2 - REVIEW OF LITERATURE

In the words of F.C. Steward (1971) "Any subject or academic discipline has a heritage from the past, it is preoccupied with the problems of present, but its viability is inherent in all potentialities for the future. One should trace past to understand and analyze the present and on the basis extrapolate into the future". With this important perspective the review of available literature particularly related to physiology of angiosperm parasitic weed *Cuscuta* spp. (field dodder), its chemical control, undesirable use of chemical herbicides due to possible phytotoxic and residual health hazards and an insight of literature on possible role of allelochemical from higher plants in weed control and management is essential to understand and to interpret the results if present investigation. For the convenience of the study literature has been divided under various heads.

2:1- PHYSIOLOGY OF ANGIOSPERM PARASITE (*Cuscuta reflexa* Roxb.)

2:1-I. Seed Germination:

To germinate seed and its *in vitro* growing is the first and most important step in procuring the plant for any type of study. Kinzel as early as in 1901,1903 studied germination of *Cuscuta* spp. under various physiological conditions and reported that hard seed coat dormancy can be broken by treatment of concentrated sulfuric acid (chemical scarification)
leading to active germination and that seeds of *Cuscuta lupiliformis* can grow immediately after harvest and favorable conditions of temperature and moisture. Seed germination of different dodder species in relation to seed ripeness and seed size was studied (Mirande, 1901; Fulton, 1912). Various problems related to seed germination, particularly effects of storage conditions, seed ripeness, breaking of dormancy was investigated and described in comprehensive review of Gaertner, 1944, 1945, 1950). He described that seeds of *Cuscuta* has long viability and can germinate even immediately after harvest. He concluded that presoaking in concentrated sulfuric acid is a expedient method of breaking its dormancy, and found that optimum soaking period requirement for dodder seed germination varied according to age and species. Various aspects of seed dormancy, seed coat permeability and seed viability were also discussed (see also Kinzel, 1901, 1903, Fulton, 1912; Stewart, 1926; Porter and Catherine, 1936).

Seeds of *Cuscuta reflexa* and *Cuscuta planiflora* were germinated successfully in *in vitro* conditions to investigate morphogenetic changes during embryogenesis by Tiagi (1951), Tiagi and Johri (1952) and Maheshwari and Baldev (1962). Chemical scarification of *Cuscuta pentagona* and *C. indicora* seeds with concentrated $\text{H}_2\text{SO}_4$ followed by surface sterilization with 1.0 % NaOCl led to 75 – 85 % germination and subsequent initial growth and morphogenetic changes were influenced by varying spectral radiations (Zimmerman, 1962; Lane and Kasperbauer, 1963, 1965). Allard and Tngey (1964) studied *in vitro* germination of dodder seeds as influenced by different atmospheric conditions.

Brown (1965) in his review stated that seeds of angiosperm parasite eg. *Cuscuta* are peculiar in not being able to synthesize
stimulatory substances spontaneously in contrast to other seeds during course of germination. Truscott (1958, 1966) cultured seeds of *Cuscuta grovonii* in vitro on white's culture medium and studied germination and subsequent morphogenic changes as influenced by various growth regulatory factors. Rahman and Krishnan (1971) concluded that seeds of *Cuscuta* species contained sufficient nutrient reserve to initiate the germination under appropriate environmental conditions and to sustain early phase of non-parasitic existence of seedlings. The nature and amount of different nitrogen, phosphorus and carbohydrate compounds of *Cuscuta* seeds as reserve nutrient were analyzed to support the view.

Nand Kumar and Krishnan (1976) made detailed study of dodder seed metabolism to examine any deficiency in key enzymes during seed germination and early seedling growth. The enzymes maltase dehydrogenase, amylase and fructose 1,6 diphosphate aldolase were assayed, activity of which exceeded 5.0 uM substrate / minute / g. while those of starch phosphorylase, a-amylase, acid phosphatase, phosphogluconate dehydrogenase (de-carboxylating), aspartate aminotransferase and alanine aminotransferase fell within range of 1 – 5 uM min. g. The activity of hexokinase and isocitric dehydrogenase was below 1.0 uM substrate min. g. seed powder. Acid invertase, alkaline invertase, phytase and glutamic dehydrogenase (GDH) were not detected. The seeds of *Cuscuta compestris* and *C. indicora* were also tested for some of the above enzymes.

Seeds of *Cuscuta reflexa* Roxb. germinated well after treatment of concentrated H₂SO₄ and being surface sterilized by 1% NaOCl followed by thorough washing with distilled water on sterile culture medium and the germination was enhanced by forms of inorganic nitrogen
(KNO₃, (NH₄)₂SO₄, and NH₄NO₃) both in light and dark conditions (Srivastava and Chauhan, 1977; Chauhan, 1978). It was concluded that nitrate salts stimulated germination better than ammonium probably by increasing supply of organic nitrogen to developing embryo and as a result of their assimilation and increasing rate of respiration and energy supply in which nitrate may function as terminal oxidant (Srivastava and Chauhan, 1977).

Seeds of *Cuscuta reflexa* Roxb. collected from local forest overgrowing on *Adhatoda vasica* (Acanthaceae) host were grown under laboratory conditions to test its germinability as affected by natural inhibitors isolated from various higher plants species and different parts in order to investigate and characterize possible phytochemical factor that can be used for its control (Chauhan and Singh, 1988; Singh, 1988; Chauhan et al., 1989).

Kneepker et al. (1990) studied exostructural features of seeds of 12 species of dodder (*C. australis, C. pentagona, C. japonica, C. grovonii, C. compestris, C. chinensis, C. palastina, C. redicellata, C. planiflora* etc.) and germinated them to obtain mature plant so as to evolve identification technique for dodder seeds, as contaminant. Identification and subgeneric classification of twelve species of *Cuscuta* based on fine exo-structural features of seed as examined by SEM and germination techniques for obtaining mature seedlings was described by them.

2:1-II Seedling Growth of Dodder.

Some efforts have successfully been made to grow *Cuscuta* seedlings *in vitro* laboratory conditions so as to study its growth behaviour.
Tiagi (1951), Tiagi and Johri (1952), Maheshwari and Baldev (1962) described some important aspects of morphogenesis and embryo development. Zimmerman (1962) grew *Cuscuta pentagona* seedlings on white's culture medium under aseptic, controlled temperature and varying photoperiodic conditions. He observed influence of different spectral radiations on autotrophic seedling growth of *Cuscuta*. The far red radiations caused tight intercoiling of dodder stem within 24 hr. after initiation of treatment and this response to far-red light varied with the seedling age. Haustoria developed after 6-days of germination. Far-red radiations had photo-stimulatory effect on haustorial development and inter-twinning of dodder stem where as red light nullified far-red response. Inclusion of nitrogen source in culture medium influenced the chlorophyll synthesis and enhanced chlorophyll content.

Lane and Kasperbauer (1963, 1965) made significant observation on photomorphogenetic response of dodder (*Cuscuta indicora*) seedlings and concluded that growth, hook opening and inter-twinning of dodder seedlings may be attributed to the phytochrome action. A single saturating red irradiation caused hook opening and continuous white light irradiation accelerated the hook opening considerably. The hook opening and inter-twinning of dodder seedlings were found to be typically a phytochrome action. Hook opening was promoted by red light while twinning was inhibited by red light. An additional phytochrome mediated photoreaction referred to as high energy photoreaction (HER) was suggested to regulate these promoting and inhibitory responses. Red light induced hook opening but rate of opening was controlled by ‘HER’.

Truscott (1966) grew dodder seedlings autotrophically on *in vitro* culture and observed the growth of root segments from dormant seeds,
radicular segments from immature embryo, whole embryo and whole seedlings of *Cuscuta grovoni* in relation to various growth regulatory factors which were supplemented with white’s medium. No correlation could be noticed between application of growth regulators or their combination and pattern of development.

Detailed study of inorganic nitrogen assimilation and growth in autotrophically grown dodder (*Cuscuta reflexa* Roxb.) seedlings was done by Srivastava and Chauhan (1977), Chauhan and Srivastva (1979, 1980). Seedling growth was found to be considerably enhanced by nitrate salts both in light and dark and ammonium nitrate supported better growth in terms of seedling height, fresh weight, and dry weight.

2:1-III. Effect of parasitic overgrowth of dodder on the host plants

The parasitic overgrowth of dodder (*Cuscuta reflexa* Roxb.) results into considerable loss in yield and productivity of the host plants by decreasing its overall growth and altering metabolic efficiency of host plants. The parasite abstract substantial amount of organic nutrients from the host through haustoria and adversely effect the host metabolism. A comparative analysis of host and parasite tissues and different metabolic processes in them has been made to evaluate the extent of nutrient depletion from the host and the losses caused by parasite.

Cutter (1955) on the basis of anatomical studies, however, suggested that nitrogen content of *Cuscuta* seedlings was limited to cause pronounced development of mechanical tissue. Gill and Hawksworth (1961), Kretovitch et al. (1964), Greenham and Leonard (1965) studied
physiology of angiosperm parasite (*Cuscuta* spp) and concluded that parasite derive their nitrogen nutrition in the form organic nitrogen compounds only, from their host through haustorial organ in substantially higher amounts and cause appreciable loss to the host plant.

Bhattacharya (1969) presented evidence for bidirectional flow of inorganic nutrients of host and parasite during dodder infection particularly in relation to phosphate absorption and accumulation.

