PHYSIOLOGICAL BASIS OF BIOLOGICAL AND CHEMICAL CONTROL OF EUPATORIUM (*Chromolaena odorata* K & R)

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(*Chromolaena odorata* K & R)

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by

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CERTIFICATE

This is to certify that the thesis entitled **"PHYSIOLOGICAL BASIS OF BIOLOGICAL AND CHEMICAL CONTROL OF EUPATORIUM** ***(Chromolaena odorata*** **K & R)** submitted by **Mr. HOLALAGOUD Y. PATIL,** for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **CROP PHYSIOLOGY,** from the **UNIVERSITY OF AGRICULTURAL SCIENCES, DHARWAD,** is a record of bonafide research work done by him during the period of his study in this University under my guidance and supervision and this thesis has not previously formed the basis of the award of any degree, diploma, associateship, fellowship or other similar titles.

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Affectionately Dedicated

TO MY BELOVED PARENTS,
BROTHERS, SISTER &
MOTHER-IN-LAW SMT. HONNAMMA

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INTRODUCTION

I. INTRODUCTION

Chromolaena odorata (L.) King and Robinson, is an aggressive weed of cultivated lands, neglected fields, wastelands, road sides, forest areas, etc. It is a bushy scrambling shrub of perennial in nature, producing large number of light cypsella annually, which germinate after the onset of rains. It has become a major menace in young and open plantations of teak, rubber, coffee, cocoa and coconut. It is a native of Central and Tropical South America and was first introduced as an ornamental plant to Calcutta.

In India, it is reported from Kerala, West Bengal, Karnataka, Meghalaya and North-Eastern parts (Ambica and Jayachandra, 1980). It is known as a "Communist weed" in parts of Kerala and Karnataka and in Asia as `Siam weed'. It is a fast growing woody and much branched shrub attaining a height of 3 to 8 m, thereby posing a serious threat for its effective control.

There are eight species of *Eupatorium* reported in India (Malhotra and Jain, 1978) of which,only two species viz. *Chromolaena odorata* K. and R (Siam weed) and *Eupatorium adenophorum* L. (craften weed) have attained the obnoxious status in western and Eastern Himalayan ranges, respectively. Other species include *E. capillifolium, E. Chinense, E. lingutrinum, E. nodiflorum, E. riparium and E. triplinerve* L.

Considering the losses caused by this weed particularly in plantations, several attempts have been made to control its infestation by mechanical and chemical methods and have proved expensive and also temporary. This is mainly because of its perennial nature and resprouting ability. Therefore much attention has been directed towards biological control in recent times.

In recent years, attention of scientists has been drawn towards the influence of allelopathy on seed germination and growth. It is nothing but the biological interaction among plants culminating in the production of biomolecules by one plant, mostly secondary metabolites that can induce suffering or give benefit to another plant. Allelopathic effects may vary with different plant species and also parts, which affect various plant processes right from germination.

The relationship between chemical constituents of plants and their physiological activity has been the subject of intensive study and speculation. In this context, changes in biochemical and physiological parameters of plants resulting from the herbicide spray, help to explain how weeds can be killed by spraying herbicides. Due to the presence of cuticle, herbicide penetration into the plant system can be a serious problem, while using the foliar applied herbicides, leading to decreased efficacy. Cuticular penetration also depends on the environment which infringes on the plant at the time of spray.

One of the most popular methods to increase the absorption and translocation of foliar applied herbicides is to use compatible additives and in this direction, serveral additives have been tried with different herbicides. These additives have also been found to reduce the concentration of herbicides to be administered thereby bringing down the cost of application considerably.

Several herbicides have been tried to control this weed, but the available information on the effective concentration, time of application and the use of best additives is very important. With this background in view, the present investigation was undertaken with the following objectives,

1. To findout the effect of both crop and weed extracts on germination parameters and seedling vigour of Eupatorium
2. To investigate the biophysical changes induced by crop and weed extracts on Eupatorium
3. To investigate the biochemical and physiological changes due to crop and weed extracts on Eupatorium
4. To findout the effective combination of herbicide, and additives and their concentrations to control Eupatorium.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

Chromolaena odorata (*Eupatorium odoratum*) belongs to the order-Asterales, family-Asteraceae, Tribe-Eupatorae, genus-*Eupatorium* (Tourn) Linn. It comprises of 1200 species, of which only eight are found in India viz., *Eupatorium adenophorum, E. capillifolium, E. chinense, E. lingutrinum, E.nodiflorum, E. odoratum, E. riparium* and *E. triplinerve* (Malhotra and Jain, 1978). *Chromolaena odorata* (siam weed) and *Chromolaena adenophorum* (Croften weed) have the status of noxious weeds in many tropical countries of the world (Rai, 1976).

The siam weed is known by a common name "communist weed" in Karnataka (Rai, 1976, Mogali, 1982), is of great concern as it is threatening to suppress the regeneration of plant species in forest plantations and newly afforested areas. *Chromolaena* is an obnoxious weed in India which has drawn the attention of scientists to look for the efficient methods to check the spread and control of this weed effectively. The review of literature pertaining to its, allelopathic effects on plant growth and development including seed germination, apart from the biophysiological and biochemical changes due to the spray of weed/crop extracts and herbicides on *Chromolaena* is presented in this chapter.

2.1 INFLUENCE OF PLANT EXTRACTS ON GROWTH AND DEVELOPMENT

The failure of new plantations of soft wood teak and leguminous crops in agricultural land is the ultimate result of intense competition and establishment of *Eupatorium*. The dominating nature and complete smothering effect of Eupatorium was reported because of its allelopathic effects (Rice, 1974 and Rai, 1976). Lovett (1986) also found allelopathic interference of Eupatorium on the growth of pasture species like *Trifolium* spp, *Pennisetum claudestivum* and *Imperata cylindrica*, where it acts like natural herbicide. On the contrary, Sun *et al.* (1987) observed that the newly introduced forage species *Styloxanthus auianensis* from Guinea, controlled the growth of Eupatorium.

Significant reduction in shoot length and root length was noticed when Eupatorium seeds were treated with 30 per cent leaf exudates of *Lantana* and *Parthenium*. The leaf exudates

of *Cassia* recorded significant inhibition of Eupatroium seed germination and also significant reduction in shoot and root lengths (Doddamani, 1992).

The phytotoxic effects of sunflower on the suppression of seed germination in *Trianthema portulacastrum*, *Parthenium hysterophorus*, *Flaveria austrealasica*, *Portulaca oleracae*, and *Amaranthus viridis*, indicated that the germination was reduced by 91, 84, 83, 95 and 85 per cent, respectively. Similarly, the weed biomass was reduced by 94, 93, 90, 79, and 92 per cent respectively, under field conditions indicating the allelopathic effect of sunflower (Dharmaraj *et al.*, 1994). At flowering, the dry weight of the *Trianthema portalacastrum* was reduced by 75.6, 80.2, 85 and 85.8 per cent by the sunflower varieties CO-2, EC-68415, BSH-1 and MFSH-1, respectively.

Investigations on phytotoxicity of parthenium plant part residues on pistia showed that dry leaf and flower residues were lethal at and above 0.25% (dry W/V) concentrations. While, stem and root residue were lethal at 1% and above 1.25% levels, respectively. The inhibitors leached out of the parthenium plant residues caused phytotoxicity resulting in an abrupt root disfunction and concomittant drastic reduction in dehydrogenase activity, massive loss of membrane integrity and loss of chlorophyll pigments in leaves. Pistia plants showed high sensitivity to sesqueterpene lactone (25-50 ppm), an isolate from parthenium. Phytotoxicity of parthenium leaf and flower residues appears to be due to parthenin content, while that of stem and root residues was probably due to combined effect of parthenin and phenolic inhibitors leaching out into the aqueous environment (Pandey, 1994).

Allelopathic effects of lantana twigs with leaves as well as of its litter were examined on the growth of *Eichronia crassipes* (Water hyacinth). In this study, water hyacinth dry weight was reduced to a greater extent by *lantana* twigs (40-50%) and litter (20-25%) extracts (Chaturvedi and Sharma, 1994).

2.2 INFLUENCE OF PLANT EXTRACTS ON BIOCHEMICAL CHARACTERS

A frequent approach followed to assess the mode of action of specific allelochemicals had been to monitor their effects on major plant functions. We know that

diverse secondary plant products exhibit allelopathic activity, but it is difficult to understand their mechanism of action partly because of complications in separating the secondary effects from primary causes, uncertainty in translating the observed effects in isolated enzymes and other biochemical systems to intact plant systems and the lack of understanding of the effects of the allelopathic agents on all photosynthetic processes i.e., changes in stomatal opening, membrane permeability, relative water content and many other processes that affect the overall photosynthetic process (Mandava, 1985).

Rice (1984) indicated that allelopathic agents influence the plant growth through following physiological processes. viz., cell division and cell elongation, phytochrome induced growth, membrane permeability, mineral uptake, availability of soil phosphorus and potash, stomatal opening and photosynthesis, respiration, protein synthesis and changes in lipid and organic acid metabolism, inhibition of porphyrin synthesis, inhibition or stimulation of specific enzymes, corking and clogging of xylem elements, stem conductance of water and internal water relations and miscellaneous mechanisms. These processes that contribute significantly to the mode and mechanism of action have also been reviewed by Mandava (1985) and Einhelling (1986).

2.3 SEED GERMINATION STUDIES

Aqueous extracts of sunflower leaf reduced the growth of sorghum seedlings through decreased leaf water potential and increased diffusive resistance. Soil incorporation of its residues @ 2.0 g/g soil inhibited the seed germination and seedling growth of sorghum (Narwal, 1994) Germacronolide isolated from sunflower inhibited the growth of oat coleoptile (Spring *et al.*, 1982) and also the aqueous extracts of sunflower leaves, stem, roots, inflorescence and plants inhibited the germination and seedling growth of crab grass, redrot, pig weed, *Erigon canadensis* and *Bromus Japonicam*.

Aqueous extracts from leaf and stem of 13 flower varieties showed mixed response to seed germination of weeds, however leachates of dry leaves and stem inhibited the growth of weed seedlings (Leather and Forrence, 1979). The leaf extract of sunflower Hybrid -201 and Hybrid 8941 inhibited the seed germination of wild mustard. Stem and leaf leachates of sunflower inhibited the seedling growth of wild mustard, red rot, pigweed, apple and red sorrel (Leather, 1983).

Parthenium root, stem, leaf and inflorescence extracts reduced the seed germination and seedling growth of wheat, barley, sorghum, peas, rapeseed, raddish, cabbage and cauliflower. The leaf and inflorescence extracts proved more inhibitory as compared with stem and root extracts (Rao *et al.*, 1977 ; Dube *et al.*, 1979 ; Ambica and Jayachandran, 1980 Srivastava *et al.*, 1985).

The leaf and inflorescence extracts of parthenium strongly inhibited the seed germination, seedling growth, cell survival and chlorophyll content of rapeseed. The aqueous extracts were more inhibitory than organic and inorganic extracts and completely inhibited the seed germination of rape seed (Kohli *et al,* 1985). The inhibitory effects of its extracts were due to the presence of inhibitors such as parthenin, coronopilin, caffeic acid, p-coumaric acid, alkaloids and sesqueterpene lactones in these extracts (Kanchan, 1975; Ambica and Jayachandra, 1980; Jarvis *et al.*, 1988).

