified. (Singh *et al.,* 2002) observed that the *Parthenium hysterophorus* seedling growth is inhibited by plant extracts of *Ocimum americanum.* The 30 percent aqueous concentration extract of *Ocimum sanctum* has shown 70% inhibition of seed germination of *Parthenium hysterophorus* (Knox *et al.,* 2010). According to Dhima *et al.* (2010) *Ocimum basilicum* incorporation in the soil as green manure inhibits the emergence of *Echinochloa sp* (barnyard grass) by 11-50 percent. The reduction in the total weed population in cowpea and groundnut has been observed by the spraying of plant extracts of *Ocimum basilicum* L as pre-emergence (Tahir, 2011). The aqueous extract of *Ocimum basilicum* has the potential to control weeds such as *Amaranthus,* jungle rice, galius, and common purslane, and also supports the growth of groundnut and cowpea. Moreover, *Ocimum basilicum* extracts may be used as natural herbicides for sustainable weed management (Kamel *et al.,* 2022). *Ocimum americanum* contains allelochemicals such as limonene, camphor and linalool have the potential to restrict the germination and seedling growth weed *Mimosa pudica* and *Senna obtusifolia* (Souza Filho *et al.,* 2009).

***Mentha* spp.:**

The *Mentha* genus is widely distributed in Northeastern Africa, western Asia and southeastern Europe (Khan *et al.,* 2011). *Mentha* genus belongs to the Lamiaceae family with 13 different species and the most common species with allelopathic activities are *Mentha spicata, Mentha suaveolens* and *Mentha×piperita* (Kumar *et al.,* 2011). In *Mentha suaveolens* (apple mint) more than 32 secondary metabolites are identified from which active allelochemicals such as 16 monoterpenes (Camphene, α-pinene, β-ocimene, (+)-Sabinene, β-myrcene, β-thujene, Tricyclene, D-limonene, γ-terpinene, α-terpinene,p-menthan-1-ol, Linalool,4-thujanol ,Endo-borneol and Terpinen-4-ol) and 5 Sesquiterpenes(α-bourbonene,Caryophyllene, Cadina-1(6),4-diene, β-cubebene 2 and Germacrene) (Puig *et al.,* 2023). Mahdavikia *et al.* (2015) have founded that GC-MS analysis of *Mentha×piperita* L.(peppermint) revealed that the presence of allelochemicals such as 8-cineole (5.9%), mentone (17.48%), menthol (35%), and menthofuran (11.7%). Additionally, the extracts also contain some determined phenolic compounds were found namely trans-ferulic acid (10.8 mg/g), hesperidin (9.3 mg/g), ellagic acid (6.8 mg/g), and sinapic acid (4.2 mg/g). According to Campiglia *et al.* (2007) seed germination of ryegrass was significantly inhibited by peppermint oil. The seedling growth of barnyard grass and *Timothy sp* are inhibited by using the aqueous methanol extracts of *Mentha sylvestris* (A. M. Islam & Kato-Noguchi, 2013b). According to Petrova *et al.* (2015) ; Nagaraja and Deshmukh (2009) *Mentha spicata* oil exhibit the allelopathic potential against some weeds namely *Amaranthus retroflexus, Sinapis arvensis, Centaurea salsotitialis, Sonchus oleraceus, Rumex nepalensis, Raphanus raphanistrum* and its extracts shows inhibitory effects on *Cynodon dactylon, Rumex crispus* and *Sorghum halepense.* The allelopathic effects of *Mentha piperita* extracts and its essential oil inhibit the seed germination (%), root and shoot growth and dry weight of weeds such as field bindweed (*Convolvulus arvensis* L.), purslane and jungle rice (*Echinochloa colonum* L.) (Azirak *et al.,* 2008; Isik *et al.,* 2016). The seed germination of *Amaranthus* spp. *and E. colona* are restricted by using essential oil produced from *Mentha spicata* (spearmint) (Argyropoulos *et al.,* 2008).

