CHAPTER 1. INTRODUCTION

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1.Introduction

1.1. Concept of allelopathy: Definition and History

Allelopathy is a branch of science which explores chemical effect of one plant or microorganism on another through various aspects. The term ‘Allelopathy’ was improvised by Molisch in 1937 for the first time (Narwal, 2003), this terminology is derived from Greek words ‘Allelon’ means each other and ‘pathos’ means to suffer, it indicates harmful effect of one on another. Consequently many other scientist also gave different definitions as per their advance research in the field.Akobundu (1987) defines allelopathy as” The detrimental effects of chemicals or exudate produced by one living plant species on the germination, growth and development of other plant species or microorganism sharing the same habitat”.At the same time, Putnam (1988) described allelopathy as a “positive plant response mediated through chemicals produced by another plant”, instead of only negative or inhibitory effect, he also considered that release of chemicals not only from living, but even from dead plant parts can affect nearby surroundings. So allelopathy is actually both beneficial and detrimental effects of chemicals derived from living or dead plant parts over another in present surroundings (Molisch, 1937). Recently International allelopathy society has accepted the definition of ‘allelopathy’ as,’ any process which involves production of secondary metabolites by plants, algae, bacteria, fungi or viruses that influence the growth and development of agricultural and biological/ natural system (Reigosa*et al.*, 2006). Reviewing the allelopathy definition, it becomes clear that any substance can have an inhibitory effect with specific concentration and it can be beneficial at lower concentration or vice a versa. Paracelsus stated that in 16th century, with reference to the dose response and its effect on plant by a phrase like, ” All things are poison and are not poisonous. Only the dose makes a thing not a poison"(Duke *et al*., 2006) which explains that in allelopathy,positive or negative effect of plant on another plant depends on dosage of the chemical recieved by the target plant (Inderjit and Keating ,1999)

First and foremost,The concept of allelopathy arose from the poisonous or detrimentaleffect of animal or plant chemicals on other animals and humans. It led to think on whether plants affect on other plants or not?(Willis, 2007). Earlier allelopathy was misinterpreted for resource competition between two or more plants present in the same vicinity. It is difficult to separate and proove allelopathic effects from competition, and so Willis (1985) suggested six criterias which were required to proove the effect due to allelopathy. These criteria were inhibition pattern of a species,toxin production by plant,mode of toxin release in environment,affected metabolism of receptor plant etc.Onthe other hand compitition involves reduction in some environmental factors which were required for the the growth of other species in the same area.During 3rdcentury B.C.,Theophrastus observed such factors which can be considered as allelopathic effect of plants in agricultural field on other plants.He observedinhibitory effect of chick pea to many weeds in surroundings, especially on *Tribulus terrestris*(Rice,1984). In5th century B.C., Democritus described the impact of allelopathy in weeds by using natural plant products, he also described about detrimental effect of lupine flowers on roots of trees (Rizvi *et. al.,*1992). Plinius Secundus in 1st A.D reported inhibitory effect of legumes like chick pea, bitter vetch (*Vicia ervilia (L.)Willd.*), and fenugreek on cornland. He observed inhibitory outcome of walnut (*Juglans regia*L.) and pine tree in the nearby vicinity andalso noted about autotoxicity of fern (*Pteridium aquilinum* (L.) Kuhn),where roots of the fern were destroyed by juice secreted from the stalk itself (Rice, 1984). In one of the 300 year old Japanese document, Banzan Kumazawa has mentioned aboutharmful effect of pine leaves after rain or water dew on crops growing nearby pine, which was later proved by many experiments(Lee and Monsi, 1963). But most of the research progress in this area has occured during the twentieth century by many plant scientist. Scientist did many research in this field analysing almost all group of plants and microorganisms. One such interesting study was conducted by Bold in 1957 who has categorizednumber of different groups in plant kingdom expressing allelopathic potential,he hasclassified all lower group of plants in 24 phyla, out of which first eight phyla are for various algal groups; that includes Cyanophyta, Chlorophyta, Charophyta, Euglenophyta, Pyrrophyta, Chrysophyta, Phaeophyta, And Rhodophyta. He described work and experiment done by many phycologist, limnologist and oceanographers on different types of algal alleopathy. Many phytoplanktons especially, blue green algae like *Nostoc* shows autotoxicity and it also prevents growth of other algal bloom in the same premise. In Chlorophyta *Chlorella, Scencedesmus, Nitzschia, Asterionella*showed retarding or accelatory effect on the growth of others.Brown algae like *Ectocarpus* and *Fucus* also inhibited growth of other algae and sometimes even were autotoxic by producing chemicals like flavonoids and tannins.Someof the red algae like *Rhodomela larix* , controls growth of many pathogenic bacteria. Around 50 phenolic compounds were identified from different group of algae which were utilized as allelopathic agents (Ragan and Craigie,1978),Bold had classified 9 to 13 phyla for bacteria and fungi in which baceria like *Protococcus* and *Trentepohlia* affected growth of radish seed germination. On other hand *Hormidium nitens* stimulated seed germination. Fungi were classified in four main groups like Mycomycota, Phycomycota, Ascomycota And Basidiomycota. There are many fungi imperfecti that also show allelopathic effect on other fungi or some plant growth,after fungi he had classified phylum14-19 for bryophyta as Hepatophyta, Bryophyta And Pteridophyta As Psilophyta, Microphyllophyta, Arthrophyta, And Pteridophyta.Many liverworts proved allelopathic to several species of bacteria as well as they also inhibited radish and pine seed germination,Pteridophytes like*Psilotum*, *Lycopodium*, *Equisetum*, *Pteris* show allelopathic effect against bacteria so can be used as antibacterial agents.Further,Gymnosperms were classified in phylum20-23 as Cycophyta, Ginkgophyta, Coniferophyta,and Gnetophyta,several experiments proved allelopathic effect of *Pinus*on surrounding crops or plants.The Last phylum included whole angiosperm group (Rice, 1984). Numerous plants from different families of angiosperm have been studied for their allelopathic potential in which Fabaceae,Euphorbiaceae, Myrtaceae, Apocynaceae, Compositae and Rubiaceae show strong inhibition towards the recepient plants(Fuji *et al.*,2003;Ilori *et al.*,2010).