Misra and Saxena (1971a) determined nitrogen balance between host and parasite and analyzed total nitrogen and its forms (ie. Free amino acids, protamines, bound amino acids and amides) of the host and parasite. They concluded that one fourth of total nitrogen of host was abstracted by the parasite and that host plant suffered a loss of 19.1% in nitrogen as a result of dodder overgrowth. There was no difference in distribution of total free and bound amino acids between host and parasite. They could notice only quantitative difference in bound amino acids between host and parasite (Misra and Saxena, 1971a, 1971b, 1971c). It was suggested that infection and overgrowth of dodder on host influenced all these forms of nitrogen on quantitative basis in the host plant.

Singh (1971a, 1971b, 1972a, 1972b) studied starch and nucleic acid metabolism of the host and parasite (*Cuscuta* spp). There occurred a decrease in starch content of about 36, 26, and 50% in shoot and 67, 59, and 70% in root as a result of infection by *Cuscuta indicora, C. compestris*, and *C. reflexa* respectively. Phosphorylase activity was appreciably increased also as a result of infection of the parasite. Significance decrease in RNA and DNA with simultaneous increase in RNAase and DNAase activity in host plant was observed by infection of
these three parasitic species respectively. Setty (1971) observed the effect of parasitism of *Cuscuta* spp. on host infecting singly or in combination with other phanerogamic parasite. The significant changes in protein and phosphorus content of host and parasite was observed and loss due to infection under experimental conditions was assessed.

Kollman and Der (1972) observed a significant relationship between highly specialized plant parasite and its host and the nutrient transport. Infection of *Cuscuta* on *Petunia* species and *Centuria* species weakened the host plant as indicated by chlorotic symptoms on leaves and the host were killed by massive dodder overgrowth (Wang, 1974). Area of *Petunia* stem penetrated by haustoria become brown with an irregular diffused margin.

Some other metabolic aspects of *Cuscuta* spp so as assess losses due to its infection viz., isolation of inorganic poly-phosphatase from *Cuscuta reflexa* Roxb (Tewari and Singh, 1964), analysis of carotenoid pigment of *Cuscuta* spp. (Machiny, 1968), carbohydrate metabolism of *Cuscuta* (Singh et al., 1970), nuclease activity in *Cuscuta* (Singh and Krishnan, 1971), saccharide content (Munteanu, 1972) Choline kinase activity (Setty and Krishnan, 1972), threonine dehydrogenase activity (Pandey and Tewari, 1976) and the effect of shading and dodder infection on content of alfa-alfa phenolics (Khanna et al., 1976) were also studied.

Tosh et al., (1977) reported that dodder (*Cuscuta chinensis Damk*) draws nutrients from the host for substance and provide a dense barrier which drastically reduces the growth and vigour of the host plant and brings down the grain yield by 50%.
Arkhipova (1987) studied some cyto-physiochemical characteristics of the host resistance of the host to parasite. He observed that infection of *Cuscuta compestris* influence various vital activities of host plant and change the protein exchange and related metabolic reactions. It was also stated that restorative ability in parasite infected host plant is related to cellular and metabolic disturbances induced by the parasite.

Sarik et al. (1991) observed relationship between mineral nutrient level of the host and parasite using five *Pelargonium* cultivars infected with *Cuscuta reflexa* Roxb. in green house conditions, to assess the influence of cultivars on mineral element concentration in the parasite tissues. They noticed higher nitrogen concentration in *Pelargonium* leaf than dodder and less concentration of it in *Pelargonium* stem than the parasite. Levels of ‘P’ and ‘K’ were higher in dodder tissue than host plant parts. Concentration of Ca and Mg was extremely low in dodder.

Debock and Fir (1992) investigated effect of abscisic acid (ABA) on sucrose transport from host (*Pelargonium zonale* L) to phanerogamic parasite (*Cuscuta reflexa* Roxb.). ABA was found to be transported from host leaf peteole to attached parasite shoot and that ABA uptake strongly depended on pH. In *Cuscuta* ABA hormone enhanced uptake and decreases eflux of sucrose. ABA was found to have a central role in the host parasite relationship by enhancing sucrose transport.

Frolisek and Novotny (1992) studied host parasite relationship between *Cuscuta epithymum* Yunker. And its host *Madinago sativa*. They analyzed protein and amino acids in the various parts of infected and un-infected host plant as well as the parasite. There was no difference in
total bound amino acid between defoliated stem of *M. sativa* (host) and dodder stem (parasite) with sporadic flowers. At full bloom stage dodder stem had significantly higher content of total amino acids, but, however, flowers contained lower levels of total amino acids than stems. The total bound amino acid was noted to be markedly lower in dodder than host plant (decrease being 30 – 50 %). Variation of various different individual bound amino acid and free amino acid were also analyzed in the host and parasite plant. The more pronounced difference were observed between dodder and its host plant. The role of bound and free amino acids in metabolism of parasite plant was described. They suggested possible hypothesis for effective dodder control through comparative chemical composition of host and parasite.

Michael and Witte (1993) investigated and observed distribution of 20 quinolizidine alkaloids in *Genesta acanthoclada* and its holoparasite *Cuscuta palaestina*. These alkaloid have been considered to be antiherbivoral chemical defense compounds in *G. acanthoclada*. It was assumed that the parasite could exploit the acquired allelochemical for its own protection.

Boumel et al (1993) investigated and studied the uptake and transport of quinolizidine alkaloid in *Cuscuta reflexa* parasitising on *Lupinus angustifolius*. The level of these alkaloids were found to be considerably higher in haustorial region of *Cuscuta reflexa* and that level was significantly reduced in distant apical parts of the parasite plant. The alkaloid profile shown a decline of alkaloid concentration from 11 mg / g. dry weight in haustorial region to 0.2 mg / g. dry weight in the apex of *C. reflexa*. Analysis of xylem sap and phloem exudate of host plant (*L. angustifolius*) suggested uptake of such alkaloids by *C. reflexa* was
mainly through the phloem. Boumel (1994) made further advance in the study and observed transfer of quinolizidine alkaloids from various host plant of fabaceae to parasitising Cuscuta species. Thirty four quinolizidine alkaloids representing spartein type as well as pyridine type were detected in host plants, out of which 26 alkaloids were found to accumulate in C. reflexa and C. platyloba. Major alkaloid pattern was similar in haustorial region of Cuscuta and respective legume host plant. A quantitative difference was observed in C. reflexa and its host Chamaecystis hersutus. The results indicated that alkaloid uptake and transport within the parasite was independent of the respective Cuscuta species. They (1995) extended the studies related to modeling of quinolizidine alkaloid net flow between host and parasite. New insights into the site of quinolizidine alkaloid synthesis were made. Net flow of alkaloid between host and parasite were measured in the transport fluid in terms of alkaloid nitrogen : total nitrogen. It was concluded that quinolizidine alkaloid are synthesized in the root of host plant and transported to apical shoot part through xylem. Parasitism by Cuscuta caused decline in alkaloid content in the host up to 53% and substantial amount of it abstracted by the parasite. Results of the study indicated that dodder infection resulted in restriction in catabolic processes within host plant. A massive shift in nitrogen metabolism and establishment of potential sink for nitrogenous compounds in the parasite (C. reflexa). By analogy to nitrogen flows, alkaloid transport from host to parasite involved xylem-phloem transport system

Huang et al. (1993) performed analysis of amino acid in Cuscuta, Orobanche and Casytha. The results showed that seed and shoot of these genera contained more than 15 amino acids which were also necessary for
human beings. Medicinal function of the amino acids and there application to seed identification as well as chaemotaxonomy were discussed.

Lee (1993) observed cellular compatibility in the self parasitising _Cuscuta australis_ R.Brown at ultra structural level. He studied mode of haustorial penetration and its invaded hyphal growth within host tissue and suggested that the compatibility response in self parasitism of _Cuscuta_ were expressed by cell wall ultra-structure of host and parasite.

The function of calcium and calmodulin in inducing initiation of haustoria in dodder with cytokinin were investigated by Huang and Li-Yang-Ham (1994). They emphasized the important role of calcium and calmodulin as second messenger in the regulation of haustorial development. The cells of haustorial primordia are rich in calmodulin. In addition tropism of haustorium towards its host was observed. It was considered that tropism may also be related to calcium and calmodulin level.

A new coplement inhibitory factor (CIF) was isolated from seeds of _Cuscuta europia_ and characterized as glyco-protein with molecular weight between 27000 and 28000 daltons and containing single polypeptide chain (Zheleo et al 1994).

Sadhana Srivastava et al, (1994) isolated two multiple forms of protein methyl esterase (PME) ‘A’ and ‘B’ having molecular weight 60,000 daltons, as a monomeric protein. Isoelectric point of both forms ‘A’ and ‘B’ was found to be 9.8 and 8.2 respectively. The Km of PME-A and PME-B proteins were recorded as 0.588 g/l and 0.016 g/l respectively. ‘Ka’ values of PME-A and PME-B for Mg was noted as 0.117 mM and 0.89 mM respectively. It was observed that the presence of 5.0 mM NaCl
in the assay mixture favored activity of PME-B. They (1995) further extended studies on purification and characterization of starch phosphorylase (EC 2.4.1.1) from the filament of _Cuscuta reflexa_. Unlike other starch phosphorylase the present enzyme isolate and purified from angiosperm parasite was not inhibited by aromatic amino acids. Mechanism of action of the enzyme was also studied and energy of activation required for enzyme activity was measured.

Yahara _et al_ (1994) investigated a new tryptophan derivative alkaloid and two lignans (A and B) from _Cuscuta chinensis_ along with four known flavonoids. The impotence of these secondary metabolites were discussed. Loeffler _et al_ (1995) analyzed soluble phenolic constituents from _C. reflexa_ and _C. platyloba_. _C. reflexa_ contained mainly caffeic acid and depsides where as _C. platyloba_ was characterized by accumulation of flavonoids of flavonol type. The phenolic pattern proved to stable in both the species irrespective of different host plant. Marked differences were noticed in concentration of phenolic compounds between haustorial region and meristematic apex of parasite plant, and that was correlated with phenyl alanine lyase (PLA) activity in respective parasite plant segments.