***Leucas* spp.:**

The genus *Leucas* is classified into 80 different species of which more than 41 species are available in India (Mukerjee, 1938). The two major species *Leucas aspera and Leucas cephalotes* are widely distributed in the world. *Leucas aspera* is a popular aromatic medicinal herb that belongs to the family Lamiaceae and consists of numerous bioactive compounds. It is a common weed species found in fallow land and roadsides widely distributed in both tropical and temperate regions of Asia (Shah *et al.*, 2010; Srinivasan *et al.*, 2011). Secondary metabolites such as terpenes, flavonoids, coumarins, steroids and lignans are present (Das *et al.*, 2012; Nirmala & Kanchana, 2018 ; Shah *et al.*, 2010). In particular, the methanolic extracts of *Leucas aspera* contains allelochemical compounds such as diterpenes (rel5S, 6R, 8R, 9R, 10S, 13S, 15S, 16R)- 6 acetoxy 9,13;15, 16diepoxy15hydroxy 16methoxylabdaneand (rel5S, 6R, 8R, 9R, 10S, 13S, 15R,16R)- 6-acetoxy-9,13;15,16-diepoxy-15-hydroxy methoxylabdane (A. M. Islam *et al.*, 2014). The growth and seed germination of *Echinochloa colona* was significantly inhibited by applying methanol extracts of *Leucas aspera* (A. M. Islam & Kato-Noguchi, 2013a). According to Thang Lam and Hisashi (2021) methanol extracts of *L. cephalotes* exhibited inhibitory and allelopathic effects on barnyard grass, *Timothy sp*, Italian ryegrass.

***Datura* spp.:**

The genus *Datura* is a most popular medicinal plant used throughout the world and also it contains higher allelopathic effects against crops and weeds (Javaid *et al.*, 2010). The two major species with allelopathic activities are *Datura metel* L and *Datura stramonium***.** Ma *et al.* (2006) have identified that the *Datura metel* contains phytotoxic compounds in the form of withanolide glycosides namely daturametelins H–J, daturataturin-A, and 7,27-dihydroxy-1-oxowitha-2,5,24-trienolide present in the aerial parts. Some other allelochemical compounds such as pyrrole compound derivative, 2-(3,4-dimethyl-2,5-dihydro-1H-pyrrol-2-yl)-10 - methyl ethyl pentanoate was extracted and identified from the leaves of *Datura metel* (Dabur *et al.*, 2004) and sphingosine compound derivatives namely (4E,8Z)-1-O (-D-glucopyranosyl)-N-(20 hydroxyhexadecanoyl)-sphinga-4,8-dienine (Sahai *et al.*, 1999). These compounds exhibit allelopathic herbicidal activity. The aqueous extracts of *Datura metel* have recorded inhibitory effects in germination and seedling growth of parthenium weed in laboratory assay, In the field evaluation the reduction in germination was observed up to 97 percent of parthenium is observed by incorporation of *D. metel* residue at the rate of 4-5 percent (Javaid *et al.*, 2010).

Datura stramonium is a small herb of 1m in height and is widely distributed all over the world (Valverde *et al.*, 2003). *D. stramonium* is another important species that contains numerous allelochemicals such as atropine, scopolamine and hyoscyamine (Alexander *et al.*, 2008); and these allelochemicals inhibit the root and shoot growth of weeds namely *Trigonella* and *Lepidium* (Oseni *et al.*, 2011). In *D. stramonium* 44 allelopathic bioactive compounds have been identified by using GC-MS analysis, compounds namely sterols and their related compounds 26,26-Dimethyl-5,24(28)-ergostadien-3. beta-ol,5. alpha. -Ergosta-7,22-dien-3.beta and 3-Hydroxycholestan-5-Acetate (Yang *et al.*, 2007). Lovett *et al.* (1987) identified some alkaloids derivates responsible for restriction of seed germination and seedling growth of weeds such as *Cenchrus ciliaris, Notonia wightii.* A new natural herbicide can be derived from methanol extracts of *D. stramonium*, these herbicides can be effectively used as both pre-emergence and post-emergence weed management herbicides against *Tagetes minuta* and *Amaranthus hybridus* in higher concentrations (Sakadzo *et al.*, 2018).