1.2 Allelopathy in natural ecosystem

This concept was restricted to plant ecology describing various factors like plant dominance,succession,and climax formation(Muller,1969). Many Plants from algae to angiosperms have allelopathic activity and release different type of chemicalsin high or low concentration in surroundings, for many reasons like,**1**) It can be part of their defence mechanism against other plants ormicroorganisms,which causesinfection anddisease. Chemicals can also be released to survive from herbivory or predation,such purposes can trigger the production of volatile organic compound. One of the good example is for a chemical named methyl jasmonate, which controls herbivory for some plants, italso supportaccumulation of phenolics in many rice varieties . These phenolics show allelopathic effect on many plants (Bi *et al.*, 2007). Likewise indirect production of allelochemicals also occurs in plant as a result of defense for survival.**2**)The adverse environmental conditions is the another reason for plants to produce many secondary metabolites as chemicals especially those plants growing in extreme heat or cold climatic conditions. These chemicals show allelopathic effect on surrounding plants. As per the season type and concentration of chemical changes even for the same area or community,resulting remarkable variation in the community structure. For example, accumulation of glucotropaeolin in *Alliaria petiolata* is three times higher in autumn than spring, while production of alliiarinoside is more during spring than in autumn (Barto and Cipollini,2009). Similarly perennial plants like *Lantana camara ,Kalmine* were recorded as invasive plants because they can release harmful chemicals to the soil for more than one time during the season or year(Bais *et al.*,2004).**3**) New chemicals can be produced by plants to survive in the new community as alien species against adapted native plant speciesandto stand dominant in the ecosystem against all other species(Yoshikawa *et al.*,1993;Narwal,2004).Ecosystem changes, sometimes due to the introduction of exotic/alien species, which can become invasive and strong competitor for the native plant species (Inderjit *et al.,* 2008;Inderjit *et al*,2011;Zhang *et al*,2010). According to one mathemetical analysis for a homogenous community structure,where growth is dependent on density of plants,invasion is possible only when the density of the alien species is more than the native species and is due to effect of allelopathic chemicals from alien species over native one (Fassoni and Martins, 2013). Some of the strong alien invaders reported are *Parthenium hysterophorus(*Pandey,1994), *Centaurea species (Riden and callaway, 2001), Cyperusrotundus(Agrawal et al, 2002).*It can cause loss of biodiversity and change in community structure after overcoming many barriers either through resource competition or through allelopathic interference (Barto and Cipollini, 2009; Lorenzo *et al*, 2010).Currently, scientists are giving utmost importanceto understand allelopathic impact of exotic plant in their native and in newplace.