Furuhashi (1995) studied photo- control of parasitism in phanerogam parasite _C japonica_ Chois cultured _in vitro_ and found that far red light induced mutual and self parasitism, blue light was less effective than far red although it stimulated mutual twining of stems. No such parasitism was observed under white or red light or in dark conditions.

Misra and Sanwal (1995) investigated changes in lipid composition of _Brassica compestris_ siliquae as affected by infection of
Cuscuta. Infection of B. compestris c.v. Sarson-T-42 by Cuscuta initiated at 24 days after sowing was more effective than that initiated at later stage of the host plant. Results indicated that about 83% increase in natural lipids (pigments and fatty acids) and a decrease in glyco-lipids and phospho lipid contents by 19% and 24% respectively in siliquae chloroplast of B. compestris. At 62 days after sowing chlorophyll content of siliqua-chloroplast decreased by 21,18, and 15% when infection by Cuscuta was initiated at 24,31 and 38 days after sowing. Carotenoid content was significantly increased upon infection. Marked changes were also notices in saturated and unsaturated fatty acids, caused by dodder infection. It was suggested that severity of damage induced by Cuscuta to rape siliquae was dependent on the developmental stage of the host plant at the time of infection.

Debick et al (1995) studied sucrose exchange characteristics at level of contact between a host (Pelargonium zonale L. Aiton) and a parasite (Cuscuta reflexa Roxb. as affected by fusicolcin. Fusicolcin stimulated ATPase in plasma membrane and increase of oxygen consumption. It inhibited sucrose uptake by 30 – 50% and enhanced by 42 – 47% sucrose release. Physiology of parasite association and role of fusicolcin isolated from Cuscuta haustoria, in sucrose exchange between host and parasite was discussed.

2:1-IV Metabolic studies in autotrophically grown dodder seedlings

In addition to studies on seed germination and in vitro cultured seedling growth of angiosperm parasite Cuscuta spp described in part 2:1-I
and 2:1-II, some metabolic studies have also been made in autotrophically grown seedlings of the parasite plant under laboratory conditions on synthetic media supplemented with appropriate nutrients. Rahman and Krishnan (1972) concluded that seed of *Cuscuta* germinate autotrophically and early seedling growth initiate at the expense of reserve nutrients of seeds prior to its access to suitable host. Zimmerman (1962) first studied autotrophic growth of *Cuscuta* on white’s culture medium under aseptic conditions and noted substantial amount of chlorophyll pigment when the medium was supplemented with nitrogen source. Dodder has feeble rate of photosynthesis and possess photosynthetic pigments (Chlorophyll and carotenoids) (Zimmerman, 1962; Pette et al., 1965; Machinny, 1968; Chauhan and Srivastava, 1977). The potential ability of inorganic nitrogen assimilation and efficacy of different forms of inorganic nitrogenous salts into organic nitrogen composition in autotrophically grown dodder (*Cuscuta reflexa* Roxb.) seedlings was first investigated and evidenced by Srivastava and Chauhan (1977), Chauhan and Srivastava (1979, 1980). Application of inorganic nitrogenous salts increased organic nitrogen content of seedlings and nitrate salts were found to be assimilated at higher rates than ammonium and that maximum increase was observed with simultaneous supply of ammonium and nitrate salts together. Total free and bound amino acids, protein content, RNA and DNA content I autotrophically grown seedlings increased significantly by exogenous supply of nitrogenous salts in culture medium. Potassium nitrate supported maximum increase. Similar results were obtained with chlorophyll and carotenoid content in dodder seedlings as influenced by various forms of nitrogenous salts. Significant inducibility of key assimilatory enzyme nitrate reductase (N R) in seedlings of angiosperm
parasite *Cuscuta reflexa* Roxb. was evidenced. These results indicated that this parasite could grow autotrophically and have ability of inorganic nitrogen assimilation under laboratory conditions similar to other autotrophs.

Panda and Chaudhary (1992) investigated the effect of nutrients and irradiance on chlorophyll content and Hill reaction activity in *Cuscuta reflexa* Roxb. They found five folds increase in chlorophyll content and carotenoid content by irradiance of 6 W m. Hill reaction was more in field growing samples than grown in laboratory conditions. The photosynthetic efficiency was negligible in seedlings of autotrophically grown seedlings under laboratory conditions. It was suggested that the parasite plant were not able to utilize the nutrients from culture medium efficiently for their growth maintenance and metabolic activities.

However, in nature *Cuscuta* spp. Grow as obligate partial stem parasite. Cytogenetic studies indicated that parasitic nature of the plant is secondary and derived characteristic. The biochemical parameter and genetic basis involved in obligatory requirement of parasitism of *Cuscuta* in the nature is still not clear and need more study and insight of the problem. The parasite cause much more damage to economically important crops and other plants to a great extent and its effective control has been a great task.

### 2:2 STUDY ON WEED CONTROL

#### 2:2-1 Chemical weed control and use of herbicides

Weed infestation seriously limit crop productivity and growth and yield of wide range of economically important plants. Besides manual,
mechanical and biological methods, chemical method of weed control have been devised. Discovery of many organic herbicides in past few decades enabled significant progress in weed control management. The subject has been reviewed elsewhere in detail (Hilton et al., 1963; Klingman, 1973; Hay, 1974; Crafts, 1975; Boger and Veltor, 1978; Rizvi, 1980; Ganstad, 1982; Rao, 1983). The review of literature is limited to include the aspects related to present investigation.

The history of chemical weed control may be traced back from accidental discovery of selective activity of copper salts on broad leaf weeds in cereal crops during their trial on fungal diseases (Bolly, 1908) and their application in weed control (Schultz, 1909; Rabate, 1911; Morettini, 1915; and corsmo, 1932). Discovery of selective herbicide 2,4-D revolutionized the agriculture through weed control (Marth and Micheil, 1944; Hammer and Tukey, 1944). The concept of chemical control of weed by the herbicides was established by commercial production of 2,4-D and MCPA in 1957 (Hay, 1974; Freed, 1980).

Much work has been done to assess the losses due to weed in agricultural productivity in India (Luthra, 1921; Kumar, 1940; Joshi and Mehta, 1965; and Joshi, 1974) and abroad (Cramer, 1967; Furtic, 1967, 1970; Klingman, 1973; Allkamper, 1977). These losses rendered by weed may be attributed to the various causes such as competition with crop plants for water (Korsmo, 1930; Kurth, 1974; Alkamper, 1977) and nutrients (Kiessling, 1963; Christiansen Weniger, 1970; Kurth, 1974; Mani, 1975), detrimental phytotoxic effects on crops (Davis, 1928; Martin and radimaacher, 1960; Grummer and Boyer, 1960; Ohman and Comendahl, 1960; Bell and Koepe, 1972; Dubey, 1973; Rice, 1974), added protection cost from insects and diseases (Hanuss, 1973; Klingman, 1973;
Rice, 1974). The use of herbicide (e.g., 2,4-D) control weed and prevent the loss of productivity (Chandler, 1969; Furtic, 1970; Drozdov, 1974; Rice, 1974; Joshi, 1974 etc.). Hay (1974) reviewed importance of herbicide in weed control and management of agricultural productivity. Herbicides either alone or in combination with mechanical or manual methods provide best weed control results and considerable increase in crop yield can be achieved.

Lange et al. (1973) found increased yield resulting from herbicide use over manual methods in various crop plants. Rao (1983) described the beneficial role of chemical herbicides in agriculture. A large number of chemical compounds have been characterized as herbicides that can be used for weed control in selective or nonselective manner (Sistachs and Leon, 1973; Gruzdev and Boreznikov, 1974; Pawlowski et al., 1975). Wejnar Reinholt (1989) studied the effect of ‘diuron’ herbicide on photosynthetic pigments of *Lemna gibba* L. The herbicide caused bleaching effect and considerable decrease in photosynthetic pigments including both chlorophyll and carotenoids. Bleaching caused by diuron due to reduction of these pigments resulted in marked inhibition of growth. Work on testing of new herbicidal chemical is still in progress and use of such chemical particularly in control of dodder (test plant) need further review.

**2:2-II Chemical control of dodder overgrowth**

Successful attempt have been made to control dodder emergence and overgrowth under field condition using various synthetic herbicides. Dawson (1969) claimed dodder emergence in both field and greenhouse
conditions by treatment of chloropham (Iso-propyl-m-chlorocarbanilate). Its longevity was increased by including para-chlorophenyl-carbamate (@1.5 lb./ha.). The herbicide 2,6-dichlorobenzonitrile applied to soil at 2.0 lb./acre controlled dodder in alfa-alfa (Dawson, 1970). Dawson (1971a) found that chloropham (@6 lb/acre) controlled dodder (C. compestris and C. indicora) effectively without injury to alfa-alfa crop. DCPA also controlled dodder but injured alfa-alfa seedlings severely. Dawson (1971b) further observed dodder controlin alfa-alfa with Dinoseb and D(-)(3-chlorophenyl carbamoxyl oxy)-2N isopropyl propionamide (R.P. 11755). It was noticed to be better than chloropham (6 lb./acre). Effectiveness of dinoseb (2-sec. 4,6-dinitrophenol) was found similar to chloropham. Tosh and Pato (1975) was able to control dodder (C. chinensis Damk) in niger (Guizotia abyssinica L.) with chloropham at 4.0 kg./ha. applied on the day following the initiation of germination without damaging the crop. Tosh et al (1977) further reported that pre-emergence application of chloropham applied at 4 kg./ha. to moist soil, 6 days after sowing niger (G. abyssinica L) controlled Cuscuta most effectively without damaging the crop seedlings. Lolas (1987) used two fumigants with seven herbicides to control dodder and other weeds in tobacco fields. He observed that plant bed fumigation was necessary to make the effectiveness of herbicides for the control of dodder and production of tobacco seedlings.

