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Allelopathy in agroforestry: A review

Garima and Meera Devi

Abstract
Woody perennials release some phytochemicals into the soil which adversely affect the germination and yield of understorey crops. Allelopathic interactions in tree crop associations in agroforestry greatly influence the crop production. When the trees and crops grown together they interact with each other either inhibiting or stimulating their growth or yield through direct or indirect allelopathic interaction. The consequent effects include inhibited or retarded germination rate, reduced roots or radical and shoot or coleoptiles extension, lack of root hairs and swelling or necrosis of root. Thus. it plays an irnportant role in an agroforestry system and it is clear that a better understanding of allelopathy can help in developing more sustainable agroforestry system.

Keywords: Allelochemicals, agroforestry, allelopathy, interactions, multipurpose trees, weed management

Introduction
Agroforestry is recognized as one of the supreme strategy to attain ideal multiple benefits, through interactive and intentional land use system and technologies where trees are deliberately planted with agricultural crops or with animals. Agroforestry, other than the beneficial components also involves harmful properties on the agricultural crops because of numerous aspects like light, space competition, nutrients and organic chemicals discharged as leachates or leaf extract which influence plant crops also cause root exudation, residue decomposition.
Allelopathy refers to the detrimental effect of one plant on another crop through the release of certain chemicals. These interactions are mediated by allelopathic substances which are secreted from the organisms (donors) have effect on the others (acceptors) (Gniazdowska *et al*. 2004) [6]. Allelopathic interactions among individuals of same species termed as 'Intraspecific Toxicity' or 'Autotoxicity' or 'Autoallelopathy' have been reported in a number of species (Kumar 1991) [10]. Contrarily, the term 'Teletoxicity' is used when suspect species are taxonomically different from donor or agent species (Kushal 1987) [11].
Allelopathic compounds produced by higher plants are mostly secondary metabolites. Phenolics, cyanogenic glycosides, quinones, lactones, organic acids and volatile terpenes belong to the most active compounds. These substances are released into neighbouring environments through volatilisation, root exudation, leaching and decomposition of plants, and inhibited the growth of neighbouring plants (Belz 2007) [1].

Trees combinations with crops
Trees, especially multipurpose ones, are becoming an integral part of agriculture in agroforestry programmes. This practice increases productivity, improves soil quality, microclimate, nutrient cycling and conserves soil. However, a number of trees negatively affect performance of crops through allelopathy e.g. *Leucaena leucocephala*, *Populus deltoides*, *Eucalyptus* and *Acacia* species (Bora *et al*. 1999) [2]. Allelochemicals are present in all plant parts; roots, stems, rhizomes, flowers, inflorescences and leaves (Putnam, 1988) [17]. Often, the release of these allelochemicals from the decomposing litter affects seed germination, growth and development of adjoining crop plants in agroforestry systems.
Phyllostachys edulis (Poaceae) contains significant amounts of allelopathic compounds that can inhibit the growth of undergrowth weeds (Chou & Lee 1991) [4]. There are number of factors such as the density at which the leaves fall, the rate at which this material decomposes, the distance from other plants, and, finally, the quantity and distribution of the annual rainfall which determines the presence of allelochemicals (Escudero *et al*. 2000 and Nilsson *et al*. 2000) [5, 16].

Laboratory experiments were conducted by Krishna *et al*. (2003) [9] to study allelopathic influence of leaf of certain multipurpose tree species viz., *Acacia auriculiformis*, *Casuarina equisetifolia*, *Bambusa arundinacea* and *Tectona grandis* on test crops (Tomato, Brinjal and Chilli). The results revealed that leaf leachates of all trees significantly inhibited germination percentage and growth of vegetable crops. Response indices revealed that inhibition of radical and plumule growth was more pronounced.

Singh (2009) [21] studied the allelopathic potential of the agroforestry trees *Ficus subincisa* Buch.-Ham. ex J. E. Smith, *Bauhinia purpurea* L., and *Toona hexandra* Wallich ex Roxb. was investigated on *Triticum aestivum* L., *Brassica campestris* L., and *Hordeum vulgare* L. test crops. The leaf and bark leachates of trees were both toxic to the germination of the test crops. The effects of leachates on test crops were concentration dependent. So, higher concentrations of leaf and bark leachates showed inhibitory effects on the radical and plumule growth of all test crops. Hossain *et al*. (2012) [7] also revealed that allelochemicals released from different plant parts of ***M. oleifera*** showed higher inhibitory effects on the rate of germination of mungbean with increase in concentration of allelochemicals in laboratory condition.