1.3 Applications- agricultural aspect of allelopathy

Several applications have been studied regarding agriculture aspect of allelopathy. Many plants were scrutinized as allelopathic crops,invasive weeds, cover crops or as companion crops showing impact on other crops,pests and on near by weeds (Hirai,2003). Main perspective of the allelopathic study for agriculture is to increase the yield of the crop by reducing the survival of other noxious weeds or pests.

Agriculture aspect of allelopathy has been reported in relation with problems of weeds on crop growth (Bell and Koeppe, 1972), using mulch phytotoxicity in farming (Mc Calla and Haskins, 1964) and effect of crop residues during crop rotation(Conard, 1927). According to Weston (1996) it is difficult to assess the allelopathic influence of particular plant in farm field due to the confusion between competition and allelopathy. Young (1804) also stated about autotoxicity of the clover crop and suggested 7-8 year gap in between clover crops.

Earlier in 1832 De Candolle described effect of weeds over crops for the first time, he observed harmful effect of *Cirsium arvense* (L.) Scop.(Canada thistle) on nearby Oat crops.Weeds are defined as the non crop vegetation that reduces the quantity or quality of existing crops to such an extent that any net benefit of weed plants to themselves cannot compensate for theirunfavorable effects on crops (Alstrom, 1996). There is a conflicting view regarding a weed’s importance and activity as it plays a different role in different region, somewhere it is a pest to one plant and useful for another (Miller, 1936). For example, in Australia, weed management program ran against *Opuntia* spp.,was opposed by locals in USA and Hawaii regions where it was beneficial in many ways (Dodd, 1940). Similarly, in California, yellow thistle (*Centaurea solstitialis* L.) was damaging crops and grazing area while on the other hand it was a key plant for bee industry(Fullaway,1954).In other words weeds are crop specific for harmful and beneficial effect. For example, aquaous extract of *Stizolobium deeringianum* Bort. increased dry matter of maiz crop and no effect on cowpea crop, but it showed inhibitory effect on cabbage plants.Similarly,*Canavalia ensiformis* inhibited seed germination of cabbage but not of corn and cow pea (Gliessman,1983). Many entomologists have reported that weeds cause much more destruction in the agricultural field than insects (Robbins,*et.al.*1942).

1.3.1. Weeds -Threat to crops

Weeds cause growth reduction of many desirable plants leading to their yield and quality destruction,theyalso increase the cost of cultivation of a particular crop, and getmixed with crop seeds so need special cleaning, theycause injury to man or livestock, and most important part of their destructive role isas alternative host of the plant pathogens(Huffaker, 1970).Recent example of such plant is, *Parthenium hysterophorus* found as an invasive plant in Ethiopia since 1990's. Its flower and leaf were showing allelopathic activity towards the major staple cereal *Eragrostis tef.* Aquaous extract of parthenium leaf and flower were reported inhibitory on tef seed germination and shoot length. This problem becamesevere with affect on milk and meat quality of animals. Hand weeding of *Parthenium* sp. also become difficult as it has allergic effect on humans and animals(Tefera,2002). Weeds cause more damage to the neighboring crops than insects or plant disease through allelopathy, competition for similar growth resources and as a host of various pests (Narwal, 2004).Field study in California,Arizona and Mexico states ofUSA showed such virus (CYSDV) that makes reservoir on non cucurbit plants like *Sida hederacea* and *Physalis wrightii* which transmits virus to melon and other cucurbit crops in nearby field(William *et al.*,2009). Similarly, *Verbascum thapus* is a noxious weed in some regions of USA and Australia. It also becomes a host of many agricultural pests like Cucumber Mosaic Virus,*Erypsium cichoraceaum* and texas root rot, it also invites large varieties of insects belonging to more than 25 different families (Horton,2003). All above reasons make huge economic loss for crop producers/ farmers.According to Akobundu (1987)and Chandler (1984), it is estimated that some 1800 weed species cause serious economic losses in crop production,out of these about 300 weed species are responsible for the serious economic losses in cultivated crops throughout the world. Earlier, effect of weeds over crops wasknown for their competition for similar resources, but lateron many scientists reported number of weeds which showthe allelopathic effect to the specific crops (Ashraf and Sen, 1978; Steenhagen and Zimdahl, 1979).Putnam and Weston (1986) listed around 90 invasive weed species which cause harmful effect to the crop, Narwal in 2004 reported 129 weed species showing the allelopathic effect to crops.