The effect of chlorthal (2,3,5,6-tetrachloro teriopathologic acid) on growth and development of Cuscuta lupiliformis Krocher. Have been examined (Agev et al, 1988). Chlorthal treatment caused reduction mitotic indices of meristemetic cells along with transient blocking of mitosis. The effect was similar to those observed with colchicine. After 15
days of herbicidal application the meristematic apex and underlying zones exhibited and induced rapid arrest of the growth of young dodder.

Bewick et al (1988a) evolved a degree day model for predicting emergence of dodder and found the use of low temperature threshold (LTT) at 3.3°C or 0°C had a better fit predictor for dodder emergence and maximum dodder sensitivity thereby increasing herbicide efficacy. They (1988b) further made 3 Yr. Field study using herbicide iso-propylamine salt of glyphosate (1.7 kg./ha.) and sulphosate (trimethyl sulphonium salt of N-phosphomethyl glycene) and reported satisfactory control of swamp dodder *Cuscuta grovoni* Willd. Ex R.) in carrot (*Daucus carota*). None of these herbicides caused any decrease in corn berry yield, but increased yield of carrot root.

Effectiveness of glyphosate was tested in alfa-alfa when dodder parasitically well established and was found to control dodder selectively. Control was best when herbicide was applied while alfa-alfa were grown 20-30 cm. tall and length of dodder shoots was 30-60 cm. (both host and parasite growing vegetatively and vigorously.) (Dawson, 1988a, 1988b) He observed that glyphosate and SC 0224 had similar response and may be used for dodder control in field. The proper time application was found necessary for effective control of *Cuscuta indicora* and *C.compestris* by the use of Peri di-methalin and prodiamine herbicides. In the field trifluralin (at2.2 kg. Ai/ha.) also controlled dodder satisfactorily. Chloropropham (6.7 kg. Ai/ha.) controlled 97 to100% of dodder but control did not persist through June. Peridimethalin and prodiamine at 3.4 and 6.7 kg ai/ha, controlled dodder but did not effect yield and quality of alfa-alfa seeds. Dawson (1990b) studied control in newly seeded alfa-alfa with glyphosate and found that glyphosate sprayed over the top at 75 and
150g. ai /ha stoped the growth of alfa-alfa without any significant injury of crop. Some what similar results were also observed with glyphosate and SC-0224 ( Dawson,1990 e). Dawson,1992 extended studies on response of alfa-alfa grown for seed production to glyphosate and SC-0224 and found that herbicide applied at rate that control dodder injured flower, cause flower to abscise and reduce yield when applied to alfa-alfa at flowering stage.

Liu and Fir (1990) studied effect of parasite infestation on redistribution of synthetic herbicides applied on a legume crop (Phaseolus aureus). Liu et al. (1991a) studied dodder control by three herbicides pendimethalin {N-(1-ethyl propyl 3-4-dimethyl-2,6 dinitro benzamine)}, propazamide{3,5-dichloro(N-1 dimethyl-2-propionyl)benzamide}) and Linuron [3,4-(dichlorophenyl)-N-Methoxy-N-methyl urea]. Pendimethalin and propazamide exerted mito-depressive and mito-classic action inhibiting cell division blocking cell cycle and mitotic indices. It results in radial hypertrophy in apical zone of stem. Treated seedlings become unable to attach the host. Linuron was also found to block growth of dodder seedlings showing only mito-depressive effect blocking cell cycle at interphase. These herbicides were recommended for dodder control in legume crops, Some what similar results were obtained with another herbicide Imazaquin, a promising herbicide for control of dodder in legume crops (Liu et al.,1991b).

2:2-III Hazards of synthetic herbicide chemicals

(a)- Phytotoxic effect
There is increasing concern and apprehension about potential hazards of indiscriminate use of agro-chemicals (eg. Pesticides and herbicides). All such synthetic chemicals used in insect pest control and weed control leave significant level of residues in soil and edible parts of plants which are harmful to plants, animals and human health. Although herbicides are less hazardous than other pesticides (Rao, 1983; Gansted, 1982; Gruzdev, 1982) their indiscriminate application led to considerable harmful effect to mankind in many ways.

Herbicides exhibit phytotoxic effect and adversely affect plant growth and metabolism. Andriska and Gimesi (1975) reported inhibition of maize seed germination as that about 95% germinated seeds were destroyed after herbicide treatment. Inhibition of seed germination by MCBP, 2,4-D (sodium salt) and 2,4-D (amine salt) in lucerne seeds was noted by Lakshmi et al. (1876). Similar inhibitory effect of paraquat on seed germination of *Trifolium repense* (Segura et al., 1977) and that of 'amiben' and 'troflan' on germination of soya bean (Ciorlaus, 1977) were also noticed. Besides germination, herbicides also adversely influenced growth of many crop plants. Dinitramine and trifluralin inhibited root growth (Harvey, 1973). Glycophosphate and paraquat inhibit root growth of *Trifolium repense* and *Festuca pratensis* (Segura et al., 1977) and over all growth of broad bean was reduced by Linuron and nitrakin treatment (Ibrahim et al., 1977).

Herbicides also exhibit harmful phytotoxic effects by altering metabolic efficiency of crop plants decreasing its yield and poductivity. Considerable decrease in chlorophyll content and synthesis by HOE-22870 and HOE-23408 in corn and by atrazine, 3,4-dichloro propionallide, EPTC and 2,4-D at 2 kg./ha each in rice was observed (Koecher and
Loetzsch, 1975; Rajoo, 1977). Similar decrease in chlorophyll content an
gram citrus seedlings after herbicide treatment also observed (Purohit et

Net photosynthesis rate was found to be inhibited by Simeton,
Diuron, (Van-Leewen and Van-Oorchot, 1976) Triazine derivatives were
found to inhibit photosynthesis by about 50% in Scenedesmus
quadricauda and Chlorella vulgaris (Simona and Mariora, 1976). Some
phenyl urea herbicides inhibited photosynthesis in Caribo and Menella
varieties of wheat (Van-Leewen and Van-Oorchot, 1976). Similar results
were also noticed with monuron, atrazine and simazine respectively (Sbarma et al., 1977) Rajoo (1977) reported reduced photosynthate (carbohydrate) in paddy with treatment of EPTC. Inhibition of respiratory
metabolism of non-target crop plants by herbicides was also noticed
(Thompson et al., 1974; Koecher and Loetzsch, 1975).

Inhibition of biological nitrogen fixation (Kruglov et al., 1975; Davies and Marsh, 1977), of nitrogen assimilatory enzymes (Klepper, 1974); Finke et al., 1977) and decrease in total nitrogen content and protein content (Ibrahim et al., 1977) as well as tillering in barley (Samosov and Prischepa, 1978) was observed in various studies. Decrease in protein content in oat after treatment phenoxy herbicides in Canthus
setigerus was noticed (Skuterud, 1976; Baur et al., 1977). Again similar
results were obtained with metaphos and phosalone which decreased
protein content in tillering of barley (Samerov and Prischepa, 1978). Many
herbicides are known to inhibit nodulation and consequently nitrogen and
protein content in leguminous crop plants (Kruglov et al., 1875).
Besides protection of crop from weed most herbicides themselves reduce yield and productivity in crop plants (Benada, 1975; Skuterud, 1976; Arle and Hamilton, 1976; Hatfield, 1978). For more informations regarding phyto-toxic effect of herbicides studies of Brejcha (1972), Rola and Pioszynski (1974), Stecko and Svensson (1976), Smitt (1977) and Wolf (1977) are worth to refer.

For the past several decades, use of synthetic chemicals as pesticides and herbicides for insect pest and weed management was encouraged by agricultural scientists in order to get more productivity and profitability. But during the past few years evidence has been accumulating that long term and intensive use of these chemicals threatens the agriculture to sustain production in future. Use of synthetic chemicals is now linked to a variety of “on and off” farm and environmental problems (see Jackson et al., 1984; Stinner and House, 1987; Allen and Van-Dusen, 1988).

(b)- Residual effect

Herbicides being non-biodegradable leave substantial amount of residue in edible plant parts and in the soil which in turn cause harmful effect to the consumers and to the successive crop productivity respectively. Effect of herbicide residue on successive crop was observed by many workers (Sistachs and Leon, 1973; Sheriff et al., 1973; Giardini and Geovanardi, 1974; Rao et al., 1978).

Residue up to 20.6 52.5 % of picloram applied at 1.5 to 3.0 kg / ha were found even after a period of three years. Residue of Dicamba
persisted in soil for more than six months where as about 50% residue of 2,3,6-TB were found after 12 months of application (Berezovskii, 1974). Similar residual effects observed by Wang et al., (1977) with atrazine and simazine herbicides respectively.