Lantana camara is one of the ten worst weeds of the world and is a serious weed in 14 crops and 17 countries (Holm, *et al.*, 1979), but its dried shoot residues mixed in soil inhibits the root and shoot elongation and drymatter accumulation in maize, soybean, and wheat (Singh *et al.*, 1992) and the inhibition was minimum in wheat. Its leaf extracts contained 14 phenolic compounds viz., protocatechuic acid, vanillic acid, caffeic acid, syringic acid, p-coumaric acid, m-coumaric acid, ferulic acid, salicylic acid, o-coumaric acid, t-cinnamic acid, vanillin and methyl coumarin. The phytotoxicity of its leaf extracts was due to the complex interactions between these phenolic compounds (Jain *et al.*, 1989). Its plant extract delayed the seed germination and seriously inhibited the root, shoot and leaf development in wheat and chickpea (Angrias *et al.*, 1988).

The aqueous extracts of rice residues at 5 and 10 per cent concentrations significantly inhibited the seed germination and seedling growth of wheat, oat, berseem and lentil as compared with control. The order of inhibition in seed germination with aqueous extract treatments in all the test crops was oat > wheat > lentil > Berseem (Tamak *et al.*, 1989). Rice residues reduced the population of *Echinochloa colonum* and broad leaved weeds by 40 and 56% and biomass by 39 and 64%, respectively (Khan and Vaishya, 1992).

The study conducted by Tripathi and Khan (1992) on the allelopathic influence of *Taget minuta* (marigold) on germination of 6 field crops viz., cowpea, maize, blackgram,

greengram, soybean and sunflower revealed significant reduction in root dry weight of maize by the aqueous extracts of roots as well as leaves of *T. minuta*. A study conducted by Ambica and Vidya (1994) on the germination of ragi seeds by using the aqueous extracts of root and leaf of *Lantana camara*, indicated stimulatory effect to the growth of ragi plants which was due to the presence of certain allelochemicals.

2.4 CHEMICAL CONTROL OF EUPATORIUM

Agricultural technology has recently made considerable progress in many ways, especially in chemical weed control. Although, the use of herbicides in agriculture started only 40 years ago, its intensive practice these days has provoked most radical changes that agriculture has ever experienced. Herbicides have been of great help in controlling weeds with certain limitations like residual toxicity in the soil, which is deleterious to several crops.

A herbicide or combination of several herbicides having a broad spectrum activity, without residual toxicity would be of added advantage. In addition, a herbicide proposed to control Eupatorium should be such that it should be translocated into plants to kill the entire plants including the below ground rhizome and herbicide used should be in the range of economic feasibility. It should be safe for soil microbes and animals. The herbicides that satisfy these requirements could be suggested for practical use. Hence, the efforts are being made by several workers to findout these chemicals and an attempt has been made to review the available literature on the control of *Euptaorium*.

In the laboratory and field trials, George (1968) found out that of paraquat (0.1%) and 2,4-D (1.5%) were more lethal to *Eupatorium*, after 3 days under laboratory conditions. Whereas in the field, good results were obtained with 1.5 kg/ha paraquat or 2,4-D spraying at 17.5 kg/ha is required. But for effective control, the spraying should be carried out before the flowering of Eupatorium. Edberink (1969) suggested the application of dimethyl urea at 20 kg/ha to kill the Eupatorium effectively.

The foliage of Eupatorium is very susceptible to growth regulating type of herbicides but the control of whole plant does not appear to be easy (Ivens, 1974). 2,4-D ester or amine 2,4,5-T at 2 kg/ha caused severe dieback of plants of 80 cm height and killed smaller plants. Nevertheless, in grown up conditions, the phenoxy herbicides are less effective on the weed and stronger concentration of the chemical will be required.

The most effective combination of herbicides for the control of grown up Eupatorium is picloram and 2,4-D (Ivens, 1973; Olaoye, 1974; Dufer and Quencez, 1978). Ivens (1974) observed that the weed was eliminated by picloram at 0.4 kg + 2,4-D amine at 1.6 kg/ha after six months of application. The herbicides were much more effective on plants that were allowed to resprout after slashing than on unslashed plants. Picloram persisted in the soil for seven months after application, while 2,4-D was less persistent.

In a pot experiment conducted by Risidino (1975), it was observed that the application of Tordon 101, (Picloram 10% + 2,4-D 40%) Tordon 105 (Picloram 5% + 2,4-D 20%) and Tordon -155 (Picloram 12% + 2, 4 5-T 48%) at 1.0 kg/ha was very effective against Eupatorium and it was not toxic to *Brachiaria brizantha*, an introduced pasture grass in Indonesia. Picloram at the rate of 1.0 kg/ha was also effective after twelth week but 2,4-D at 2.0 kg and 2,4,5-T 1.0 kg/ha were less effective to control the Eupatorium.

Higher dose of Glyphosate resulted in the reduction of starch grains indicating the interference of glyphosate with Hill reaction (Campbell *et al.*, 1976 ; Mollerhauer *et al.*, 1960). The degenerative changes observed in chloroplasts of glyphosate treated leaves are reminiscent of senescence changes reported in higher plants (Buttler and Simon, 1971).

Experiments conducted in Indian west coast rubber plantations and semi evergreen forests indicated that the control of Eupatorium could be achieved by using a combination of paraquat and 2,4-D three to four times a year (Rai, 1976). However, chemical control is prohibitory, expensive and a cover crop like *Pueraria phoseloides* (Tropical Kudzu) should be used in combination with slashing or uprooting. Similarly, Mathew *et al.* (1977) reported that the spraying a mixture of paraquat at 1.15 kg/ha and feronoxone (2,4-D + sodium 80%) at 0.75 kg/ha was ideal in rubber plantations infested with *Eupatorium*.

The best results were obtained by Dufer and Quencez (1978) in oil palms for the control of *Eupatorium* with metribuzin and glyphosate each at 6.0 kg/ha but was not found practicable due to the danger of erosion by metribuzin and high cost of glyphosate. Further, trials by them with Tordon 101 showed that it was selective in oil palm, since it did not reach the leaves. While slashing of *Eupatorium* two weeks before the treatment in young trees gave good control.

Turner and Loader (1978) reported that the orthophosphoric acid and ammonium sulphate increased the herbicide penetration through the leaf surface and help in the better absorption, translocation thereby leading to increased glyphosate activity. Richardson (1977) also reported that the foliar absorption and translocation of 2,4-D and 2,4 5-T were affected by both environmental and chemical factors and the nitrogeneous compounds like urea and KNO_3 were found to be efficient carriers of 2,4-D and gramaxone (paraquat).

The application of imazatphayr 2,4,5 dihydro 4 methyl (1-methyl)-5.oxo-1 H-indozolyl) 5-ethyl, 3-pyridine carboxylic acid at the rate of 0.375 to 0.5 kg/ha controlled the growth of *Eupatorium* under rainy season more consistantly than glyphosate in rubber plantations of Ivory coast (Keli, 1986).

In a preliminary screening trial of herbicides on *Eupatorium*, Mumbareddy (1989) found that 2,4-D and glyphosate were more effective in controlling the weed. Paraquat (gramaxone), 2,4-D and glyphosate did not allow the plants to attain more height even at lower concentrations. In another trial of herbicidal combinations, he found that the application of 2,4-D, glyphosate and paraquat was more effective in checking the weed growth.

Singh *et al.* (1992) reported that *Eupatorium adenophorum* could be effectively controlled by hand cutting and spraying of herbicides on the resprout foliage. Herbicides DOWCO 433 (Gallant) at 0.25 kg/ha, paraquat at 1.0 kg/ha and glyphosate at 1.0 kg/ha were found to be most effective in checking this weed in Himachal Pradesh. Although 2,4-D suppressed the weed growth, but failed to control completely.

Doddamani (1992) reported that *Eupatorium* can be effectively controlled by spraying glyphosate and 2, 4-D both at 7.5 ml/lit. However, the lower concentrations of these herbicides were effective only at early growth stages and did not control the regrowth of this weed at later stages. It was also pointed out that glyphosate is environmentally safe with no mammalian toxicity as compared to 2,4-D and hence it was advocated to use glyphosate for controlling *Eupatorium*.

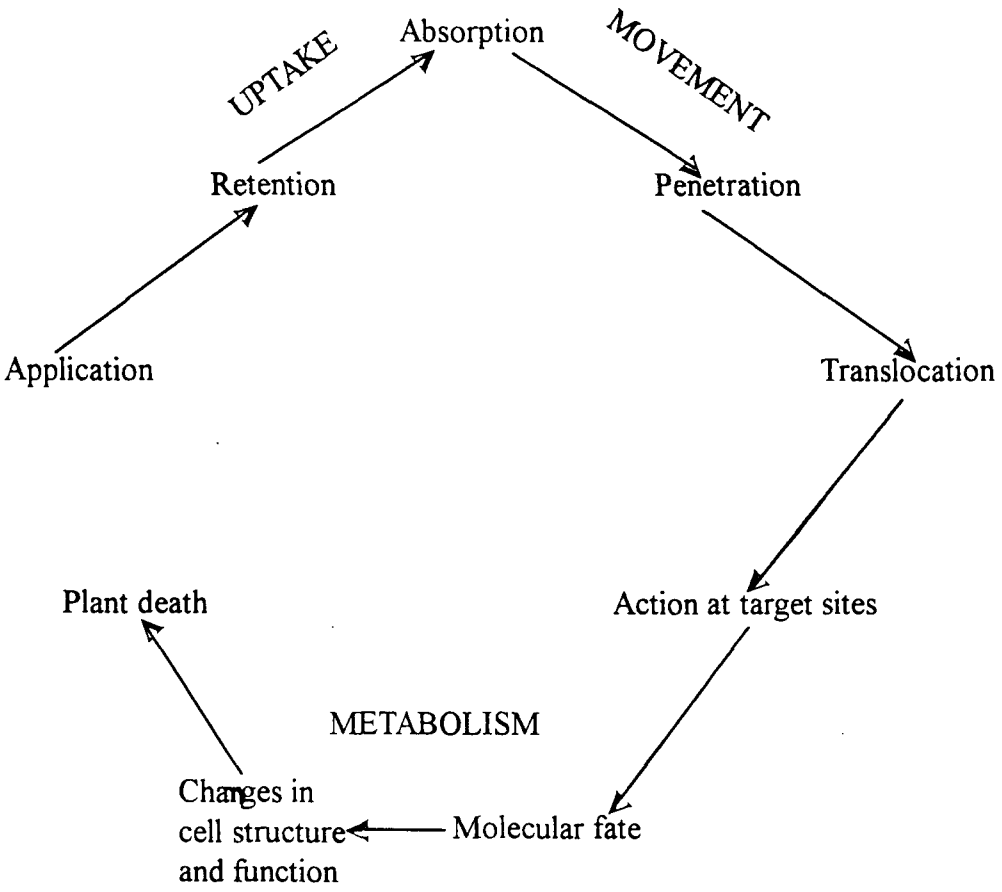
2.5 MODE OF ACTION OF HERBICIDES

The term mode of action may be defined as the complete sequence of events leading to plant injury and therefore includes all areas of interaction between a herbicide and a crop or test species. A great many features contribute to successful weed control and such interactions may be categorized into areas of herbicide uptake, movement and metabolism (Fletcher and Kirkwood, 1982).

Mode of action of herbicides comprises the sum total of anatomical, physiological and biochemical responses that make-up the total phytotoxic effect of a chemical in the plant (Ashton and Crafts, 1973).