Parthenium hysterophorus L. is an invasive exotic plant causing major destruction in Indian cropland, which is mainly a roadside weed, but also poses problems in agricultural fields,It is spreading in agricultural land through irrigation. It is considered a native of central and north America (Mani *et al.*, 1975) and first appeared in India in 1956 near Pune in Maharastra state (Parihar and Kanodia. 1987). It was introduced in India accidently with imported food grains (wheat) and till 1980’s it was spreading fast throughout India occupying hectares of lands in villages, waste land, roadsides and grazing lands. All parts of this weed shows allelopathic potential. Allelopathic effect of this weed has been reported for inhibiting seed germination and seedling growth of legumes like soyabean and haricot bean (Netsere and Mendesil,2011), cereals like wheat,maiz and rice (Devi and Dutta,2012; Maharajan,2007) and also inhibiting few of cruciferous members like *Lactuca sativa*(Wakjra *et. al*,2009), *Raphanus sativus*L.,*Brassica campestris* L. and *Brassica oleracea*L.(Maharajan,2007)

Narwal in his one of the book based on allelopathy in agriculture described about many major and minor weeds showing allelopathic potential. He has listed some of the major weeds like Quack grass (*Agropyron repens*(L.) Beauv.) reduces production of major cereal crops like wheat,barley,oat,maize, legumes like alfalfa,peas,kidneybean and ,potato. Johnson grass (*Sorgham halpenes* (L.) Pers.) showed allelopathy to maize,sugarcane,soybean,wheat,chick pea and cotton.it also showed reduction in sunflower,raddish and tomato seed germination.,Canada thistle *(Cirsium arvense* (L.) Scop.) inhibited seed germination and seedling growth of many important crops such as wheat,barley,alfalfa,soybean,cucumber,lucerne, and sesame with its residue and root and leaf residue., Cogon grass (*Imperata cylindrica* (L.) Beauv.) is one of the most noxious weed intropical regions.it shows maximum effect to the seedling growth of legumes and cereals and delays seed germination., Cocklebur (*Xanthium* species) decreses seed germination of main cash crops like wheat,tobacco,chick pea,pearlmillet and lettuce,thorn apple (*Datura stramonium* L.) is a weed mainly in tropical and sub tropical countries.it contains high amount of alkaloids which affects plants through changing soil nutrients and texture.Velvet leaf (*Abutilon theophrasti* Medic.) is affecting seed germination and seedling growth of radish,turnip,soybean and maize.leaf,stem and seeds of the plants were reported showing allelopathic activity due to their phenolic compounds. Crab grass (*Digitaria* species) was reported as major weed more than 30 countries. It is affecting nitrogen content of the soil or plant as it was inhibiting nitrogen fixing bacteria.It shows allelopathy towards kidneybean,wheat,sorghum,sunflower,tomato and pepper., *Argemone maxicana* L.inhibited seed germination of wheat,mustard and fenugreek and seedling growth of cucumber,pearlmillet,sorghum and tomato with leaf aqueous extract.,*Lantana camara* L.is listed in 10 worst weeds of the world as it has been reported as allelopathic to many crops in more than 40 countries.*Phalaris minor* Retz.showed major inhibition for wheat crop in India. It showed allelopathic effect to seedling growth of rice and nodule formation in roots of green gram, *Croton bonplandinum* Baill caused inhibition in rice,mustard and lettuce in many regions of India. *Commelina benghlensis* L. Inhibited seed germination and seedling growth of soybean,green gram,sunflower,groundnut and sorghum(Channappagoudar et al,2005).