(c)- Hazards to animals and human beings

Herbicide residues in edible plant parts cause adverse effect on animals and human health. Herbicide that inhibit energy metabolism in weeds are more toxic to animals and fishes than those inhibiting photosynthesis (Matsunaka, 1973). Bankowska (1973) reported liver damage in rats from rupture of smooth endoplasmic reticulum after oral feeding of diuron, linuron and chlorotoluron at 1/10 of LD 50. Severe injuries to liver, nervous system and other internal organs causing malignancy or even death was observed by Axelsson and Sundell (1974). Herbicide residues exhibit carcinogenic effect in many cases (Epstein, 1967). The experimental investigations showed significant increase in tumor incidence and mortality among workers exposed to aminol, 2,4-D, 2,4,5-T respectively (Axelson and Sndell, 1974). Hays (1976) reported 17 deaths in USA caused by exposure or non-intestinal inhalation of herbicides. Herbicides are also known to cause pollutive (Matsunaka and Kuwatsuka, 1975; Purohit, 1977), mutagenic (Murnk and Nash, 1977) and teratogenic (Matsunaka, 1973; Javorska, 1978) effects as well as synergistic toxicity by interaction of herbicides with one another or with other pesticides (Samersov and Prischepa, 1978).
It was noted that less toxic herbicides after their degradation transform some times in more harmful and highly toxic products and are found as toxic impurities (Matsunaka, 1973). Cited references include only selective examples of harmful effects of synthetic chemicals used as herbicides. Much work is in progress and it has been realized that such chemicals solve less problems than they create and must be discouraged. It is essential to evolve alternative way of weed control through less toxic or non-toxic natural products for safe and sustainable crop productivity.

2:3 Natural Plant Growth Inhibitors: Role of Allelochemicals in Weed Control

There is growing evidence for the occurrence of natural plant inhibitors and production of phyto-toxic substances by plant themselves which may be used as natural herbicides for weed control management. Natural inhibitors (allelochemicals) are secondary metabolites that play important role in plant-plant, plant-microbe and plant-insect interaction both beneficially and detrimentally. The phenomenon of such interaction is known as allelopathy (Rao, 1983; Waller and Chou, 1989; Klocke and Barnbey, 1989; Harborne, 1986; Putman and Tang, 1986). Rice (1974) stated that allelopathic effects depends upon chemical compounds being added to environment by allelopathic agent (plants). Allelopathic chemicals act as ecological factors and have marked effect on plant dominance, succession, climax vegetation and crop productivity. Many international symposia related to this subject has been held in many countries since 1982. Such international seminars held at Academia Sinica
Taipai ROC with support of National Science Foundation of USA and National Council Of Republic Of China (ROC) in 1988-1989 which made real emphasis on possible role of allelochemicals in agriculture particularly including weed control management. It is now obvious that development of more environmentally safe herbicides based on natural products is of great practical importance. Use of allelopathy and natural inhibitors in weed management may reduce use of synthetic hazardous herbicides and pesticides, cause less pollution and diminish autotoxicity hazards.

The allelochemicals may be released to the environment from plants by means of volatilization, leaching, root exudates and decomposition of plant residues in soil (Chou, 1989). The substances can suppress seed germination and growth by inhibiting many metabolic activities including photosynthesis, respiration, transpiration and by inhibition of biochemical activity. Rice (1984) stated that soil sickness problem in agriculture might be due to exudate of plants. Molish as early as in 1937 reported that allelopathic interaction of plant is due to inhibitory effect of one plant on another by means of chemical products added into the environment. Real emphasis on allelopathic research as related to agricultural productivity was initiated in first half of twentieth century (Bode, 1940; Borner, 1960; Evanari, 1949; Havis and Gilkeson, 1947; Patrick, 1955). Muller (1966) found *Salvia leucophylla* releases toxic substances (monoterpenoids) which suppress the growth of many plants nearby, resulting in formation of bare area.

These allelochemicals (natural inhibitors) can be classified into two major groups – germination inhibitors and growth inhibitors respectively.
Natural germination inhibitors are extremely numerous which exhibit great variation in their chemical nature (see Evanari, 1949; Audus, 1972; Chou, 1989). Aqueous extract of binweed (Convulvulus arvensis) and Canada thistle (Cirsium arvense) inhibited seed germination and growth of seedlings in many crops (Helgeson and Konzak, 1950). Grassel and Holm (1964) investigated the inhibitory effect of aqueous extract of some weed seeds (Amaranthus retroflexus, Abutelon sanguinalis, Echinochloa crusgialis, Polygonum pensylvanicum, Portulaca oleracea etc.) on seed germination of different crop species.

A widely distributed substance caumarin and its derivatives are highly effective as germination inhibitors (Spath, 1937; Lerner, et al., 1959). Various phenolics viz. 4-hydroxy cinnamic acid, 4-hydroxy 3-methoxy cinnamic acid (ferulic acid), 4-hydroxy benzoic acid etc. were analyzed from sugar beet (Raubaix and Lazar, 1957), flash of strasberry fruits, lemon and apricot (Vorga, 1957) and tomato (Akrman and Voldstra, 1947) which are potential germination inhibitors like caumarins.

A group of closely related compounds is phthalides which inhibit germination of many umbelliferous seeds for example n-butylidine hexa hydroxy phthalide (Moews and Schader, 1951). A potent germination inhibitor of sugarbeet has been identified as cis-4-cyclohexine1,2-dicarboxymide (Mitchell and Tolbert, 1968).

Other results revealed seed germination inhibition by some natural organic acids such as citric acid and malic acid (Akerman and Voldstra, 1947), acetic acid, butaric acid, phenyl acetic acid and vanillic
acid (Cook and Pollock, 1954) and p-hydroxybenzoic acid and vanillic acid (Grummer and Boyer, 1972).

Essential oils (Weintraub and Price, 1948; Audus, 1972) and alkaloids (Americo, 1932) were also found to inhibit germination of seeds in some plant species. Significant suppression of radicle growth by aqueous extract of *Miscanthus floridulus* (Chou and Chung, 1974) and high phytotoxic activity by leachates of *Digitaria decumbens* (Liang et al., 1983) was reported.

A natural growth inhibitor called ‘Juglone’ (5-hydroxy a-naphthoquinone) from *Juglans nigra* was reported as powerful phytoxin much earlier (Davis, 1928). Cinnamic acid isolated from guava roots (Kafeli and Kadyrov, 1971) and 3-aceyl-6-methoxy benzaldehyde isolated from *Encelia farinosa* leaves (Gray and Borner, 1948a, 1948b) was found to be effective growth inhibitor and toxic to many plant species. Martin and Rademacher (1960) reported scopolatin from oat roots as potent growth inhibitor. Chlorogenic acid and flavonoids like naringenin or floridgin may also inhibit straight growth of coleoptile. Many alkaloids are also known for their growth inhibitory properties (Waller and Burstrom, 1969; Waller and Edmund, 1978; Roeper and Roeper, 1977; Becerra, 1977). Addicott and his associates in 1963 isolated abscisic acid from fruit of cotton that is a potential growth inhibitor even more than phenolics (see Carns, 1966; Addicott and Leon, 1969; Kafeli and Kadyrov, 1971). It accelerates loss of chlorophyll, induce senescence and cause growth retardation, prolong bud dormancy, inhibit flowering in L.D.-plants under short day conditions. However, the effect of ABA on short day plant is varied. In addition ABA interact with phyto-hormones.
and inhibit synthesis and / or activity of enzymes (eg. Amylase, protease and ribonuclease) in aleurone layer of endosperm.

Various different allelopathic compounds were isolated from corn pollen including flavonoids, phenolics, methyl esters of fatty acids etc. that determine allelopathic potential of corn plant at its flowering stage (Stanley and Linskens, 1974; Anaya-Lang, 1989).

Chou and Chen (1976) reported that some woody plants (eg., Bouhnia purpuria, Bridellia balance, Ficus gibbosa, Ficus retusa, Ficus vasculosa, Glochidion fortunii, Phyllostachys machinoi and Rhododendron spp. Et.) contained significant phyto-toxin in the leaves and litter of these plants which suppress the growth of understory species in same habitat of woody vegetation. Rizvi et al. (1980) isolated 1,3,7-trimethyl xanthine (1,3,7-T) from Coffea arabica that inhibited germination and growth of Amaranthus spinosus. It caused marked reduction of amylase activity which could not be counteracted with GA3. Similar results were obtained by Chou and Young (1982). Chou and Kuo (1986) determined allelopathic effect and inhibition of weed growth from leaf leachates of Leucaena leucocephala. Nature of allelopathic substances released by above mentioned plants were water soluble phenolic acids, flavonoids and alkaloids (see Chou, 1989). Phenolic acids in particular included p-hydroxybenzoic acis, vanillic acid, p-caumaric acid and ferulic acid. These compounds become fixed with humic acid in soil micelles and play important role in regulation of plant growth.

Unharvested plant parts and plant debris decomposed in soil result in the formation of allelopathic chemicals which inhibited germination, respiration and growth of many crops (Borner, 1960; McCalla, 1971; Chou
and Lin, 1976; Chou and Kuo, 1986). It was noted that litter of Chinese fir retarded growth of many weeds in field. Even freshly fallen leaves of the plant released phyto-toxins that significantly inhibited the growth of local weeds (Chou et al., 1989).

Root exudates of some plants exhibit auto-toxication and allelopathic effect on other plants in many cases (see Rovira, 1971; Tang, 1986; Young, 1986). Studies related to allelopathic interaction of pasture forest system, its possible role in sustainable agriculture and weed management was reviewed (see Chou, 1989). A potential growth inhibitor was isolated from *Agrostemma githago* and characterized as agrostemin that has been extensively used as herbicide for weed control in eastern European countries which was considered as environmentally safe herbicide (Gajic, 966; Gajic et al., 1983; Wete and Szabolcs, 1987; Jelenic, 1987). Nishimura et al. (1982) and Mizutani (1989) isolated and identified p-methane 3,8, cis diol and p-menthane 3,8 trans diol from *Eucalyptus citriodora* as germination and growth inhibitor and found that cis isomers were more active than trans isomers. It was suggested that such cis and trans diols are formed by cyclization of citronellal by an obvious biogenetic pathway. The essential oil obtained from *E. comalduensis* hve potential allelopathic effect and active principle spathunelol was characterized as germination and growth inhibitor in lettuce bio assay (Mizutani, 1989).