Thakur (2014) [24] also confirmed that mulberry, plum and pomegranate leaf extract had adverse effect on seed germination, root length, shoot length and dry matter production of soybean. Further, Khan *et al.* (2016) [8] observed that allelopathic effects of *Populus nigra* bark on germination, plumule length, radical length, fresh weight and dry weight of Z. mays.

Benefits of allelopathy

Plants are known to synthesize allelochemicals that affect germination, growth, metabolism, development, distribution, behavior, and reproduction of other organisms (Rice 1995) [18]. Allelochemicals often imparts resistance to plants from pathogens, insects, nematodes, and further, reduces weeds. Agroforestry systems provide an excellent opportunity to explore the pest controlling properties of AF species. Most of the AF species produce a good amount of leaf, litter and debris that are rich in allelochemical content. These allelochemicals in turn provide various kinds of pest controlling properties to AF species. Thus, their allelopathic materials can be used as mulch, and their leachates and purified compounds may be eco-friendly alternatives to synthetic pesticides.

Allelopathy in Weed management

Allelochemicals released from plants are useful for weed management options in several agriculture settings to reduce dependency on commercial herbicide (Putnam 1988, Weston 1996, Narwal 1999) [17, 14]. In general, leaves are the most potent source of allelochemicals, however, the toxic metabolites are also distributed in all other plant parts in various concentrations. An allelopathic crop can potentially be used to control weeds by planting a crop with allelopathic qualities, either as a smother crop, in a rotational sequence, or when left as a residue or mulch, especially in low-till systems, to control subsequent weed growth.

Trees can control germination and growth of weeds, through its allelochemicals. Scopolin and Scopoletin isolated from *Celtis laevigata* are reported to suppress *Amaranthus palmeri* (Lodhi and Rice 1971) [13]. *Annona squamosa, Carica papaya, Coffea arabica,* and *Tamarindus indica* were found to inhibit germination of *Amaranthus spinosus* by 13, 58, 100, and 36%, respectively through its ethanolic extracts of seeds (Rizvi *et al*. 1980) [19].

Aqueous extract from bark and leaf of *Eucalytus citriodora* showed allelopathic effect on the growth of some weeds i.e. *Bidens pilosa*, *Digitaria pertenuis*, *Eragrostis cilianensis*, *Setaria geniculata* (Cao and Luo 2005) [3]. Similarly, *Eucalyptus citriodora* oil completely inhibited the germination of noxious weed *P*. h*ysterophorus* (Singh *et al*.2005) [22].

Allelopathy in pathogen control:

One strategy to exploit allelopathy is the use of allelochemicals for the control of pathogens (Rice 1995) [18]. The plant allelochemicals can be used either in the purified form, in the form of crude plant extracts or as volatile extracts. However, very few tree-based allelochemicals have been exploitd for this purpose. Neem (*Azadirachta indica*) is one tree, which possesses potential to kill pathogens. Its seed cake, seed and fruit extracts, seed kernel powder, and seed oil have been reported to control a wide spectrum of fungal pathogens (Srivastava *et al*.1997) [23]. The biological activity of neem against pathogens is attributed to the presence of sulfurous compounds in its seed oil. Moreover, neem products also act as deterrents to pathogen-carrying insects, thereby decreasing the disease incidence (Saxena *et al*.1985) [20].

Under natural conditions, only very small amounts of allelochemicals are leached or volatilized directly and subsequently come into contact with receptor plants (Ni *et al*. 2011) [15]. Furthermore, after they are released into the soil, allelochemicals would be affected by the soil, such as by absorption, migration, or decomposition by microorganisms and enzymes. Phenolic allelochemicals can be decomposed by soil microbes, and thus they do not reach active concentrations (Yenish *et al*. 1995) [27]. Ceratiolin, a non allelopathic active substance secreted by *Ceratiola ericoides*, can be transformed into activated phenylpropionic acid and subsequently converted into a more poisonous chemical, hypnone (Walker *et al*. 2003) [25]. Moreover, soil nutrient content might influence the final results of allelopathy.

Conclusion

Allelopathy is a vital mechanism in which plants scatter toxic substances in nature as their competitive technique; it is a significant environmental favourable methodology to weeds control, to the diminishment of herbicide application and to yield increment. Allelopathy plays a major role in ecosystems with both positive and negative impact on plants. From the literature cited, it can be concluded that rate of germination, plant height, number of leaves per plant, plant dry weight and yield were suppressed by presence of allelochemicals. Growth and yield parameters suffered more in higher concentration of extracts than lower concentration. Based on the results it can be concluded that allelopathy is a concentration dependent phenomenon, as the concentration of allelochemicals increases gradually, its harmful effects also increases on receptor plants.

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