Narwal has mentioned about manygenera having multiple species showing allelopathic effect over important crops including cereals,pulses and vegetables .Some of them are,many species of *Cyperus,* (*C.rotundus L.,C.esculantus L.,C.iria L.,C.seronitus L.),* Amaranthus (*A.spinosus L., A.virdis L., A.retroflexus L., A.tricolour L., A.palmeri (L.) Wats.), Setaria (S.faberii Herm.,S.glauca (L.)Beauv.,S.italica (L.)Beauv.,S.viridis (L.)Beauv.),Digera (D.alternifolia (*L.*)Ascher, D.aarvensis Forsk.,D.muricara (L.)Mart.),Euphorbia (E.escula* L.,*E.geniculata Ort.,E.granulata* L.,*E.heterophylla* L.*),Chenopodium (C.album* L.,*C.murale* L.*), Trichodesma (T.amplexicaule* Roth., *T. sedgwiichianum* Benerji*) etc.*The wide array shows how harmful effect weeds can produce to the crops and can reduce the agricultural production through out the world.

1.3.2. Synthetic Herbicides - Chemical solution to Weeds(World and India)

Detrimental effect of weeds over many crops has been estimated and reports are published by many agriculture institute world wide. According to Indian Council of agriculture Research report,crop loss in India due to weed is 33% which is the highest as compared to insect (26%) and other pathogens(20%). Highest yield loss occur in rice,maize,finger millet and jute because of weeds (ICAR,2011). There are several methods to control weeds which include plant breeding,seed control while sowing crop seeds ensuring crop seed purity,burning of the field after crop harvesting to destroy weed seeds present in the field. Combination of many crops to supress weeds by crop rotation and intercropping.Likewise, handweeding and using many mechanical tools to uproot weeds from the field has been utilized vastly especially, where easily labour is available. Most easy and effective method to control weeds is through chemical control (Alstrom,1996).

There are many synthetic herbicides developed to control weeds. Proper concentration and application of it was necessory to make it effective. Synthetic herbicides like Acetyl coenzyme A carboxylase (ACCase) inhibitors which kills grasses, The acetolactate synthase (ALS) inhibitors includes sulfonylureas, imidazolinones, triazolopyrimidines, pyrimidinyloxybenzoates, and sulfonylamino carbonyl triazolinones which affect grasses and dicot weeds,Glyphosate is a systemic herbicide, enol pyruvyl shikimate 3-phosphate synthase (EPSPS) inhibitor is activated by soil contact and is effective against both monocots and dicot weeds. 2, 4-D is a synthetic auxin herbicide.It is a broadleaf herbicide and most widely used herbicide in the world, and third most commonly used in the United States.

Aminopyralid,Clopyralid, Fluroxypyr, Picloram are broadleaf herbicides in the pyridine group and also a type of synthetic auxins, used to control weeds in grassland.

The Triazine herbicides (including atrazine) and urea derivatives (diuron) are photosystem I and II inhibitors that affects chlorophyll pigments and photosynthesis system of the weed plant and causing plant to suffer (Devine *et.al*.,1993)

Imazapyris used to control a broad range of weeds, including terrestrial annual and perennial grasses, broadleaf herbs, woody species, and riparian and emergent aquatic species.Use of synthetic herbicide for crop protection increased in mid-1970 and became general trend for all developed and developing countries like India,Vietnam,Korea and Thailand during the 1970’s. Over consumption of herbicides by farmers caused detrimental effect on environment and all living organisms including humans (Alstrom, 1996).

Continuous use of many herbicides made important weeds to develop resistance against it and become tolerant from susceptible variety(FAO,1970). Glyphophate-resistant weeds are present in the fields of soybean, cotton and corn farms in USA. Horseweed (*Conyza canadensis* (L.) Cronquist) is one of the weed that has developed glyphosate resistance (Marking, 2002). In earlier period,2,4,5-Trichlorophenoxyacetic acid (2,4,5-T) was a widely used broadleaf herbicide until the indirect effect of it was found out. The manufacturing process for 2,4,5-T contaminates this chemical with trace amounts of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). TCDD is extremely toxic to humans. 2, 4, 5-T was withdrawn from use in the USA in 1983.2, 4, 5-T has since largely been substituted by dicamba and triclopyr. During application of herbicides/ pesticides 98-95% of the content destined to other places and pollute air,water and soil. Most of the synthetic herbicides directly or indirectly contribute into environmental pollution,many diseases in humans including respiratory and cardiovascular disorders,diabetes,different type of cancers especially brain, lung, breast cancer.They affect the most to the newborn child or pregnant women, which are sensitive,lead to birth defects and develop skin problems. They also reducesurvival and reproductive ability in small mammals,birds and rodents. Excess use of these chemicals makes hazardous effect on biodiversity and population of healthy organisms. Impact of it can reduce immunity in vertebrates, dysfunction of thyroids,weak eggshells of birds, reproductive capacity of many invertebrates,birds and butterflies (AnithaKumari*et. al*, 2014). Current research is focusing more towards finding other alternatives of chemical herbicides to overcome such hazardous effect on environment(Avila-Adame*et. al*, 2008; Boyetchko, and Rosskopf, 2006).