Pollen of corn have potential allelopathic effect and possibly has significant effect on germination and growth of different weeds (Jimenez and Shultz, 1981; Jimenez et al., 1983; Anaya et al., 1987). Cruz et al. (1988) demonstrated that ethanolic extract of corn pollen inhibit electron pathway in isolated mitochondria of watermelon hypocotyls. A large number of
compounds actually were isolated from corn pollen, some of which had potential allelopathic effects. Alpha-alfa a versatile species contain saponins and two lactigenic alkaloids in their seeds, also showed allelopathic response on rhizobium. Allelopathic effect of the aqueous leachates from leaves and inflorescence have been demonstrated by Kumari et al. (1985) against *Brassica compestris*.

It was noted that such allelopathic chemicals are produced under stress conditions. Waller and Nowacki (1975) reported higher level of alkaloids in plants growing in soil poor in nitrogen and Koepppe et al. (1976) found that significantly higher amount of allelopathic substances were produced in sunflower plants grown in phosphorus deficient soil. Chou (1983) indicated that root of rice seedlings under water logged and oxygen deficient conditions developed abnormally resulting in decreased tillers and yield (Chou and Lin, 1976). Phenolic phyto-toxins are substantially produced by *Leucaena leucocephala* under draught conditions (Chou and Kuo, 1986).

Residue of many plants species may affect germination, growth and production of succeeding crops and may also contribute to weed management (Lovett, 1989). He also comprehensively reviewed the works related to allelopathic response of plant residues. Mason Sedom et al., (1986) noticed that four different species of *Brassica* produce and release allelopathic residue that reduced grain yield and plant dry weight as well as plant height and tillering in wheat crops. Residue of some crop species have been shown to effect a degree of selective weed control. Under field conditions residue from sorghum, sunflower, rape seed, wheat and pea @ 5 t/ha selectively checked broad leaf and grass weeds (Purvis et al., 1985). They noticed that germination and growth of other grass weeds was
significantly inhibited by all types of residues. Similarly Overland (1966) showed much earlier, that barley inhibited germination of some broad leaf weeds due to phyto-toxin produced by them. Barley produced alkaloid gramine and hordenine which inhibit radicle elongation (Lovett and Liu, 1987).

Stephano and Lydon (1987) studied phyto-toxic compounds from higher plants and micro-organisms and their mechanism of action to evaluate allelopathic potential in development of new natural herbicides. They suggested microbial products including Bialophos[L-2-amino (hydroxymethyl) (phosphonoyl) butaryl-L-alanine] and glufocinate(L2-amino-4(hydroxy methyl)(phosphonoyl)-butaric acid] as natural product of herbicidal nature that can be patterned commercially in future. Kuo (1989) also studied fungal metabolite as growth inhibitors of sugar cane and described the mechanism of phytotoxicity. He found the phyto-toxic effect of metabolites of *F. oxysporum* and *Tricoderma harzianum* which significantly inhibited respiration and other metabolic processes, retarded cell division cell division and restricted growth of sugar cane. Active principle were considered to be herbicidal also.

The efforts have been made to develop strategies for reducing costly inputs and inhibition of weed by residues, leachates and exudates produced by plants and role of allelopathic chemicals in weed control has been evaluated by Einhellig and Leather (1988).

Kill and Yim (1983) and Kill (1989) investigated the inhibitive effect of aqueous extracts from leaves, fallen leaves and root of five pine species on plants growing as under- story or in nearby areas. They reported that degree of inhibition of germination and seedling growth was
severe with increasing concentration of extract. Fourteen different chemicals were isolated and characterized from leaf extract of pine and most of them proved to be phenolic compounds which were considered as responsible for observed allelopathic effect.

Koeppel et al. (1976) and Hall et al. (1983) reported that stressed sunflower plants released more phenolics and their residues in soil caused greater inhibition of *Amaranthus retroflexus* germination. Einhellig and Echrich (1984) found that extreme temperature enhance phyto toxic effect and production of ferulic acid. Chemical constituents released from plants have an impact that is a part of multitude of constraints which plant encounter (Einhellig, 1987). Allelopathic chemicals influence mineral nutrient level in plants eg. level of phosphorus and potassium and magnesium were significantly lower in sorghum seedlings grown with 0.5 mM ferulic acid (Kobza and Einhellig, 1987).

Other reports confirmed that several benzoic acid and cinnamic acid decreased mineral content of effected plants (Alsaadawi et al., 1986; Mersie and Singh, 1988). Phenolic acid can alter ion accumulation and assimilation by plants (Balke, 1985). Einhellig (1989) stated that allelopathic chemicals in plants increase when subjected to various environmental stresses, such as water stress, mineral deficiency, extreme temperature, varying radiations etc. The inhibitive effect of ferulic acid for example was found to increase at supra optimal temperatures and lower osmotic potentials.

It is now accepted that alllopathic response and the interference are the combined effect of several different compounds and more than one chemical is actually is involved (Einhellig, 1987). Similar results were obtained with combination of phenolic acid that act in additive or
synergistic way to suppress growth (Rasmisson and Einhellig, 1977, 1979; Einhellig and Rasmusson, 1978; Williams and Hoagland, 1982; Blum et al., 1984; Blum et al. 1985a, 1985b). Likewise monoterpenes (Asplund, 1969), volatile methyl ketones and alcohols (Bradow and Connick, 1988a, 1988b) and alkaloids (Wink, 1983) show their synergistic impact in allelopathic response. Fisher et al. (1988) reported that interactions of more than one compounds may result in an increase in phytoxicity.

G.R. Waller (1989) reviewed allelochemical action of some natural products and various related aspects including molecular and biological basis of action of allelopathic substances. He described caffeine autoxicity in coffee and significant decrease in growth. He suggested that caffeine can be incorporated into nucleic acid chains of DNA and RNA and thus prevent normal cell division (also see Lang, 1976). The de-stabilizing effect was found to be concentration dependent. He presented possible interaction of unicorn plant (weed) and cotton and noticed reduction in cotton yield up to 83% due to allelochemicals produced by weed. The nature of allelopathic substances in unicorn was found to be essential oil. It was noted that detrimental effect on cotton involved series of functions e.g. impaired mitochondrial integrity, inhibition of respiration leading to death of cells (Woodhouse, 1987). Waller and his associates found certain diterpenoid alkaloids from *Dalphinium ajacis* to be allelopathic which probably act by inhibition of GA 3 action and/or its transport within the plant. Allelopathic response was explained as delcosine and delsolin may compete with GA for enzyme active site which changes catalytic function of the enzyme or it may involve feed back control of GA synthesis. He studied allelochemicals from wheat straw and successfully isolated some
significant compounds responsible for growth inhibition in subsequent crops. Humic acid was isolated from wheat plots and shown to be inhibitory in wheat germination and growth. He also reviewed possible role of alfa-alfa root saponins which is less toxic to crops and more resistant to bio-degradation and that can be used as an effective means of weed control.

Richardson and Williamson (1988) reported water soluble allelo-toxins from four plants (*Ceratiola ericoides*, *Calmintha asheishinnr* and *Conradina canescens*) which inhibit germination and growth of sandhill species. The active principle from *C. ericoides* was found to be a flavonoid argoletin(2,6-di-hydroxy-4-methoxy-3',5' di methyl di hydrochalcone, 2,4-dihydroxy chalcone,7,hydroxyflavanone and 6,8-dimethylpinocembrin) Water soluble principle from fresh leaves lacked above phenolics but yielded a new dihydro chalcone ceratiolin (Tanrisever et al.,1987). Biological activity of saturated aqueous extracts of eight *C. canescens* monoterpenes have been tested and that exhibited strong phyto-toxicity (Williamson, et.al.,1989; Fisher et.al. 1989).

Mizutani (1989) described role of allelochemicals and reported allelopathic effect of p-menthane3,8,diol isolated from *Eucalyptus citriodora* that inhibited germination and growth of lettuce (Nishimura,1982). Anaya-Lang(1989) described allelopathic potential of corn, cultivated leumes,*Amaranthus,* and *Dioscoria composita* and studied possible mechanism of action of active compounds and suggested role of allelopathy in crop-weed management.

Cheng (1989) reviewed and discussed the important aspects related to transport of allelochemicals from producer plants species to
target plant, cause and effect relationships and presented a conceptual framework of inter relationships among the processes and factors effecting the transport from its source to its target. He also discussed the retention of allelopathic substances in the soil, factors effecting its biological transformation and the effectiveness of allelochemicals.

Worsham (1989) described possible techniques using allelopathy as an aid of weed management. A large number of allelochemicals representing numerous chemical groups have been isolated from plant of different families but none could be established as commercial herbicide. Extensive studies have been made on allelochemicals from rye, sorghum, and wheat involving isolation, identification and selective toxic action on weeds. Allelochemicals implicated in weed management from these crops include 2,4-di hydroxy benzoxagin-3 from rye, cyanogenic compounds and some organic acids from sorghum and ferulic acid from wheat. It was found that microbial decarboxylation of some of these compounds greatly increased the phyto-toxicity of certain weed species which can be used in suppression of weeds under field conditions. Allelopathic potential has now been suggested for control of about 90 species of weeds (Putman, 1988a, 1988b). Possible technique involving these chemicals for weed suppression have been suggested (Warsham, 1989). Warsham in his review proposed new techniques in weed control that include transfer of allelopathic traits into commercial crop cultivars to increase the ability of crop to compete naturally against weeds, crop rotation, companion plantings and smother crops, use of phyto-toxic mulches and cover crops management for weed suppression, use of allelochemicals for stimulating weed seed germination and decreasing weed seed load in soil etc.
Michihiko Takahashi (1989) reviewed mechanism of allelopathic action of *Lycoris radiata* and suggested its use in weed control. Active phytotoxic principle of *L. radiata* inhibit radicle growth. It was found that allelopathic effect results in hypertrophy in initial cells, progressive inhibition of cell division in root apex, inhibition of procambial activity and finally physiological imbalance of nutrients and water. It was also noticed that *L. radiata* completely controlled *solidago allisima* weed. Similar allelopathic action was also observed with other plant species and he stated that *L. radiata* may be useful for biological control of weed such as *Solidago allisima* and *Rumex crispus* (see Takahashi, 1989).