Generally, most of the herbicides have both primary and secondary mechanisms of action. The primary mechanisms of action are mainly related to the processes in which herbicides interfere biochemically or biophysically with molecules or structures of cell such as proteins, DNA, RNA, membrane, or enzymes. Inhibition of photosynthesis at a specific site in the electron transport chain (ETC), formation of toxic radicals which inturn oxidise pigments and lipids, inhibition of enzymes synthesizing carotenoids or chlorophyll or interferences with membranes influencing the ion transport are some of the instances of primary mechanism of action.

Secondary mechanisms of action of herbicides include the sequence of reactions following the primary response leading to the physiological alterations of plant metabolism and cell structure and finally to the death of the plant. These include the interference with photosynthetic reactions, destruction of chlorophyll, lipid peroxidation, loss of membrane functions, suppression of cell division and disorganization of the ultrastructure of plant cell and cell organelles (Pfister and Urabch, 1983). The mode of action of herbicides used in the study as studied by several workers is given below.



MODE OF ACTION OF HERBICIDES

(Andrew Cobb., 1992)

2.5.1 2,4-D

2,4-D (Dichlorophenoxy acetic acid) is a selective, systemic post emergent herbicide used to control many annual broad leaf weeds in cereal crops, sugarcane, plantations and non cropped areas. It is available in salt and ester formulations. The esters of 2,4-D have low toxicity to both human and warm blooded animals and LD_{50} for rats is 490-1500 mg /kg) (Gruzdyev *et al.*, 1980). 2,4-D absorbed by leaves, stems and roots, when applied to the foliage enters the plant tissue through the cuticle by diffusion and moves inside the plant both apoplastically and symplastically causing characteristics phytotoxic symptoms such as epinasty, swelling, twisting and bending of the treated parts and also distant parts. The plants stop growing and meristematic cells stop dividing. Young leaves stop expanding and the mesophyll tissue stops developing. Roots may loose the ability to absorb water and mineral nutrients and leaves may loose photosynthetic ability.

2.5.2 Glyphosate

Glyphosate (N-phosphonomethyl glycine) is a broadspectrum, post emergent, non selective herbicide, usually formulated as mono-isopropylamine salt. It has low soil residual activity combined with great systemic action in plants. Foliar applied glyphosate is absorbed and translocated through phloem (Fletcher, 1983). It is environmentally safe with low mammalian toxicity. The acute oval LD_{50} for rat is 4320 mg/kg, tolerance to fish and wild life is high and has half life of less than 60 days.

The mode of action of glyphosate has been the subject of much research and it appears to affect a number of biochemical processes within the plant. It has been reported to inhibit the aromatic amino acid biosynthetic pathway (Jaworski, 1972), induce chromosomal abberrations (Boyle and Evans, 1974), affect respiration (Sprankle *et al.*, 1975), ion absorption (Breeke and Duke, 1978), modify the chloroplast ultrastructure (Hoagland *et al.* 1979) and alter the metabolism of phenolic compounds by inducing the synthesis of phenylalanine amonia Lyase (PAL) activity (Duke and Hoagland, 1978 and Hoagland *et al.*, 1979). Results of experiments by Cole *et al.* (1978) on *Agropyron repens* indicate that the rate of protein synthesis is limited by reduced level of phenylalanine.

Glyphosate treated plants may take upto three weeks to die and the precise sequence of events is by no means clear. This slow action in the field probably reflects the time taken for depletion of aromatic aminoacids pool size to cause decreased rates of protein synthesis.

2.6 USE OF ADDITIVES FOR INCREASING THE EFFICACY OF HERBICIDES

The activity of foliar applied herbicides is influenced by many factors including surface retention, cuticle penetration, translocation from the region of active sites together with its inherent effect on biochemical processes. Enormous amount of work has been done in trying to find ways of improving the efficiency of herbicides. In this respect, one of the most popular ways has been to investigate the effect of different carriers and additives on the efficacy of the choosen herbicide (Richardson, 1977).

The addition of nutrient elements to 2,4-D sprays to enhance its efficacy was tried by Sexsmith (1953) on russian thistle and he found enhanced 2,4-D activity with ammonium phosphate, ammonium sulfate, ammonium nitrate and potassium phosphate. He also found that nitrogen additives were more effective than phosphorus additives and ammonium nitrogen being better than organic nitrogen and combined nitrogen, phosphorus and potassium was not as effective as ammonium nitrogen alone.

Szabo and Buckholtz (1961) examined the effect of ionic additives and pH on the penetration of living and non living membranes and found that 2,4-D penetration was enhanced by the additives tried, with ammonium and phosphate ions giving the greatest effect when the experiment was repeated using sedum sp. epidermis. Similarly, the penetration into sunflower and beans cotyledon surface was measured by Szabo (1961) and found that ammonium and phosphate ions gave the maximum penetration at pH 3.0 and concluded that inorganic additives especially ammonium and phosphate ions enhance the foliar penetration. Greenham (1962) showed that when phosphate was applied to the leaf blade and 2,4-D to the petioles of Skeleton weed (*Chondrilla juncea*) leaves, the translocation was increased by 50 per cent over the control.

Brady (1970) examined the effect of ammonium nitrate and phosphoric acid on the uptake of 2,4,5-T by four woody species. He found that the addition of 0.1 per cent ammonium nitrate (pH 4.0) was more effective and doubled the absorption of herbicides by sweet gum post oak (*Quercus stellata*) and red maple (*Acer rubrum*) and gave a 77 per cent increase in the absorption by lobolly pine (*pinus taeda*). Phosphoric acid was more effective than ammonium nitrate in increasing 2,4,5-T uptake in post oak. A mixture of the two was less effective than ammonium nitrate alone and less effective than phosphoric acid alone except in red maple.

Growth stage of the target plant has marked influence on the absorption of herbicides. Agbakoba and Goddin (1969) measured the absorption of 2,4-D over 48 hours by leaves of different age seedlings of field bind weed (*Convolvlus arvensis*) and found that five week old plants absorbed and translocated 2,4-D significantly less than the older plants. On the contrary, Sargent and Blackman (1972) reported faster and more absorption of 2,4-D by immature leaves than mature leaves of *Phaseolus vulgaris*.

Burr and Warren (1972) observed that the effect of the addition of isoparaffinic oil carrier to 2,4-D on the penetration of purple nutsedge (*Cyprus rotundus*) and found that after three days, 2,4-D was absorbed significantly more with oil (43%) than with water (18%). Similar results were reported by Prendeville and Warren (1975) on beans (*Phaseolus vulgaris*) leaves. Penetration of 2,4-D was greater through the lower leaf surface when applied in a water surface carrier. This suggested that the stomatal entry was involved for aqueous solutions. However, the penetration of 2,4-D in oil carriers was essentially the same on both surfaces which suggests stomatal entry is not an important factor with oils.

Que and Sutherlad (1973) reported that aqueous emulsion of ammonium salt of 2, 4-D penetrated faster into sunflower leaves than diethyl amine salt. The initial absorption (70% in 13 hours) was independent of light but the following much lower absorption was strongly light dependent. The amine salt sprayed in diesel oil as a carrier had 90 per cent in four hours. They concluded that 2,4-D amine salt should be sprayed with diesel oil as a carrier to facilitate better penetration into leaves.

Glyphosate is an broad spectrum post emergent herbicide absorbed and translocated in the phloem in both annual and perennial weeds (Baird *et al.*, 1974). Many workers have reported increased efficacy of glyphosate when sprayed with additives and the effect is detrimental at various stages of weed growth (Sprankle *et al.*, 1975).

Turner and Loader, (1978) found an increased effect of glyphosate with several acids that act as complexing agents, when tried on *Agropyron repens* and *Stellaria media*. These acids include orthophosphoric, citric, tartaric, lactic and glycolic acids. It was suggested that activation of glyphsate was due to interactions with calcium or other metabolic ions, which would otherwise immobilise the herbicides. Almost 50 years ago, ammonium sulphate was used in USA to activate salt formulations of dinitrophenol herbicide, DNOC (Harris and Hyslop, 1942 ; Crafts and Rieber, 1945). Since then, enhancement of herbicidal activity by ammonium sulphate or nitrate has been demonstrated with water soluble leaf applied herbicides (Tischler *et al.*, 1951 ; Simon, 1953 ; Sexsmith, 1953).

Ammonium sulfate increased the herbicidal activity of picloram, phenoxy acid salts and glyphosate sprays in woody species (Turner and Loader, 1978). Blair (1975) also

reported enhancement of glyphosate and aminotriazole activity against field grown *Agropyron repens*. Similar effects into other perennial weeds were observed by Lutman and Richardson (1978). They also reported that the increased glyphosate toxicity with the addition of ammonium sulphate (1 to 10%) on *Agropyron repens*. Higher concentrations of ammonium sulphate were sometimes anatagonistic. Additions of ammonium sulphate without surfactant generally had less effect on phytotoxicity. Lipophilic surfactant with ammonium sulphate was found to be the best combination with glyphosate in the control of *Agropyron repens*.

Mummigatti *et al.* (1994) observed that the role of carriers in improving the efficacy of absorption and translocation of herbicides leading to increased membrane permeability and more leakage of ions resulting in increased electrical conductivity of leaf leachate. Among the treatments, glyphosate with ammonium sulphate was more effective followed by paraquat with KNO_3 and 2,4-D with urea.

2.7 EFFECT OF HERBICIDES ON PHYSIOLOGICAL AND BIOCHEMICAL CHANGES

A physiological process such as photosynthesis or respiration or trnspiration actually is an aggregation of chemical and physical processes. In order to understand the mechanism of physiological processes, it is necessary to resolve it into its physical and chemical components. Plant physiology depends more and more on the methods of biochemistry and in its efforts to accomplish this, the biochemical approach has been very fruitful.

In order to understand the relationship between physiological and biochemical systems, it is necessary to classify plant metabolism into basic, intermediate and secondary metabolism. Basic metabolism includes the production of organic compounds by photosynthesis, generation of high energy chemical bonds through respiration and oxidative phosphorylation and the synthesis of basic cellular polymers such as starch, cellulose and proteins.

The capacity of plants to adopt to differing light conditions has long been recognized. Under contrasting light regimes, leaves have different anatomical, morphological and biochemical properties leading to differences in apparent photosynthetic rates. Small thick leaves develop in the sun and large thin leaves in the shade of many plants. Sun leaves tend to

have more highly developed palisade and spongy mesophyll regions and higher photosynthetic rates at light saturation. Studies of Nobel *et al.* (1975) indicated that increases in internal leaf area of sun leaves lower the liquid phase resistance to CO_2 diffusion and is responsible for higher photosynthetic rates. Further, they concluded that changes in leaf morphology will influence more than just CO_2 resistance. Large leaves can have a temperature quite different from that of air and temperature affects photosynthesis and transpiration.

The variation in leaf characters of disert shrub *Hyptis emoryi* grown in sun and shade conditions studied by Nobel (1976) and found that plants grown in full sunlight (40 MJ/ m^2) had less than one cm length leaves while shaded (3 MJ/m^2) plants had more than seven cm leaves. Sun leaves possessed three folds higher chlorophyll per unit area, mesophyll thickness and internal to external leaf ratio than shaded leaves. Higher internal to external leaf area ratio caused sun leaves to have three folds lower CO_2 liquid phase resistance than did shade leaves.