Two important aspects as alternatives of chemicals herbicides are;

a)**Invention and use of bio herbicide**, which can be developed using any living microorganisms like bacteria, fungus, virus, or algae, are also biodegradable and environment friendly. More than 200 microorganisms or plant pathogens have been utilised to produce bio herbicides. Few of themwere successfully established in commercial market and registered as bio herbicides. Like Sarritor, developed by Canada in 2007 from pathogen *Sclerotinia minor*, was effective against Dandelion (*Taraxacum officinale*) in lawns/turf. USA also developed Smolderin 2005 from *Alternaria destruens* against a parasite Dodder (*Cuscuta* species) in agriculture,dry bogs & ornamental nurseries. Two more commercially available bioherbicides invented by Canada during 2004 are Chontrol™ / Ecoclear™ and Myco-Tech™ from *Chondrostereum purpureum* against forest weeds(Bellagard, 2008). Herbicidal properties were recognised from fungus like *Phomopsis*,*Alternaria*, *Dactylaria* and

Tobacco mild green mosaic tobamovirus(TMGMV) against weeds like *Amaranthus* spp, *Cuscuta,Cyprus* , and *Solanum viarum* respectively (Charuduttan,2005).

b) **To develop genetically modified crops** there are several genetically modified crops by introducing new genes, which make them resistance to herbicides. like, 1.a variety of Tobacco, which is tolerant to a bromoxymil, similarly many crop like wheat, soya bean, corn, rapeseed, canola, sugar beet etc. have been developed with many GM varieties against one of the most hazardous herbicide – Glyphosate. In rice, such activity has been extensively investigated. Over 10,000 rice lines have been screened for allelopathy, with the finding that 4% effectively suppress the growth of rice paddy weeds such as barnyard grass (Belz, 2007). There are number of potential allelochemicals in rice like phenolic acids, Fatty acids, terpenes and indols, of which diterpenoid momilactone are the most important one. Furthermore, the inducible nature of momilactone biosynthesis in rice (Cartwright *et al.*, 1977;Ren& West, 1992; Nojiri*et al.*, 1996; Kato-Noguchi *et al.*,2007) suggests that such induction also might be advantageous in promoting the endogenous ability of rice to suppress weed growth. Together, these potential applications provide significant agricultural relevance (Xu *et al.*, 2012).

1.3.3.Herbicides from natural products or plants.

Use of synthetic herbicides and pesticides are hazardous to the environment and responsible for polluting various natural resources like water, soil and also affecting humans and animal life cycle. Now a days awareness towards these pollutants has been increased, due to which research is focussed towards new findings on environmentally safe products as herbicides and weedicides. Herbicides can be produced from natural products which are biodegradable and safe for humans and animals. Usage of such products, offers many advantages like,

1. The plantproduce a wide amount of phytotoxic compounds having a complex chemical structure that can be discovered and extracted to make green herbicides. Many species specific chemicals can be derived from one complex compund to make species specific herbicide /pesticide product.

2. Herbicides produced from natural products will be biodegradable and will decrease soil, air and water pollution to a great extent.