Kuo et al. (1989) investigated allelopathic potential of *Acacia confusa*. They observed ground vegetation under acacia stand, Aqueous extract of fresh leaves of *A. confusa* and accompanied species *stachytapheta jamaicensis*, *vitex negundo*, *Leucaena leucocephala* were taken for bioassay and its effect on germination and growth of *Lactuca sativa*, *Brassica chinensis* and *Bidence bipinnata* was studied. In addition to aqueous leaf extracts, leachates, seed pod, leaf litter of Acacia were also tested to evaluate its phytotoxic effects. The samples of test plant species were analyzed and phenolic substances were characterized by paper chromatography and HPLC. In field conditions it was noted that there was relatively less undergrowth and vegetation growing under *Acacia* stand. The bioassay revealed significant inhibitory effect of test plant samples on lettuce, cabbage and *Bidens bipinata*, reducing germination and radicle growth. Similar phyto-toxic effect was noted with 1% of aqueous extract of seed pod of *Acacia* on lettuce seedlings. Responsible allelochemicals were found to be phenolic compounds including caffeic acid, resorcylic acid, hydroxy benzoic acid and hydroxy phenylacetic acid from *Acacia*
and that caffeic acid, ferulic acid, vanillic acid, anthranilic acid from *Stachytapheta*. It was noted that these phenolics are biodegraded in soil as leaf litter was not much inhibitive. It was suggested that *Acacia* accumulates phyto-toxins during prolonged dry season which leach out to the environment and inhibit growth of under growing species.

Hsu and his associates (1989) made further advance in the study of allelopathy and presented action model of allelopathic compounds on seed germination and estimated critical concentrations of various allelopathic compounds for inhibiting alfa-alfa (*Medicago sativa*) and lettuce (*Lactuca sativa*). Fifteen allelopathic compounds- ferulic acid, vanillic acid, caffeic acid, p-caumaric acid, p-hydroxybenzoic acid, salicylic acid, resorcylic acid, hydrocinnamic acid, gallic acid, phenylbutaric acid, p-hydroxyphenylacetic acid etc. were tested for inhibitive effect on alfa-alfa and lettuce seed germination in varying concentrations. Percent germination and its rate both decrease considerably with increasing concentration of allelopathic compounds, tested. The critical concentration of alelochemical ranged for alfa-alfa seed germination from 616 ppm for PBA t 9095 ppm for CFA and those for germination of lettuce from 337 ppm for salicylic acid to 7023 ppm for caffeic acid. Phenylbutaric acid, salicylic acid, hydroxy phenylacetate exhibited maximum inhibitory effect on seed germination of both alfa-alfa and lettuce.

Bradov (1991) studied phytotoxic effect of some bio-active volatile alkanes, alkanols, alkanals ranging from 6 to 9 carbon atoms which are emitted from stem, flower, fruit and root residues. Germination of onion, carrot, and tomato seeds was inhibited and such inhibitive effect depended on the nature of compounds and their concentrations as well as
plant species tested. Twenty five volatile substances were examined, 2-alkanals were most effective followed by 2-alkanols.

Christer (1992) isolated a allelopathic chemical 5-methoxy-3,3’dihydroxy-dihydrostilbene named as batatasin-III from leaves of Bropitrum hermaphrodium showing marked inhibition of germination of Populus seeds. They found that pure substance was less active than crude water extracts and suggested that difference in inhibitory activity might be explained by the presence of glucoside conjugate in the crude extract.

Einhellig (1992) reported that root exudates of Sorghum bicolor contain a dihydroquinone that is quickly oxidized into p-benzo-quinone named ‘sorgolone’. The allelopathic potential of sorgolone as an inhibitor of weed growth was investigated. 125 uM of sorgolone reduced radicle growth of Eragrastis weed and 50 uM of it inhibited growth of Lemna minor. Only 10uM of sorgolone in nutrient medium reduced growth of weed seedlings including Abutelon theophrasti, Datura stramonium, Amaranthus retroflexus, Setaria viridis, Digitaria sanguinalis and Eichinocloa crusgalli. The sorgolone was found to have inhibitive effect at extremely low concentrations indicating strong contribution to Sorghum allelopathy.

Various phenolics including hydroxybenzoic,vanillic, syneric acids from acid fraction and hirsutin (8-methyl sulphinyl-octyl isothiocyanate), 4-methoxy indole-3-acetonitrile and paracatachal from neutral fraction of Kircha inaugarishi and Rorippa sylvestris were reported to have inhibitive effect on lettuce seed germination (Yamane et.al.,1992 ). Similarly many phenolic acids and other compounds were identified from leaves of Gliricidia sepium and tested for allelopathic
effect. A marked inhibition of germination of *Sorghum valgare* seeds and root elongation was noticed by Kamamurti and Palliwal (1993). Hishashi et al., (1994a) made significant efforts for assessment of allelopathic potential of extract of oat shoot. The aromatic amino acid L-tryptophan was reported to be inhibitory principle for germination and growth of lettuce and other many plant species. L-tryptophan caused growth inhibition of root and hypocotyl or coleoptyles of cress (*Lipidium sativum*), lettuce (*Lactuca sativa*), coscomb (*Amaranthus caudatus*), timothy (*Phelem pretens*), rice (*Oriza sativa*), wheat (*Triticum aestivum*), and oat (*Avena sativa*). Inhibition was increased by increase in dose of L-tryptophan in the plant species tested. The level of L-tryptophan in oat seedlings was recorded as 29.3mg/g.fr.wt. and root exudates 0.25 mM under light conditions. The level decreased in dark. It was suggested that L-tryptophan may play important role in growth inhibition of various different plants in nature at higher concentrations (Hishashi, et al., 1994b).

Aliotta et al. (1994) reported delayed and decreased rate of radish seed germination when treated with aqueous extract of *Ruta graveolans*. Marked inhibition of water uptake into seed and radicle growth was reported which was higher in light than dark conditions. Active substance was found to be 5-hydroxy caumarin a new phenolic compound, consistent to many other studies. Germination and growth inhibition by sesquiterpene lactone and a flavone isolated from *Tilthonia diversifolia* was reported by Baruah et al. (1994a). The flavonoid *hispidulin* was found to cause maximum phyto-toxic effect followed by tagitinin A and C. Study of structural requirement related to their biological activity have also been investigated by these workers. Baruah et al. (1994b) isolated cordinene and 3-sitosterol from *Eupatorium adenophorum* which significantly inhibited
germination and growth of *Allium cepa* (onion), *Raphanus sativus* (radish) and *Cucumis sativus* seeds. Inhibition was found to be dependent upon seed species and concentration of compounds tested.

Yamada et al. (1995) reported occurrence of allelopathic substance ‘lepidmoid’ in exudates from several plant species, particularly its higher concentration in exudate of germinating sunflower and back wheat followed by lettuce and rice. Chung and Miller (1995) studied allelopathic potential of nine forrage grass extracts which all inhibited germination and seedling growth of alfa-alfa. The inhibitory effect of extracts from test plants were due to allelochemicals present in grass residues. Velu and Mohamed Ali (1995) investigated allelopathic effect of pigweed and horse-purslane on *Boerhaavia diffusa* leaf and whole plant extract of test plant adversely affected and caused marked inhibition of germination, dry weight, and vigor of *B. diffusa* at early stage but at later stage of growth, inhibitive effect was insignificant possibly due to dilution of phyto-toxic substance. The analysis showed that toxicity could be caused due to non-phenolic compounds contained in the extract of test weed.

Indrajeet and Dakshni (1995a) reported allelopathic potential of phenolic substances isolated from root exudate of *Pulchea lanceolata* and characterized simple phenol, chlorogenic acid, fluroglucinol, formononetin-70-glucoside and methylated caumarins from root laechates which inhibited germination and seedling growth of mustered (*Brassica juncea*). They also investigated allelopathic effect of an annual weed *Polypogan monospeliensis* under field conditions and attributed inhibitory effect on crop to phenolic substances consistently with many earlier findings (Indrajeet and Dakshini, 1995b).
Linn et al. (1995) identified growth inhibitory principles in *Ailanthus altissima* and *Castela tortuosa* and tested against *Brassica juncea, Eragastris* spp. And *Lemna minor*. The active substance was named ailanthione and chaparrinone which were found inhibitive at low concentrations and these exhibited inhibitory activity against several weed species. The inhibition was more pronounced in post-emergent than pre-emergent conditions. Freib et al. (1995) investigated allelopathic constituents of shoot and root exudates from *Agropyron repens*. Active substances in shoot extract were characterized as cyclic hydroxamic acid, 2,4-dihydroxy-7 methoxy2-H-1,4 benzoxazin–3one (DIMBOA) and 2,4-dihydroxy2-H-1,4-benzoxazin-3-one (DIBOA) as well as the corresponding lactam derivatives. Root exudates contained cyclic hydroxamic acid as important constituent in addition to ‘DIMBOA’ and ‘DIBOA’. Vanillic acid, ferulic acid, and hydroxybutaric acid were also released by intact living quack-grass seedlings. Allelopathic potential of these constituents were estimated.