Patterson *et al.* (1978) studied the effect of different irradiance levels on velvet leaf (*Abutilon theophrusti*) and cotton (*Gossypium hirsutum*) and indicated that in both species, photosynthetic rate decreased with decrease in irradiance. Reduction of atmospheric O_2 concentration from normal 21% to 1% increased the photosynthetic rate by 1.5 to 2.3 times. The stomatal conductance was not significantly affected by irradiance and the differences in maximum photosynthetic rate were found to be associated with differences in mesophyll conductance. Mosophyll conductance increased with irradiance and correlated positively with mosophyll thickness, chlorophyll content and photosynthetic activity per unit leaf area.

Patterson (1979) demonstrated the inhibitory effect of shading on dry matter production by itchgrass (*Rottboelia exalata*). The plants grown at 2, 25, and 60 per cent of ful sunlight produced only 0.3, 16, and 55 per cent as much dry matter, respectively as plants grown in full sunlight.

Leaf anatomy and ultrastructure can be greatly changed by the irradiance under which a plant is grown (Paul and Patterson, 1980). Itchgrass plants grown under 100, 60, 25 and 2 per cent sunlight of normal (2000 $\mu E\ m^{-2}\ S^{-1}$) showed that shading causes reduction in starch deposits and vacuolization of the cytoplasm. In general, plastids and mitochondria retained their membrane integrity but underwent stomatal deterioration. The conspicuous

movement of mesophyll chloroplasts away from the bundle sheath mesohyll borders was noticed at 60 per cent sunlight. These observations suggested that the structural relationship could be necessary for intercellular transfer of C-4 acids and the functioning of the C_4 photosynthetic pathway were disrupted by shading.

A reduction in the relative water content in leaves due to herbicidal treatments has been reported by Patil (1990) in *Cynodon dactylon*. Sprayed leaves were characterized by Swollen fret channels, more diffuse stroma and ruptured tonoplasts. The relative water content was found to decrease more in glyphosate in combination with ammonium sulfate under both open light and shaded conditions. Among various combinations of herbicides and carriers, it was found that 2,4-D with urea, paraquat with KNO_3 and glyphosate with ammonium sulfate was found to be best combination under open light (Mummigatti, 1994).

MATERIAL AND METHODS

III. MATERIAL AND METHODS

Chromolaena odorata (L.) King and Robinson, a native of West Indies is a serious weed of pastures, forests, orchards and commercial plantations. It is a serious weed mainly in Karnataka, Kerala, Assam and all along Western Ghat areas. Its rapid vegetative development and massive production of air borne seeds have allowed to spread to larger parts of the region. Bright sunlight, higher soil moisture, increased relative humidity and low temperature favour the vigorous growth of chromolaena.

In the past, several attempts have been made to control the spread and infestation of this weed by chemical, mechanical and biological methods. Due to quick regrowth habit, it has become impossible to control the infestation of this weed by any one method. It can also be envisaged that the allelopathic effect of different crop/weed species could be utilised to suppress not only the growth and development but also the seed production capacity of the plant, which could bring in the effective control for the spread of this weed, in addition to chemicals being used. With this in mind, field and laboratory investigations were made in the present study and the materials used and methods adopted are described in this chapter. The investigation consisted of two experiments.

3.1 EXPERIMENT I : STUDIES ON THE ALLELOPATHIC EFFECTS OF CROP AND WEED EXTRACTS ON EUPATORIUM *(Chromolaena odorata)*

It was intended to findout the allelopathic effect of leaf and root extracts of different crop and weed species on the growth and development of *Chromolaena* and subsequently, the viability of the seeds produced as a result of spraying these plant extracts.

3.1.1 SELECTION OF EXPERIMENTAL SITE

A field experiment was conducted on the naturally grown Eupatorium (Plate 1) at the Farm Forestry Department, University of Agricultural Sciences, Dharwad during 1995-96.

3.1.2 WEATHER PARAMETERS

The weather data during the experimental period (September, 1995 to August, 1996) presented in Table 1 indicated that the total rainfall was 801 mm. The maximum rainfall

PLATE 1. GENERAL VIEW OF THE EXPERIMENTAL SITE

Table 1. **Monthly Meteorological data for the years 1995 and 1996 and average of 45 years (1950-1994) recorded at the Meteorological Observatory of the Agricultural College Farm, U.A.S., Dharwad**

Months	Rainfall (mm)			Temperature (°C)						Mean Relative Humidity (%)		
				Mean maximum			Mean minimum					
	1995	1996	Average*	1995	1996	Average*	1995	1996	Average*	1995	1996	Average*
January	5.2	0.0	0.0	27.7	30.1	29.1	13.7	14.7	14.6	83.0	75.0	61.9
February	0.0	0.0	0.0	32.6	32.6	34.9	16.7	16.3	15.6	73.0	72.0	55.1
March	0.0	5.0	7.0	35.1	36.0	35.8	19.1	19.7	18.7	68.0	64.0	56.0
April	20.6	13.2	50.0	36.8	36.8	37.3	21.3	21.1	21.4	66.0	62.0	60.2
May	56.6	65.5	90.0	33.8	36.8	36.8	31.3	21.1	21.5	68.0	63.0	67.2
June	143.4	130.1	112.0	31.4	30.2	29.9	21.1	21.5	21.2	75.0	78.0	82.1
July	184.4	95.3	158.0	27.1	26.8	27.1	21.0	20.9	21.0	87.0	88.0	88.4
August	50.5	70.9	102.0	28.1	26.3	27.1	20.7	20.5	20.7	86.0	90.0	86.6
September	121.6	134.5	105.0	28.3	29.0	28.8	20.6	20.5	20.3	82.0	82.0	83.3
October	127.5	170.5	137.0	29.3	29.0	30.2	20.2	18.7	19.2	80.0	84.4	75.9
November	81.0	—	34.0	29.1	—	29.4	15.2	—	16.3	81.0	—	67.6
December	0.0	—	6.0	29.4	—	29.2	13.5	—	13.3	77.0	—	63.7
Total	789.8	685.1	801.0									

* Average of 45 years (1950-94), Experimental period -September 1995 to August 1996

was received during June (130 mm) and the minimum in March (5.0 mm). The maximum temperature at Dharwad varied from 36°C (March) to 36.8°C (May) whereas, the minimum temperature ranged from 13.5°C to 21.5°C during December and June, respectively. The relative humidity however, was maximum during July (87%) and minimum during April (62%).

3.1.3 DESIGN AND LAYOUT

The experiment was laid out in factorial randomized block design with concentrations of leachates and the species extracts as the factors with three replications in naturally grown Eupatorium stand. The plan of layout is given in Figure 1.

3.1.4 PLOT SIZE

The plot size adopted was 3.0 X 3.0 m for each treatment.

3.1.5 TREATMENT DETAILS

The experiment consisted of twentynine treatment combinations, the details of which are furnished in Table 2.

Table 2. Treatment details of the experiment

Crop/Weed	Extract of plant parts	Concentrations (%)	
Paddy	Leaf	5	10
Paddy	Root	5	10
Sunflower	Leaf	5	10
Sunflower	Root	5	10
Lantana	Leaf	5	10
Lantana	Root	5	10
Marigold	Leaf	5	10
Marigold	Root	5	10
Cassia	Leaf	5	10
Cassia	Root	5	10
Parthenium	Leaf	5	10
Parthenium	Root	5	10
Clerodendron	Leaf	5	10
Clerodendron	Root	5	10
Control		Water spray	

LEGEND

EXPERIMENT - I	
1 Paddy leaf extract - 5%	16 Marigold root extract - 10%
2 Paddy root extract - 5%	17 Cassia leaf extract - 5%
3 Paddy leaf extract - 10%	18 Cassia root extract - 5%
4 Paddy root extract - 10%	19 Cassia leaf extract - 10%
5 Sunflower leaf extract - 5%	20 Cassia root extract - 10%
6 Sunflower root extract - 5%	21 Parthenium leaf extract - 5%
7 Sunflower leaf extract - 10%	22 Parthenium root extract - 5%
8 Sunflower root extract - 10%	23 Parthenium leaf extract - 10%
9 Lantana leaf extract - 5%	24 Parthenium root extract - 10%
10 Lantana root extract - 5%	25 Clerodendron leaf extract - 5%
11 Lantana leaf extract - 10%	26 Clerodendron root extract - 5%
12 Lantana root extract - 10%	27 Clerodendron leaf extract - 10%
13 Marigold leaf extract - 5%	28 Clerodendron root extract - 10%
14 Marigold root extract - 5%	29 Control (water spray)
15 Marigold leaf extract - 10%	