3. Major registered herbicides are of halogenated hydrocarbons which is making major health hazards will be decreased after new findings of natural herbicides/plant herbicides. (Narwal, 2004)

Many plants or microbial chemicals have been utilized as bioherbicides now a day,of which few are *Closteridium, Alternaria,Colletotrichum,Fusarium,Xanthomonas* species utilised to develop many bioherbicides which are plant specific in their effect.(Hougland et al, 2007)There are many chemical inhibitors like Cinmethylin, which can be a good source for natural herbicides. It is a compound derivative of 1,4 –cineole obtained from *Eucalyptus*.(Cai and Gu,2016;Vishwakarma and Mittal,2014)

1.4. Weed managment through various means of allelopathy

Weed control refers to the actions used to achieve the immediate elimination of an existing weed population, usually through the use of herbicides and tillage, while Weed management goes beyond control of existing weed problems and focuses on reducing weed invasion and emergence, preventing weed reproduction, and minimizing weed competition with crops. Thus, while weed control reacts to problems after they occur, weed management emphasizes understanding the causes of weed problems with the goal of preventing weeds from becoming problematic in the first place (Smith *et.al.,* 2006). Allelopathy can play a significant role to control the growth and germination of weed plants and also some of the pest (Duke and Lydon, 1987).At present the new trend is to find an organic solution to lessen the noticeable hazardous impacts from synthetic pesticides in agriculture production. In this regards, the detrimental impact of allelopathy can be exploited for pest and weed control (Sodaeizadeh and Hosseini, 2012).*Cucurbita* spp. in Maxico was established for its allelopathic effect over some weeds present in the field of maize and beans to which it is not hazardous.Some non crop species showing allelopathic potential towards weeds and also stimulate the crop growth are encouraged by maxican farmers (Gliessman,1983). Similarly Putnam(1998) reported allelopathic effect of *Tagetes patula* on weeds present in maize field but not to the maize. He also observed many crops like sorghum,oat,soyabean,sunflowr and cucumber having weed supressing ability.Allelopathic potential of various plants can be utilized to control weeds in the form of dry leaf and stem mulch,rain and dew droplets through plant or through rhizospere effect (Rice ,1984). Plants which show allelopathic potential against weeds but are not harmful to the crops can be grown as companion crops or cover crops.

Legumes are utilised as cover crops as they are beneficial for crops with their nitrogen fixing ability and so no need for additional nitrogen based fertilizers. Some legumes also provide weed supression activity, such as *Pisum sativum, Trifolium spp., Vicia villlosa ,Medicago lupulina* are commonly used as cover crops in USA. Some cereal crops like black oat , rye, and wheat are also utilised for the same purpose as they have weed controllng potential.(Kelton *et al*,2005).An experiment showed that *Sorghum bicolor* and *S.sudans* as cover crops give maximum benefit reducing weeds in the barley crop field compared to hand weeding (Urbano et al,2006). Sweet corn cultivated with velvet bean (*Mucuna deeringiana*) and Jack bean (*Canavalia ensiformis*) gives more yield of corn crop when compared with herbicide and mechanical weeding(Caamal-maidonado *et al*,2001). Companion cropping system is also very useful to reduce density of weeds in the crop field establishing another crop's allelopathic activity on present weeds. Oats are proved as effective companion crop with alfa alfa as it reduces weeds. On the other hand it produces good feed for the milk producing animals, and also not affecting alfa alfa growth(Lanini et al,1992).

1.5 Allelochemicals

Allelochemicals are the chemicals which are produced by one plant or microbes and affect the other, they are mostly the secondary metabolites produced by plants which are by product of primary metabolism(Levin,1976).There are many metabolically active secondary chemicals produced by plants / microbes which play important role in various activities of the organisms they are produced(Waller and Dermer, 1981).It is expected that in the future many allelochemicals will play important role in developing natural pesticides and bioregulators. Secondary metabolites can affect neighboring plant by affecting soil moisture, temperature or microbial growth of the soil and other factors (Einhelling and Eckrich, 1984). They can affect in various forms, like volatile and water soluble compounds.A field research has shown that plant growth was affected due to release of allelochemicals from water based extract of leaf debris in soil environment and not due to reduction of present soil nutrients (Batish *et al.*, 2009)

These chemicals can be produced by different parts of the plant. According to Rice (1974) roots, stems, leaves, flowers, pollens, fruits along with seeds may produce allelochemicals, in which leaves are the most important source, whereas roots have least the amount of allelopathic potential (Sisodia and Siddiqui, 2010).Chemicals released from the donor plant can also be lethal for themselves sometimes. They are replenished in soil by living or dead plant tissues in the form of volatization from leaf, stem or leaf leachates by rainfall,dew or plant litter, root exudates and decomposition of dead plant residues (Grodzinsky, 1982; Rice, 1984; Putnam, 1985).