2.4 MODE OF ACTION OF NATURAL GROWTH INHIBITORS: ALLELOPATHIC RESPONSE

Studies on mechanism of action of such natural inhibitors is scarce and only some efforts have been made to understand the inhibitory properties of different chemical groups

Methyl substituted xanthin and di-terpenoid alkaloids of *Dalphinium ajacis* effect on synthesis and release of amylase enzyme – the hydrolyzing enzyme involved in primary steps of seed germination
(Duffus and Duffus, 1969). These alkaloids are also known to adversely effect plant growth and development through inhibition of G.A. biosynthesis and/or their impaired metabolism within the plant (Waller, 1989). Waller and Edmund (1978) reported inhibition of auxin translocation and antiauxin activity of some alkaloids including nicotine.

Many of alkaloids are known to interfere in nucleic acid and protein synthesis, for example caffeine (Ogawa, 1970; Lang, 1975, 1976; Waller, 1989), emitine (Perlman and Penman, 1970) and narciclasine (Jimnez, 1975) inhibited nucleic acid synthesis. Emitine, miscaline and narsicaline have inhibitory effect on protein biosynthesis (Perlman and Penman, 1970; Datta et al., 1971; Papas et al., 1973).

Besides inhibiting nucleic acid and protein synthesis some alkaloids inhibit chlorophyll and cellulase enzyme synthesis and effect the over all growth of plants (Waller and Edmund, 1978).

Phenolics and flavonoids inhibit plant growth through interaction with phyto hormones. Santz (1966) reported adverse effect of phenolic compounds on IAA synthesis and its degradation. Di-phenolic compounds (viz. Caffeic acid and chlorogenic acid) and some other natural substances (viz. Anthocyanin, leucoanthocyanin, flavonoids, and phenolic acids etc.) enhanced IAA induced growth while monophenols and m-diphenols nullified this effect through IAA oxidase system (Henderson and Nitsch, 1962; Nitsch and Nitsch, 1962). Mumford et al., (1961) and Furuya et al. (1962) reported that ‘Quercetin’ a flavonoid promoted growth and inhibited IAA oxidation at low concentration and restricted the growth at higher concentrations. It was found that phenolic inhibitors are actively synthesized in green tissues in high light intensities and that depressed seed
germination, bud opening, root formation etc. through interaction with phyto hormones (see Kafeli and Kadyrov, 1970). Kafeli and Kadyrov (1971) concluded that para and ortho-diphenols exhibit their inhibitory effect only after conversion into corresponding para and ortho-quinones which impaired growth of coleoptyle and root elongation more strongly than phenoles themselves. The nature of inhibition by the phenols which are not convertible to quinone was not clear. It was noted that many phenolics depress enzyme activity and cause nonspecific inhibition of total metabolism probably through metabolic blocks of ATP synthesis, nucleic acid synthesis and protein synthesis. Flavonoids like margenine and isosatipuroside not only depressed growth of oat coleoptile but also restricted release of sugars in barley endosperm through impaired hydrolyzing enzyme activity. Inhibition of various above processes by phenolic compounds may thus impair and adversely effect any form of growth induced by phyto-hormones.

It is evident that biological responses to allelochemicals are characteristically stimulation/attraction at lower concentrations and inhibition at higher concentrations, and that young juvenile seedlings are most susceptible to such allelochemicals (Selander, et al., 1974). A consistent response of plant root tip cells to such compounds is the development of vacuolation (Lovett, et al., 1989). They also observed significant disturbance of biochemical pathway of starch hydrolysis.

Phytochemicals are now also known to operate in cell-cell signaling system in plant – microbe interaction for example abetic acid (a diterpene) induced basidiospore germination (Fries et al., 1987) and that extract of canada thistle root stimulate telespore of canada thistle rust (Castle and Day, 1984; French et al., 1988). The study indicated that the
effect of phytochemical through a unique interaction at gene level (see Halverson and Stacy, 1986; Towers et al., 1988). Djordjevic et al. (1987) have reported that flavonoid allelochemical may exhibit both stimulatory and inhibitory effects. In addition flavonoids influence membrane and vacuolar activity as well as active uptake system (Gabriel et al., 1988).

Anaya-Lang (1989) described allelopathic potential of corn and Cruz et al. (1988) demonstrated that ethanolic extract of corn pollen act as inhibitor of electron pathway in isolated mitochondria of watermelon hypocotyl, decreasing oxygen consumption. The same extract was also found to decrease mitotic activity. He approached other physiological studies with different allelopathic compounds particularly related to the mechanism of action focussing mainly on respiration and cell division process.

Takahashi (1989) studied the mechanism of the allelopathic action of *Lycoris radiata* on some weeds. Active principle isolated from *L. radiata* inhibited formation of growing radicles involving hypertrophy of initial cells of radicles, progressive inhibition of cell division in root tips, decreased cell line number, inhibition of procambium differentiation and consequently the physiological imbalance of nutrients and water followed by inhibition of root growth. Of all organs of plants, growing radicles were found to be most susceptible and that growth of apical meristem in particular was significantly blocked. Allelopathic potential of inhibitory component was tested against *Solidago altissima* and inhibition of root cap cell formation, initial cells of growing radicles and number of cell lines were observed. Similar bioassay tests were performed against *Rumex cryspus*. The possible mechanism of allelopathic effect of the active component of *L. radiata* involving impairment of cell division and growth
as described above was discussed and a systematic model for mechanism was proposed. Takahashi (1989) proposed the use of inhibitory component in weed control and suggested the possibility for development of new natural herbicides.

Hsu et al. (1989) presented a comprehensive review and action model of some allelopathic compounds including ferulic acid, vanillic acid, caffeic acid, p-caumaric acid, p-hydroxybenzoic acid, salicylic acid, resorcylic acid, hydrocinnamic acid, gallic acid, phenylbutaric acid, m-hydroxybenzoic acid, cinnamic acid, m-hydroxy-phenyl acetic acid, p-hydroxyphenyl acetic acid, vanillin and estimated their critical concentration for inhibiting germination of alfa-alfa (Medicago sativa) and lettuce (Lactuca sativa).

An additional approach related to study of allelopathy and natural growth inhibitor from fungal source (Fusarium oxysporum and Tricoderma harzianum) was made by Kao (1989) and the results indicated that these two fungal metabolites significantly inhibited respiration and metabolic processes of sugarcane cells and retarded cell division and reproduction. Similar inhibitory effect was observed on germination and growth of corn and rice involving similar mechanism (Kao, 1989).

Einhellig and otmar (1992) studied Sorghum allelopathy and found that sorgolone isolated from Sorghum bicolor inhibited radicle elongation at extremely low concentrations involving blocked cell division. Similar mechanism was reported by Alliota et al. (1994) in study of
allelopathic activity of aqueous extract of *Ruta graveolens* on radish seed germination.

**2:5 ADVANTAGE OF NATURAL PRODUCTS IN WEED CONTROL MANAGEMENT**

Biochemically many plant products proved to be phyto-toxic which inhibit growth and survival of other plants, a process called allelopathy. Such allelopathic chemicals have been demonstrated to be a factor of great ecological importance by influencing plant succession, dominance, species diversity, plant community structure and productivity (Whitlaker and Finny, 1971; Rice, 1971, 1984; Kuo et al., 1989). Bell and Koepppe (1972) suggested that allelopathic effect of some crop plants on weed seed germination and seedling growth can be utilized as basis of its use in weed control (see Rizvi et al., 1980). The use of natural growth inhibitors in weed control may be advantageous over synthetic herbicides in many ways. Natural products being easily available and cheap to procure, can be used in crude formulations without any health hazards. Such allelopathic compounds have no or little phytotoxic effect on crops and other economically important plants and thus may be used as specific herbicides (Tripathi, 1976, 1977; Tripathi et al. 1978; Dixit et al., 1979; Rizvi, 1980). In addition to it natural allelopathic compounds are easily bio-degradable and have no residual effect (Beye, 1978). In contrast to synthetic pesticides/herbicides, natural products would not result in any mutagenic, teratogenic, or carcinogenic effect (Mc Cann et al., 1975).

Recent advances in allelopathic research would help to find ideal model of management of biotic resources in agro-ecosystem that make
their permanent and sustainable use compatible with modern agricultural technology (Anaya-Lang, 1989).

From the review of literature it is now obviously clear that natural growth substances and their allelopathic potential can be used as herbicide and efficient means of weed control management (see Rice, 1974, 1984; Kuo, 1989; Hsu, 1989; Kuo et al., 1989; Takahashi, 1989; Worsham, 1989). Dodder (*Cuscuta reflexa*) an troublesome angiosperm parasite exhibit marked host range specificity (see Gaertner, 1950; Chauhan, 1978; Singh, 1988). In view of these all facts it is evident that higher plants on which the parasite does not grow, might produce some specific allelopathic chemical substance that can inhibit dodder seed germination and early seedling growth. Thus it is now possible to explore a new specific natural growth inhibitor from higher plants to control this parasitic weed—‘dodder’ (*Cuscuta reflexa* Roxb.). A project has been undertaken with this important perspective so as to screen higher plants for such inhibitory allelopathic compound as well as assay, isolation and characterization of biologically active phytotoxic compound, under this lab. And consequently a flavonoid ‘Quercetin’ was isolated and characterized from leaves of neem plant (*Azadirachta indica* A. Juss) to have most potential inhibitory effect on dodder seed germination and subsequent seedling growth (Singh, 1988; Chauahn and Singh, 1988; Chauhan et al., 1990). The present study has been undertaken to investigate some more higher plant species so as to explore possible role of allelopathy in weed control particularly in relation to dodder (*Cuscuta reflexa* Roxb.) control management.

*Madhuca indica* Gmel (Sapotaceae) has been found to have high allelopathic potential and the aqueous extract of plant part caused marked