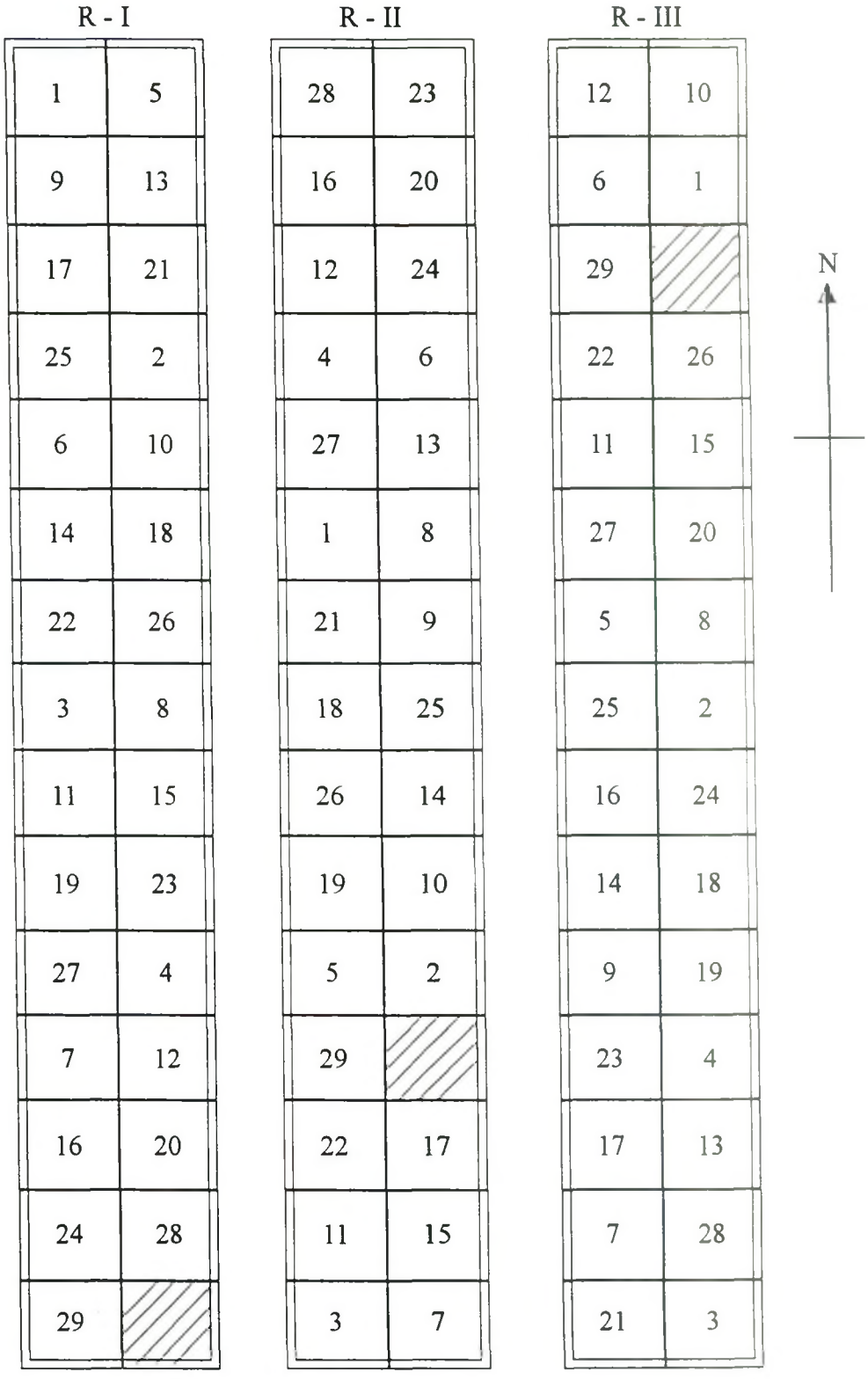


FIGURE 1. PLAN OF LAYOUT OF EXPERIMENT - I

3.1.6 IMPOSITION OF TREATMENTS

Leaf and root samples were collected from the matured plants of various species and were dried in the shade completely during the previous season. After complete drying of the samples, they were finely powdered in Willey grinder. Different concentrations of these samples were prepared in distilled water on W/V basis. A known quantity of the powdered sample was soaked in desired volume of distilled water for 24 hours, after which, the solutions were filtered through muslin cloth after vigorous shaking. Various aqueous concentrations (5 and 10%) were prepared. Approximately 800 ml of the extract was sprayed on an area of 9.0 m^2 for each treatment. The treatments were imposed on 14th September (before full bloom (4), the stages of flower development are shown in Plate 2) by which time, plants were of approximately 90 days old. The spray was administered only once.

3.1.7 COLLECTION OF EXPERIMENTAL DATA

Five plants from each treatment were tagged randomly immediately after the imposition of treatments for recording various biophysical and biochemical parameters.

3.1.7.1 BIOCHEMICAL STUDIES

3.1.7.1.1 Estimation of chlorophyll content

Total chlorophyll, chlorohyll a and chlorophyll b contents were determined following the method of Arnon (1949) at 5, 10 and 15 days after spraying in Experiment I and at 2,4 and 6 DAS in experiment II.

Third fully opened fresh leaf from the top was used for chlorophyll estimation. Leaf sample of 0.25 g from each treatment were cut into small pieces and homogenised by adding sufficient pure acetone in pestle and morter. The homogenate was filtered through a Whatman no. 42 filter paper into 25 ml volumetric flask. The extraction was repeated twice by using 80 per cent acetone and the final volume was made upto 25 ml using 80% acetone. The absorbance of the leaf extract was measured at 645 and 663 nm in UV-VIS spectrophotometer (Systronics Model, CL-54). The chlorophyll a, chlorophyll b and total chlorophyll contents were calculated by using the following formulae and expressed in mg g fresh $weight^{-1}$.

1. Bud intitiation

2. Flower initiation

3. Flower opening

4. Full bloom

PLATE 2. STAGES OF FLOWER DEVELOPMENT IN EUPATORIUM

$$\text{Chl.a} = 12.7\,(A_{663}) - 2.69\,(A_{645}) \times \frac{25}{1000 \times W}$$

$$\text{Chl.b} = 22.9\,(A_{645}) - 4.68\,(A_{663}) \times \frac{25}{1000 \times W}$$

$$\text{Total chlorophyll} = \frac{20.2 \times (A_{645}) + (8.02 \times (A_{663}) \times V \times D}{a \times 1000 \times W}$$

Where,

A_{645} = Absorbance of the extract at 645 nm

A_{663} = Absorbance of the extract at 663 nm

a = Path length of the cuvette (1 cm)

v = Volume of the extract

w = Fresh weight of the sample (g)

D = Dilution factor (1.0)

3.1.7.1.2 Estimation of total soluble sugars

The sugars were estimated as per the procedure given by Mahadevan and Sridhar (1986).

Alcohol extract

A known quantity (0.1 g) of dry leaf sample was suspended in 10-15 ml of 80 per cent alcohol. The mixture was kept on hot water bath for few minutes and the supernatant was decanted and collected. This was repeated two to three times to ensure complete extraction. This supernatant was filtered through Whatman no.41 filter paper and the filtrate was made upto 10 ml. The alcohol extract was clarified by adding neutral lead acetate and the mixture was shaken thoroughly, to which saturated disodium hydrogen phosphate was added. The mixture was again filtered and the filtrate was stored in a refrigerator for the estimation of sugars and phenols

A known amount of alcohol extract was taken in a test tube, evaporated to dryness on hot water bath and cooled. To this, 1.0 ml of 1 N H_2SO_4 was added and the mixture was kept at 50°C in waterbath for 30 minutes. Then the tubes were cooled and the mixture was

neutralized by 1.0 N NaOH using phenopthalene indicator. The contents of the tubes were made to a known volume with distilled water. This formed an aliquot for the estimation of sugars.

A known amount of aliquot was drawn in a test tube and the volume was made upto 2.0 ml with distilled water. One ml of alkaline copper reagent was added and the tubes were kept in a boiling water bath for exactly 20 minutes. The tubes were cooled under running tap and one ml of arsenomolybdate reagent was added. The contents were mixed thoroughly and the volume was made upto 10 ml with distilled water. The absorbance of the blue colour developed was read in UV-VISspectrophotometer (Systronics, Model CL-54) at 540 nm. The quantity of sugar was calculated by using the glucose standard curve and expressed as mg g dry weight^{-1}.

3.1.7.1.3 Estimation of total free phenols (mg g dry weight^{-1})

Total free phenols were estimated by employing the procedure of Bray and Thorpe (1954).

A known quantity of aliquot was drawn in test tubes to which two ml of distilled water followed by one ml of 1.0 N Folin-ciocalteau reagent and two ml of 2 per cent sodium carbonate solution were added. The mixture was stirred and placed in a boiling water bath for exactly one minute. Then, the tubes were cooled under running tap. The blue colour developed was diluted to 25 ml with distilled water and absorbance was measured at 650 nm in UV-VIS spectrophotometer (Systronics, Model, CL-54). The total phenols in the sample was determined by using catechol standard curve and expressed as mg per g dry weight.

3.1.8 GERMINATION STUDIES

For germination studies, seeds were collected from the five tagged plants which were sprayed with plant extracts at maturity. Seeds were air dried and stored in paper bags at room temperature (25°C) before using for germination tests. For recording various germination parameters, 25 seeds were kept in double layered filter paper in petridishes. The filter paper was moistened with distilled water and was kept continuously wet until the completion of germination count (10 days). Germination count was taken daily. The germination per cent was worked out by the following formula,

$$\text{Germination \%} = \frac{\text{No. of seeds germinated}}{\text{Total No. of seeds}} \times 100$$

The other germination parameters were workedout as follows,

3.1.8.1 Germination rate index

Germination rate index (GRI) was calculated by the formula given by Guneyli *et al.* (1969).

$$GRI = \frac{\text{No. of seeds germinated} + \ldots\ldots}{\text{Days to first count}} \quad \frac{\text{No. of seeds germinated since prior count}}{\text{Days to final count}}$$

3.1.8.2 Bartletts rate index

Bartletts rate index (BRI) denotes the earliness of germination or emergence (Bartlett, 1937) and it is calculated as follows,

$$BRI = \frac{P_1 + (P_1+P_2+ ((P_1+P_2+P_3)+\ldots\ldots+ (P_1+P_2\ldots +P_n)}{N\ ((P_1+P_2+ \ldots\ldots\ldots P_n)}$$

Where, P_1, P_2, P_3....and P_n are the germination percentage at 1,2,3..... and n days, respectively.

'N' denotes the total number of days for which the test was carriedout.

3.1.8.3 Germination resistance

Germination resistance (GR) was calculated by the following formula given by (Gorden, 1973).

$$\text{Germination resistance} = \frac{\text{Germination percentage (Total or final)}}{\text{No. of days required to reach final germination}}$$

3.1.9 BIOPHYSICAL STUDIES

3.1.9.1 Determination of relative water content

Relative water content was estimated as per the the method of Barrs and Weatherly (1968) at 5, 10, and 15 days after spraying (DAS) in experiment I, whereas, in experiment II,

it was estimated at 2,4 and 6 days after spraying. Twenty five discs from the third leaf from the top were collected and weighed accurately to three decimals on electronic balance. This was taken as fresh weight. The weighed leaf discs were floated in petridishes containing distilled water and allowed to take up water for four hours. After four hours, leaf discs were blotted gently and weighed. This was referred to as the turgid weight. After taking turgid weight, the leaf discs were dried in an oven at 80°C for 48 hours and the dry weight was recorded. The RWC was calculated by using the following formula.

$$RWC\ (\%) = \frac{\text{Fresh weight - Dry weight}}{\text{Turgid weight - Dry weight}} \times 100$$

3.1.9.2 Measurement of stomatal resistance, transpiration rate, photosynthetic rate and leaf temperature

Measurement of various biophysical parameters viz., stomatal resistance, transpiration rate, photosynthetic rate and leaf temperature were made on the adaxial surface of third fully expanded leaf from the top at 5, 10 and 15 DAS in experiment-I and 2,4 and 6 days after spraying in experiment-II, using Infra red gas analyzer (Model, CI-301). These measurements were made between 9.30 am to 12.30 noon at all the sampling dates. Stomatal resistance was expressed as sec cm^{-1}, whereas, the transpiration rate, photosynthetic rate and leaf temperature were expressed in terms of μ g H_2O cm^{-2} s^{-1} and μmol of CO_2 dm^{-2} sec^{-1} and °C, respectively.

3.2 EXPERIMENT II : USE OF ADDITIVES TO INCREASE THE EFFICACY OF HERBICIDES

One of the most popular methods to increase the absorption and translocation of foliar applied herbicides is to use compatible additives and in this direction, several additives have been tried with different herbicides. These additives have also been found to reduce the concentration of herbicides to be administered and thereby bringing down the cost of application considerably. Among the additives, KNO_3, $(NH_4)_2\ SO_4$, Urea, Teepol, are the most commonly used and are relatively inexpensive as compared to others. With this in mind, the present experiment was carriedout with KNO_3, $(NH_4)_2\ SO_4$, Urea, in combination with 2,4-D and Glyphosate.

3.2.1 EXPERIMENTAL SITE

The experiment was conducted under pot culture conditions at Department of Farm Forestry, College of Agriculture, University of Agricultural Sciences, Dharwad.

3.2.2 DESIGN AND LAYOUT

The experiment was laidout in completely randomized block design with three replications and the plan of layout is given in Fig. 2.

3.2.3 PLANTING

The seedlings of uniform height (30 cm) were selected and three plants were transplanted in earthern pots of 15" diameter and 13" height. The pots were watered regularly, until establishment and were arranged in completely randomized block design with three replications. Plants were allowed to acclimate and establish. After 60 days of establishment of the seedlings, treatments were imposed.