***Eucalyptus* spp.:**

The *Eucalyptus sp* belongs to the family Myrtaceae and is mostly cultivated for paper production in addition it contains many medicinal values and is distributed widely in the Mediterranean regions of the world (de Almeida & Freitas, 2006; Giardina *et al.*, 2007). The two major species are *E. globulus Labill.* and *E. camaldulensis Dehnh* (Andreu *et al.*, 2009) are widely cultivated. May and Ash (1990) reported that allelochemicals such as phenolic acids and terpenes are available in leaves barks and roots of *Eucalyptus* spp. The leaves contain many phenolic and volatile compounds capable of producing allelopathic effects on weeds (Al-Naib & Al-Mousawi, 1976; May & Ash, 1990). The existence of several allelopathic terpenes compounds namely limonene, 1,8-cineol, α- and β-pinene has been identified from the foliage of *Eucalyptus* spp (Muller *et al.*, 1964). Putnam (1984) observed that compound such as benzoic, cinnamic and phenolic acids are released from *Eucalyptus* species and they are capable of suppressing the growth of some neighboring crops and weeds. (Iqbal *et al.*, 2004) analyzed the essential oil of *E. camaldulensis* and reported that 16 allelopathic potential compounds were identified, the major constituents of compounds namely,1-8 cineole, α-pinene, p-cymene and βphellandrene. Due to the application of leachates extracted from fresh leaves of blue gum Eucalyptus (*E. globulus Labill.)* at the rate of 20 percent has a significant effect in reducing the rate of resprouting of purple nutsedge (*Cyperus rotundus* L.*)* by 57-68 percent (Babu *et al.*, 1997) and also when this leachates extracts applied at the rate of 25 percent the growth of bermudagrass is suppressed by 66 percent in the greenhouse experiment (Daneshmandi *et al.*, 2009). According to Azizi and Fuji (2005) observed that 80 percent of germination of *Amaranthus retroflexus* L. and 90 percent *Portulaca oleracea* L. are reduced by the application of *E. globulus* essential oils applied at 0.2 percent. In addition, aqueous extract of *E. citriodora* inhibits the germination and growth of parthenium seeds. In *Echinochloa colona* the application of *E. globulus* dry leaves in soils can reduce the number of branches produced by 59 percent and also reduce the fresh weight of weed by 66 percent (El-Rokiek and Eid, 2009).

Limitations of using allelochemicals and natural herbicides:

Although the identification and selection of allelochemicals from medicinal plants are comparatively easier than compared to other groups of plants, but the extraction of allelochemicals and synthesis of natural herbicides are very expensive, laborious, difficult, and time-intensive processes (Islam *et al.*, 2018). For example, from the allelochemicals cyclic tetrapeptide tentoxin has ability to synthesis natural herbicide but the extraction and isolation methods are very expensive and tedious processes (Inderjit *et al.*, 2005; Khamare *et al.*, 2022), and some allelochemicals like aflatoxin and ricin exhibits toxic to living organisms especially human and animals (Zimdahl, 2018). Moreover, the shelf-life of active allelochemicals is less, than compared to synthetic chemicals (Ferguson *et al.*, 2013 ; Maurya *et al.*, 2022). According to Maurya *et al.* (2022), allelochemicals composition and quality varies even in the same locations and taxonomic groups of plants. In addition, the major limitations in using allelopathic potential and allelochemicals are delay in the suppression of weeds in field conditions and the information about mode action in targeted plants by using allelochemicals and natural herbicides are not yet identified but, incontrast distinct mode of action using synthetic herbicides in weeds and targeted plants are studied and identified in detail (Ray *et al.*, 2022). The Final and foremost limitation on natural herbicides and allelopathic potential is in the laboratory and controlled conditions the allelochemicals contain greater phytotoxicity on targeted plants but in field experiments while using the same allelochemicals the phytotoxicity ability is very much decreased due to various physical, chemical, and biological factors of the environment (Vidal and Bauman, 1997); (Kobayashi and management, 2004); (Inderjit *et al.*, 2005); (Khanh *et al.*, 2005).

Future researchable areas:

1. In the future more researches are needed for identification and isolation of the potential allelochemicals for weed management in the field conditions.
2. In addition to weed management the pest and disease-controlling ability of synthesized natural herbicides should be identified and studied to increase the efficacy in their application.
3. More studies are needed on physiology changes, mode of action, and bioassay of targeted plants by using allelochemicals.

Conclusion:

From this review, it is clear that the medicinal plants are capable of producing several secondary metabolites with allelopathic potential and these secondary metabolites can be utilized as potent source for sustainable weed management as allelochemicals. The allelochemicals have the ability to reduce and suppress weed growth and development. These compounds after extraction and identification can be effectively used for development of new natural herbicide. The developed natural herbicides can be used as source for weed management in organic farming. It helps to maintain sustainability and pave the way for eco-friendly farming without affecting the environment.

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Details of the AI usage are given below:

1. NO AI TOOL USED (OPTION 1)

2. GRAMMARLY WAS USED TO CHECK GRAMMAR MISTAKES

3.

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