Secondary metabolites are produced via acetate or shikimic acid pathways which are linked with primary metabolic processes(Robinson, 1967). Many of these are classified as allelopathic agents and are divided by Rice (1974) in fourteen different chemical categories and Putnam (1985) in 11 classes:

1. Toxic gases
2. Coumarins
3. Organic acids and aldehydes
4. Flavonoids
5. Aromatic acids
6. Terpenoids and steroids
7. Simple unsaturated lactones
8. Quinones
9. Tannins
10. Alkaloids
11. Miscellaneous and unknown

Out of all these derivatives, phenolics and terpenoids are the most often reported allelochemicals (Mandava,1979; Robinson,1967). Although production of secondary metabolite, is in small quantities and many biotic and abiotic factors like radiation, temperature, water stress, age of plant, pathogenic attack, predators etc.affects its production (Rice, 1984). It is difficult to understand its mode of action due to complicated separation method from primary products, uncertainty in translating the effects in isolated enzymes and other biochemical system to intact plant, lack of understanding of the effects of allelopathic agents on all changes that occur due to photosynthesis (Mandava, 1985).

Contemporary research in allelopaty focuses on isolation,identifying and quantifying specific active allelochemicals. Specific chemical can be utilized as natural herbicide for few weeds . Much research has been carried out on several medicinal plants to see their potential as allelopathic plants(Fuji,Y.,2003).Medicinal plants have been used in one form or another under indigenous systems of medicine since time immortal. These plants are rich in secondary metabolites and through these metabolites they show their medicinal activity. These active components can be derived from any part of the plant like bark, leaves, flowers, seeds, etc (Crag and David,2001).Knowledge of the chemical constituents of plants is desirable because such information will be of value for the synthesis of complex chemical substances. Such phytochemical screening of various plants is reported by many workers (Siddiqui *et.al*,2009; Chitravadivu *et al.*,2009; Ashok kumar *et al.*,2010).Currently in India emphasis has been given in identification and evaluation of complete phytochemical studies of medicinal plants.Many plants were screened for secondary metabolites for their medicinal properties (Nandagopal and RanjithaKumari, 2007). Studies indicate that being rich source of secondary metabolites, medicinal plants can also be used as source of allelochemicals.

1.4. Need of the study:

Crops are being raised from time immemorial without damaging the environment. But the use of herbicides for weed control in agriculture, during last 50 years, has raised serious environmental questions. In this line allelopathic suppression of weed is receiving greater attention as a possible, natural and environment friendly alternative technique for weed management. It may prove to be a unique tool for weed management and thereby increase crop yield. Allelochemicals are secondary metabolites. Medicinal plants being rich source of secondary chemicals do show great allelopathic potential. There are numbers of other benefits in using medicinal plants as source of allelochemicals viz.

- Medicinal plants as Companion crop with food /cash crops can give double benefit to farmers.
- Secondary metabolites of medicinal plants can play dual role. i.e. as active principle and as allelochemicals.
- Medicinal plants' parts, which are not of medicinal value, can be assessed and utilized in weed suppression (if proven so), leading to multiple utility of the plant.

Inspite of having great allelopathic potential, their usage to supress weed growth cannot be generalized; more over care should be taken to avoid any harmful effect of selected medicinal plant on the respective crop. Much research has been done to explore allelopathic potential of a large number of medicinal plants, but little attention has been given to their impact on crops.

Present study was taken up with intention to fill up this lacuna to some extent. Legume crops, their associated weeds and few medicinal plants were selected for the study. The main objectives of the study were:

1.5. Objectives

1. To screen few medicinally important plants for their allelopathic effect on legumes and their associated weeds.
2. To select the combinations of allelopthic plant and crop. (with minimum inhibition)
3. To experiment the selected combination in field for weed suppression as companion crop / as mulch.
4. To assess the impact of allelopathy on quantity & quality of legume seed protein.
5. Chemical analysis of allelopathic plants parts which will be used
6. Chemical analysis of suppressed plant part to identify the allelochemicals and its uptake.