3.2.4 TREATMENT DETAILS

The experiment consisted of 13 treatments with different concentrations of herbicides and different additives in fixed concentrations, the details of which are given below

Treatments

T1	-	Control (unsprayed)
T2	-	2,4-D (2000 ppm) + Urea (1%)
T3	-	2,4-D (2000 ppm) + KNO_3 (1%)
T4	-	2,4-D (2000 ppm) + $(NH_4)_2 SO_4$ (1%)
T5	-	2,4-D (2000 ppm)
T6	-	2,4-D (3000 ppm)
T7	-	2,4-D (4000 ppm)
T8	-	Glyphosate (2000 ppm) + Urea (1%)
T9	-	Glyphosate (2000 ppm) + KNO_3 (1%)
T10	-	Glyphosate (2000 ppm) + $(NH_4)_2 SO_4$ (1%)
T11	-	Glyphosate (2000 ppm)
T12	-	Glyphosate (3000 ppm)
T13	-	Glyphosate (4000 ppm)

LEGEND

EXPERIMENT - II		
Treatments		
T1	- Control	
T2	- 2,4-D (2000 ppm)	+ Urea (1%)
T3	- 2,4-D (2000 ppm)	+ KNO_3 (1%)
T4	- 2,4-D (2000 ppm)	+ $(NH_4)_2SO_4$ (1%)
T5	- 2,4-D (2000 ppm)	
T6	- 2,4-D (3000 ppm)	
T7	- 2,4-D (4000 ppm)	
T8	- Glyphosate (2000 ppm) + Urea (1%)	
T9	- Glyphosate (2000 ppm) + KNO_3 (1%)	
T10	- Glyphosate (2000 ppm) + $(NH_4)_2SO_4$ (1%)	
T11	- Glyphosate (2000 ppm)	
T12	- Glyphosate (3000 ppm)	
T13	- Glyphosate (4000 ppm)	

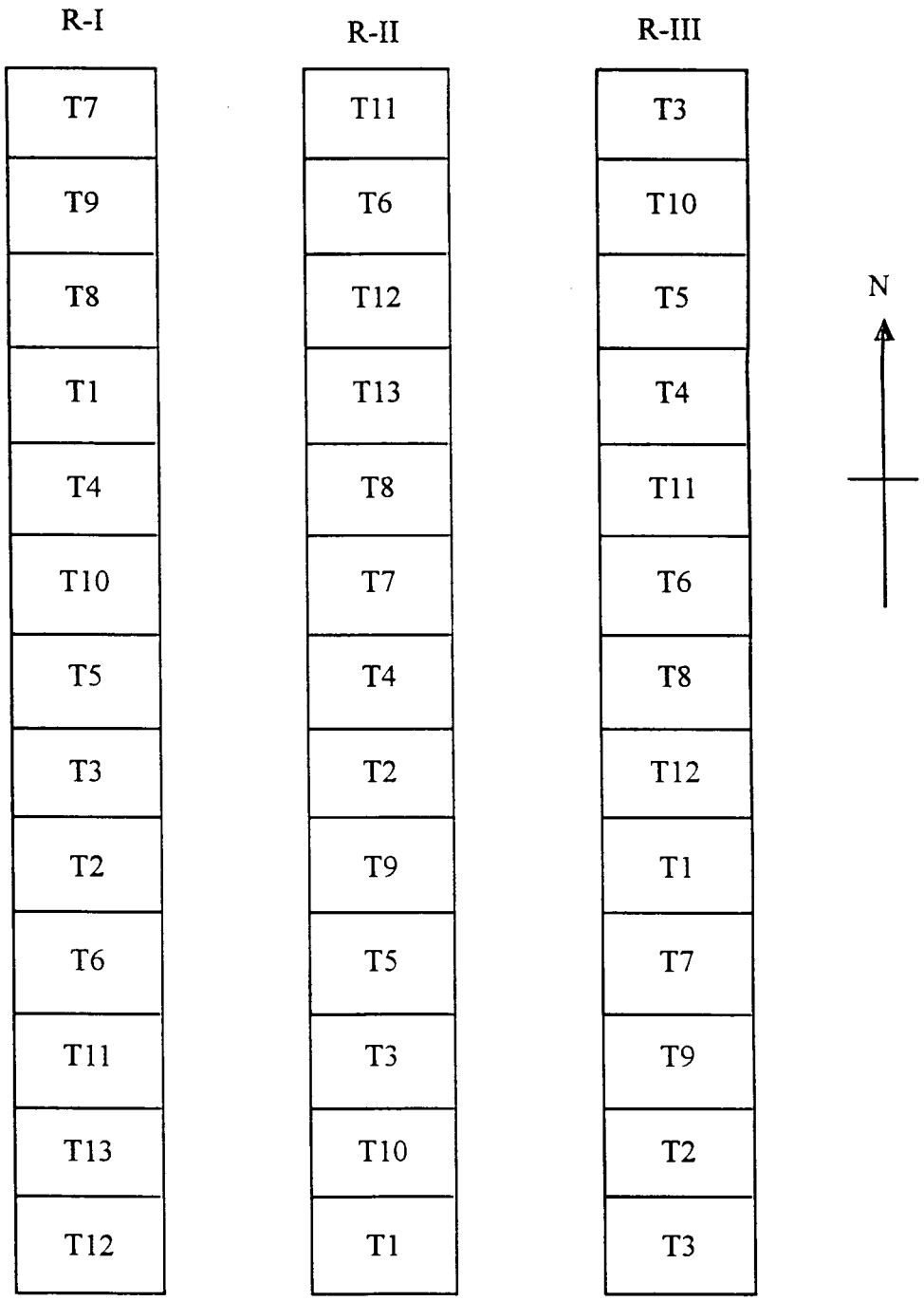


FIGURE 2. PLAN OF LAYOUT OF EXPERIMENT - II

3.2.5 COLLECTION OF EXPERIMENTAL DATA

After the imposition of treatments, plants were sampled for biophysical and biochemical parameters at 2, 4 and 6 days after the spray. At the end of the 15th day, plant height was measured on the main shoot from base to the growing tip. The total dry matter was also recorded at 15 days after spraying.

3.2.6 BIOCHEMICAL PARAMETERS

The procedures adopted for estimating the above listed biophysical and biochemical parameters, chlorophyll content, total sugars and total free phenols are same as given in 3.1.7.1.

3.2.7 BIOPHYSICAL PARAMETERS

Various biophysical paremters viz., relative water content, transpiration rate, Stomatal conductance, photosynthetic rate and leaf temperature were measured at 2,4 and 6 days after the spray, the details of which are described in 3.1.9.

3.3 STATISTICAL ANALYSIS

Results obtained from both experiment I and II were subjected to statistical analysis as per the procedures of Panse and Sukhatme (1967). The level of significance used in F and t-tests was P = 0.05 and 0.01 for field and pot experiments respectively. Critical difference values were calculated wherever F-test was significant.

EXPERIMENTAL RESULTS

IV. EXPERIMENTAL RESULTS

The rapid infestation of *Chromolaena odorata* (L.) K and R (earlier known as *Eupatorium odoratum*) in forests and plantations has created a great concern due to its fast regeneration capacity and allelopathic effect on several field crops, forest species and plantations. There have been several efforts to control and suppress the regeneration ability of *chromolaena odorata* by several conventional and chemical methods, but have proved futile. There are also some reports using plant extracts and herbicides to control chromolaena, but no systemic work has been done to check its spread and regeneration.

Keeping all these aspects in mind, an investigation was carried out to control the growth and development of chromolaena by using different crop /weed extracts in different concentrations. It was also intended to find out how best the efficacy of herbicides can be increased in combination with additives and their impact in modifying various physiological, biochemical and biophysical changes in chromolaena. Two experiments were conducted to achieve the objectives and the results are presented separately experimentwise in this chapter.

4.1 EXPERIMENT-I : STUDIES ON THE ALLELOPATHIC EFFECTS OF CROP AND WEED EXTRACTS ON EUPATORIUM (*Chromolaena odorata*)

4.1.1 BIOCHEMICAL PARAMETERS

4.1.1.1 Chlorophyll a content (mg/g fresh wt.)

Results indicated that chl.a content decreased from 5 to 15 days after spraying (Table 3). At 5 DAS, significant differences due to various species and concentrations were noticed. All the extracts significantly reduced the Chl.a content and it was lowest with parthenium leaf extract (0.75) followed by clerodendron (0.89) and the highest in control (1.35). Leaf extracts recorded significantly lower Chl.a content as compared to root extracts. The order of reduction in chl.a a content with leaf extracts was parthenium followed by clerodendron, marigold, lantana, sunflower, cassia and paddy.

Table 3. **Effect of crop/weed extracts on chlorophyll a content (mg/g fresh weight) at different stages in *Chromolaena odorata* leaves**

Treatments	5 DAS			10 DAS			15 DAS		
	Concentrations (per cent)								
	5	10	Mean	5	10	Mean	5	10	Mean
Paddy (L)	1.28	1.19	1.23	1.19	1.03	1.11	0.89	0.91	0.90
Paddy (R)	1.18	1.16	1.17	1.08	1.05	1.06	0.91	0.92	0.91
Sunflower (L)	1.11	1.06	1.08	0.98	0.78	0.88	0.63	0.48	0.55
Sunflower (R)	1.21	1.13	1.17	1.16	1.01	1.08	0.69	0.51	0.60
Lantana (L)	1.05	0.98	1.01	0.71	0.46	0.58	0.56	0.39	0.47
Lantana (R)	1.20	1.06	1.13	0.82	0.68	0.75	0.57	0.42	0.49
Marigold (L)	0.98	0.92	0.95	0.79	0.52	0.65	0.58	0.41	0.49
Marigold (R)	1.13	1.10	1.11	0.87	0.73	0.80	0.61	0.49	0.55
Cassia (L)	1.22	1.12	1.17	1.00	0.98	0.99	0.75	0.69	0.72
Cassia (R)	1.27	1.20	1.23	1.06	0.99	1.02	0.83	0.78	0.80
Parthenium (L)	0.79	0.71	0.75	0.43	0.16	0.29	0.39	0.14	0.26
Parthenium (R)	0.88	0.74	0.81	0.51	0.26	0.38	0.42	0.22	0.32
Clerodendron (L)	0.96	0.82	0.89	0.53	0.38	0.45	0.49	0.32	0.40
Clerodendron (R)	0.99	0.86	0.92	0.61	0.52	0.56	0.49	0.36	0.42
Control	1.35	1.35	1.35	1.21	1.21	1.21	0.96	0.96	0.96
	SEm±	CD 5%		SEm±	CD 5%		SEm±	CD 5%	
For comparing species (S)	0.009	0.025		0.008	0.022		0.009	0.025	
For comparing concentrations (C)	0.003	0.010		0.003	0.008		0.003	0.009	
Interaction (S X C)	0.013	0.036		0.011	0.031		0.012	0.035	

L = Leaf extract DAS - Days after spraying

R = Root extract

Chl. a content decreased significantly with an increase in the concentration of extracts (5 to 10%). At 10 per cent concentration of leaf extracts, Chl.a reduced to a greater extent as compared to root extracts, and was significant. Higher concentration of leaf extracts significantly reduced the Chl.a content and lower values were recorded with parthenium (0.71) followed by clerodendron (0.82), marigold (0.92), lantana (0.98), sunflower (1.06), cassia (1.12) and paddy (1.19).

At 10 DAS, significant differences due to various species and concentrations were observed. All the extracts significantly reduced the Chl.a content and it was lowest with parthenium followed by clerodendron, lantana, marigold, sunflower, cassia and paddy. Increasing concentrations of extracts (5 to 10%) decreased the Chl.a content significantly. At 10 per cent concentration of leaf extracts, Chl.a content reduced to a greater extent and was significant as compared to root extracts. Higher concentrations of leaf extracts significantly reduced the Chl.a content and the lower values were recorded with parthenium (0.16) followed by clerodendron (0.38), lantana (0.46) and marigold (0.52).

The observations recorded at 15 DAS showed significant differences due to various species and concentrations. All the extracts significantly reduced the Chl.a content and it was lowest with parthenium followed by clerodendron, lantana, marigold, sunflower, cassia and paddy. A significant reduction in chl.a content was observed with increasing concentrations of extracts (5 to 10%) and at 10 per cent leaf extract, Chl.a content reduced significantly as compared to root extract. At 10 per cent leaf extract, the lower values were recorded with parthenium (0.14) followed by clerodendron (0.32), lantana (0.39), marigold (0.41) and sunflower (0.48).

4.1.1.2 Chlorophyll b content (mg/g fresh wt.)

The effect of crop/weed extracts on Chl.b content (mg/g fresh weight) on *Chromalaena odorata* leaves at different stages presented in Table 4 indicated that it decreased from 5 to 15 days after spraying and the decrease was more between 10 to 15 DAS. The observation at 5 DAS showed significant differences due to various species and concentrations. All the extracts significantly reduced the Chl.b content and it was lowest with parthenium (0.24) followed by clerodendron and the highest in control (1.01). Leaf extracts recorded significantly lower values as compared to root extracts.

Table 4. Effect of crop/weed extracts on chlorophyll b content (mg/g fresh weight) at different stages in *Chromolaena odorata* leaves

Treatments	5 DAS			10 DAS			15 DAS		
	Concentrations (per cent)								
	5	10	Mean	5	10	Mean	5	10	Mean
Paddy (L)	0.92	0.91	0.91	0.90	0.84	0.87	0.69	0.63	0.66
Paddy (R)	0.98	0.96	0.97	0.92	0.85	0.88	0.72	0.78	0.75
Sunflower (L)	0.88	0.78	0.83	0.76	0.62	0.69	0.61	0.52	0.56
Sunflower (R)	0.95	0.82	0.88	0.81	0.76	0.78	0.65	0.56	0.60
Lantana (L)	0.47	0.39	0.43	0.43	0.32	0.37	0.36	0.27	0.31
Lantana (R)	0.46	0.40	0.43	0.43	0.42	0.42	0.38	0.36	0.37
Marigold (L)	0.56	0.48	0.52	0.49	0.43	0.46	0.41	0.36	0.38
Marigold (R)	0.62	0.55	0.58	0.58	0.51	0.54	0.53	0.48	0.50
Cassia (L)	0.80	0.76	0.78	0.78	0.70	0.74	0.66	0.61	0.63
Cassia (R)	0.91	0.88	0.89	0.81	0.84	0.82	0.72	0.74	0.73
Parthenium (L)	0.35	0.14	0.24	0.32	0.10	0.21	0.28	0.18	0.23
Parthenium (R)	0.40	0.39	0.39	0.36	0.30	0.33	0.26	0.21	0.23
Clerodendron (L)	0.43	0.30	0.36	0.40	0.29	0.34	0.26	0.21	0.23
Clerodendron (R)	0.46	0.40	0.43	0.43	0.35	0.39	0.39	0.32	0.35
Control	1.01	1.01	1.01	0.95	0.95	0.95	0.74	0.74	0.74
	SEm±	CD 5%		SEm±	CD 5%		SEm±	CD 5%	
For comparing species (S)	0.004	0.011		0.006	0.018		0.007	0.020	
For comparing concentrations (C)	0.001	0.004		0.002	0.007		0.003	0.008	
Interaction (S X C)	0.005	0.015		0.009	0.026		0.010	0.029	

L = Leaf extract DAS - Days after spraying

R = Root extract

With an increase in the concentration of extracts from 5 to 10 per cent, Chl.b content decreased significantly and at 10 per cent concentration, the reduction in Chl.b was significant as compared to root extracts. Higher concentration of leaf extract significantly reduced the Chl.b content and the lower values were recorded with parthenium (0.14) followed by clerodendron (0.30), lantana (0.39) and marigold (0.48)

At 10 DAS, significant differences due to various species and concentrations were observed and all the extracts significantly reduced the Chl.b content and it was lowest with parthenium followed by clerodendron, lantana, marigold, sunflower cassia, and paddy. With an increase in the concentration of extracts (5 to 10%), a significant decrease in Chl.b content was observed. At 10 per cent concentration of leaf extracts, Chl.b was significantly reduced as compared to root extracts. At this concentration, the lower values were recorded with parthenium (0.10), followed by clerodendron (0.29) and lantana (0.32).

The observations at 15 DAS showed significant differences due to various species and concentrations. All the extracts significantly reduced the Chl.b content and it was lowest with parthenium followed by clerodendron, lantana, marigold, sunflower, cassia and paddy. A decrease in the Chl.b content was observed with an increase in the concentration of extracts (5 to 10%) and the decrease was significant. At 10 per cent concentration of leaf extracts, Chl.b content was reduced significantly as compared to root extracts. The maximum reduction was observed with parthenium followed by clerodendron, lantana, marigold, as compared to control.

4.1.1.3 Total Chlorophyll content (mg/g fresh weight)

The results revealed that the total Chlorophyll content decreased from 5 to 15 days after spraying (DAS). The observations at 5 DAS showed significant differences due to various species and concentrations (Table 5). All the extracts significantly reduced the total Chlorophyll content and it was lowest with parthenium (0.99) followed by clerodendron (1.25), and the highest was in control (2.36). Leaf extracts recorded significantly lower total Chlorophyll content as compared to root extracts. The reduction in the total Chl. content was higher with parthenium followed by clerodendron, lantana, marigold, sunflower, cassia and paddy leaf extracts.

Table 5. Effect of crop/weed extracts on total chlorophyll content (mg/g fresh weight) at different stages in *Chromolaena odorata* leaves

Treatments	5 DAS			10 DAS			15 DAS		
	Concentrations (per cent)								
	5	10	Mean	5	10	Mean	5	10	Mean
Paddy (L)	2.20	2.10	2.15	2.09	1.87	1.98	1.58	1.54	1.56
Paddy (R)	2.14	2.12	2.13	2.00	1.82	1.91	1.63	1.70	1.66
Sunflower (L)	1.99	1.84	1.91	1.74	1.40	1.57	1.24	1.00	1.12
Sunflower (R)	2.16	1.95	2.05	1.97	1.77	1.87	1.29	1.07	1.18
Lantana (L)	1.52	1.37	1.40	1.15	0.78	0.96	0.92	0.66	0.79
Lantana (R)	1.66	1.46	1.56	1.25	1.10	1.17	0.94	0.78	0.86
Marigold (L)	1.54	1.40	1.46	1.28	0.95	1.11	0.99	0.77	0.88
Marigold (R)	1.75	1.65	1.70	1.45	1.24	1.30	1.10	0.97	1.03
Cassia (L)	2.02	1.88	1.95	1.78	1.68	1.73	1.41	1.30	1.35
Cassia (R)	2.18	2.08	2.13	1.87	1.83	1.85	1.55	1.52	1.53
Parthenium (L)	1.14	0.85	0.99	0.75	0.26	0.50	0.68	0.32	0.50
Parthenium (R)	1.28	1.13	1.20	0.87	0.56	0.71	0.68	0.43	0.55
Clerodendron (L)	1.39	1.12	1.25	0.93	0.67	0.80	0.75	0.53	0.64
Clerodendron (R)	1.45	1.26	1.35	1.04	0.87	0.95	0.88	0.68	0.78
Control	2.36	2.36	2.36	2.16	2.16	2.16	1.70	1.70	1.70
	SEm±	CD 5%		SEm±	CD 5%		SEm±	CD 5%	
For comparing species (S)	0.036	0.027		0.015	0.042		0.014	0.039	
For comparing concentrations (C)	0.004	0.010		0.006	0.016		0.005	0.015	
Interaction (S X C)	0.013	0.038		0.021	0.060		0.019	0,055	

L = Leaf extract DAS - Days after spraying

R = Root extract

With an increase in the concentration of extracts (5 to 10%), total Chlorophyll content decreased significantly. At 10 per cent concentration of leaf extracts, the total Chlorophyll content reduced significantly as compared to root extracts. However, paddy root extract is more deleterious as compared to paddy leaf extract. The lower values with respect to leaf extract were recorded with parthenium (0.85), clerodendron (1.12), lantana (1.37) and marigold (1.40).

At 10 DAS, significant differences due to various species and concentrations were noticed. All the extracts significantly reduced the total Chlorophyll content and it was lowest with parthenium followed by clerodendron, lantana, marigold, sunflower, cassia and paddy. Increasing concentration of extracts (5 to 10%) decreased the total Chlorophyll content significantly. At 10 per cent concentration of leaf extract, total Chlorophyll content reduced significantly as compared to root extracts. The lower values were recorded with parthenium (0.50), followed by clerodendron (0.80) and lantana (0.96). At 15 DAS also, a similar trend was observed.

4.1.1.4 Total soluble sugar content (mg g dry weight^{-1})

The effect of crop/weed extracts on total sugar content at different stages indicated that it decreased from 5 to 15 days after sparying (DAS) and the decrease was more between 10 to 15 DAS (Table 6). At 5 DAS, significant differences were observed due to various species and concentrations and all the extracts significantly reduced the sugar content. It was lowest with parthenium (22.1) followed by clerodendron (23.2) and the highest sugar content was observed in control (27.1). Leaf extracts recorded significantly lower sugar content as compared to root extracts.

With an increase in the concentration of extracts (5 to 10%), there was a significant decrease in sugar content. At 10 per cent concentration of leaf extract, sugar content reduced significantly as compared to root extracts. The lower values for sugar content were recorded with parthenium (22.1) followed by clerodendron (23.2), lantana (23.8), marigold (24.1), sunflower (24.4), cassia (24.5) and paddy (24.9).

Similar to that at 5 DAS, the observations at 10 DAS also showed significant differences due to various species and concentration. All the extracts significantly reduced the

Table 6. Effect of crop/weed extracts on sugar content (mg/g dry weight) at different stages in *Chromolaena odorata* leaves

Treatments	5 DAS			10 DAS			15 DAS		
	Concentrations (per cent)								
	5	10	Mean	5	10	Mean	5	10	Mean
Paddy (L)	25.2	24.9	25.1	25.0	24.6	24.8	24.0	23.1	23.5
Paddy (R)	25.4	25.2	25.3	25.3	25.4	25.3	24.5	23.9	24.2
Sunflower (L)	24.7	24.4	24.5	24.2	23.8	24.0	23.1	22.3	22.7
Sunflower (R)	24.8	24.5	24.6	24.6	24.2	24.4	23.8	22.7	23.2
Lantana (L)	23.9	23.8	23.8	23.1	22.9	23.0	21.8	19.6	20.7
Lantana (R)	24.1	23.9	24.0	23.5	23.0	23.2	22.5	22.5	22.3
Marigold (L)	24.3	24.1	24.2	23.9	23.6	23.7	22.8	22.3	22.5
Marigold (R)	24.4	24.2	24.3	24.1	23.8	23.9	23.6	23.3	23.4
Cassia (L)	24.8	24.5	24.6	24.3	23.6	23.9	23.0	22.4	22.7
Cassia (R)	24.9	24.7	24.8	24.6	24.4	24.5	23.9	23.8	23.8
Parthenium (L)	23.2	22.1	22.6	21.8	20.6	21.2	20.2	18.1	19.1
Parthenium (R)	23.8	23.1	23.4	22.2	20.7	21.4	20.7	19.2	19.9
Clerodendron (L)	23.4	23.2	23.3	22.8	22.7	22.7	20.3	18.9	19.6
Clerodendron (R)	23.5	23.4	23.4	23.0	22.8	22.9	21.8	19.8	20.8
Control	27.1	27.1	27.1	26.8	26.8	26.8	25.2	25.2	25.2
	SEm±	CD 5%		SEm±	CD 5%		SEm±	CD 5%	
For comparing species (S)	0.750	0.211		0.077	0.218		0.041	0.116	
For comparing concentrations (C)	0.028	0.080		0.029	0.082		0.015	0.044	
Interaction (S X C)	0.105	0.299		0.109	0.308		0.058	0.164	

L = Leaf extract DAS - Days after spraying

R = Root extract

sugar content and it was lowest with parthenium followed by clerodendron, lantana, marigold, cassia, sunflower and paddy. Even at this stage, increasing concentration of extracts (5 to 10%) decreased the sugar content significantly. At 10 per cent concentration of leaf extracts, sugar content reduced significantly as compared to root extracts and the lower values were recorded with parthenium (20.6) followed by clerodendron (22.7) and lantana (22.9).

At 15 DAS, significant differences due to various species and concentration were observed with respect to total sugars. All the extract significantly reduced the sugar content and it was lowest with parthenium followed by clerodendron, lantana, marigold, sunflower, cassia and paddy. A similar trend with respect to the concentration of extracts was observed at 15 DAS as has been observed at 5 and 10 DAS.

4.1.1.5 Total free phenols (mg/g dry weight)

Results indicated that total free phenols increased from 5 to 15 days after spraying (DAS) and the increase was more between 5 to 10 DAS (Table 7). All the extracts significantly reduced the phenol content and it was lowest with lantana (7.0) and cassia (7.1) and the highest in control (8.2). Leaf extracts reduced the total free phenol content as compared to root extracts and the reduction was more with lantana followed by cassia, paddy and clerodendron.

With an increase in the concentration of extracts (5 to 10%), there was a significant decrease in total free phenol content. At 10 per cent concentration of leaf extract, phenol content reduced significantly as compared to root extracts. The lower values for phenol content were recorded with lantana (7.0) followed by cassia (7.1), parthenium (7.2) paddy (7.3) clerodendron (7.5), marigold (7.6) sunflower (7.7). At 10 DAS, all the extracts significantly reduced the total free phenol content and it was lowest with marigold root extracts and the highest in control.

At 15 DAS, all the extracts significantly reduced the total free phenol content and it was lowest with marigold root extract (7.4) and the highest in control (10.8). Even at this stage, increasing concentration of extracts (5 to 10%) decreased the total free phenol content. At 10 per cent concentration, significantly higher phenol content was recorded in paddy root

Table 7. Effect of crop/weed extracts on total free phenol content (mg/g dry weight) at different stages in *Chromolaena odorata* leaves

Treatments	5 DAS			10 DAS			15 DAS		
	Concentrations (per cent)								
	5	10	Mean	5	10	Mean	5	10	Mean
Paddy (L)	7.4	7.3	7.3	8.6	8.4	8.5	9.2	9.0	9.1
Paddy (R)	7.5	7.6	7.5	9.0	9.2	9.1	9.8	9.6	9.7
Sunflower (L)	7.8	7.7	7.7	7.7	7.7	7.7	7.9	7.8	7.8
Sunflower (R)	7.8	7.9	7.8	7.8	7.4	7.6	8.0	7.9	7.9
Lantana (L)	7.2	7.0	7.1	8.3	7.9	8.1	8.6	8.1	8.3
Lantana (R)	7.4	7.6	7.5	7.8	7.6	7.7	7.9	7.8	7.8
Marigold (L)	7.8	7.6	7.7	7.7	7.6	7.6	7.7	7.6	7.6
Marigold (R)	7.8	7.8	7.8	7.4	7.3	7.3	7.5	7.3	7.4
Cassia (L)	7.2	7.1	7.1	8.2	7.8	8.0	8.3	7.9	8.1
Cassia (R)	7.3	7.4	7.3	8.0	7.9	7.9	8.1	7.8	7.9
Parthenium (L)	8.1	7.2	7.6	8.2	8.2	8.2	7.9	7.8	7.8
Parthenium (R)	8.0	7.6	7.8	8.0	7.7	7.8	7.8	7.6	7.7
Clerodendron (L)	7.6	7.3	7.5	8.5	8.3	8.4	8.3	7.8	8.0
Clerodendron (R)	7.5	7.8	7.6	8.4	8.2	8.3	8.4	8.1	8.2
Control	8.2	8.2	8.2	9.8	9.8	9.8	10.8	10.8	10.8
	SEm±	CD 5%		SEm±	CD 5%		SEm±	CD 5%	
For comparing species (S)	0.052	0.147		0.054	0.153		0.043	0.123	
For comparing concentrations (C)	0.020	0.056		0.020	0.058		0.016	0.046	
Interaction (S X C)	0.073	0.208		0.076	0.216		0.061	0.173	

L = Leaf extract DAS - Days after spraying

R = Root extract

extracts (9.6) followed by paddy leaf extracts (9.0) and the lowest in marigold root extracts (7.3), whereas in control, the value was (10.8).

4.1.2. GERMINATION STUDIES

The effect of crop/weed extracts on seed germination on *chromolaena odorata* indicated that the per cent germination was reduced significantly as compared to control (Table 8). The leaf extracts were more deleterious in reducing the seed germination values than root extracts. The lowest germination was recorded with parthenium extract (0.70%) followed by clerodondron (1.20%) as compared to control (65.32%). Among the species, the reduction was more with parthenium followed by clerodendron, lantana and marigold.

With an increase in the concentration of extracts a significant decrease in per cent germination was observed. The leaf extracts were more deleterious in reducing the germination as compared to root extracts. At 10 per cent concentration, the leaf extracts of parthenium significantly reduced the per cent germination (0.0%), which was on par with clerodendron (0.0%) followed by marigold (1.32%) and lantana (9.32%) as compared to control (65.32%). The different crop/weed extracts influenced significantly the rate of germination values such as GRI, BRI and GR of Eupatorium seeds. The lowest values of GRI, BRI and GR (1.17, 0.23, 0.14, respectively) were observed. The highest values were observed in control (19.40, 0.88, 9.29; GRI, BRI and GR, respectively). Higher concentration of extracts decreased the rate of germination values in parthenium followed by clerodendron and marigold.

4.1.3 BIOPHYSICAL PARAMETERS

4.1.3.1 Relative water content (RWC, %)

The effect of crop/weed extracts on relative water content (RWC, %) of *chromolaena odorata* leaves at different stages presented in Table 9 indicated that RWC decreased from 5 to 15 days after spraying (DAS) and the decrease was more between 10 and 15 DAS. The observations at 5 DAS showed significant differences due to various species and concentrations. All the extracts significantly reduced RWC and it was lowest with parthenium leaf extract (80.7%) followed by clerodendron leaf extract (81.9%) and the highest

Table 8. Effect of crop/weed extracts on germination values in *Chromolaena odorata*

Treatments	Germination percent			GRI			BRI			GR		
	Concentrations (per cent)											
	5	10	Mean	5	10	Mean	5	10	Mean	5	10	Mean
Paddy (L)	22.60 (27.97)	10.60 (18.43)	16.6	10.67	9.53	10.10	0.84	0.58	0.71	2.47	1.57	2.02
Paddy (R)	33.30 (35.06)	28.00 (31.95)	30.9	18.43	8.57	13.50	0.91	0.75	0.83	4.70	4.00	4.35
Sunflower (L)	18.60 (25.10)	6.64 (14.18)	12.6	10.68	6.40	8.54	0.80	0.75	0.78	2.57	1.20	1.88
Sunflower (R)	26.60 (30.66)	25.30 (30.00)	26.0	11.67	10.97	11.32	0.87	0.86	0.87	3.72	3.50	3.61
Lantana (L)	4.00 (11.66)	1.20 (8.55)	2.6	8.67	7.20	7.93	0.38	0.27	0.32	0.57	0.28	0.42
Lantana (R)	20.00 (26.57)	9.32 (17.46)	14.6	9.33	8.93	9.13	0.72	0.65	0.68	2.85	1.27	2.06
Marigold (L)	13.30 (21.13)	1.32 (6.55)	7.3	6.37	5.87	6.12	0.60	0.50	0.55	1.85	0.31	1.08
Marigold (R)	34.60 (35.67)	14.60 (21.97)	24.6	7.10	6.90	7.00	0.77	0.70	0.73	4.85	2.00	3.43
Cassia (L)	32.00 (34.45)	29.30 (32.50)	30.6	6.70	6.30	6.50	0.59	0.48	0.54	4.56	4.14	4.35
Cassia (R)	38.60 (38.06)	25.30 (30.00)	31.9	8.13	7.93	8.03	0.60	0.56	0.58	5.42	8.33	6.87
Parthenium (L)	1.32 (5.74)	0.00 (0.00)	0.7	3.40	0.00	1.70	0.46	0.00	0.23	0.31	0.00	0.16
Parthenium (R)	2.64 (8.13)	1.32 (6.55)	2.0	4.30	2.43	3.37	0.53	0.41	0.47	0.42	0.31	0.37
Clerodendron (L)	2.32 (8.12)	0.00 (0.00)	1.2	2.33	0.00	1.17	0.68	0.00	0.34	0.28	0.00	0.14
Clerodendron (R)	3.64 (9.97)	1.32 (6.55)	2.5	2.40	2.13	2.27	0.70	0.63	0.66	0.57	0.31	0.44
Control	65.32 (53.73)	65.32	65.32	19.40	19.40	19.40	0.88	0.88	0.88	9.29	9.29	9.29

	SEm±	CD 5%
For comparing species (S)	0.150	0.425
For comparing concentration (C)	0.057	0.161
Interaction (S X C)	0.212	0.601

Figures in parenthesis indicate original values DAS - Days after spraying GR - Germination resistance
L = Leaf extract R = Root extract GRI - Germination rate index BRI - Bartlett rate index

Table 9. Effect of crop/weed extracts on relative water content (%) at different stages in *Chromolaena odorata* leaves.

Treatments	5 DAS			10 DAS			15 DAS		
	Concentrations (per cent)								
	5	10	Mean	5	10	Mean	5	10	Mean
Paddy (L)	86.6	85.9	86.2	85.1	84.9	85.0	80.1	76.3	78.2
Paddy (R)	86.7	86.1	86.4	85.6	84.9	85.2	82.2	80.0	81.1
Sunflower (L)	86.1	85.6	85.8	83.6	80.1	81.8	78.1	74.6	76.3
Sunflower (R)	86.6	86.2	86.4	84.2	83.9	84.1	80.6	79.2	79.9
Lantana (L)	83.1	82.7	82.9	80.3	76.2	78.2	70.7	68.2	69.4
Lantana (R)	84.3	82.9	83.6	81.9	80.0	80.9	75.1	73.1	74.1
Marigold (L)	85.1	84.8	84.9	81.9	78.2	80.1	73.1	71.6	72.3
Marigold (R)	85.8	84.9	85.3	82.5	80.1	81.3	76.6	75.2	75.9
Cassia (L)	86.7	85.8	86.2	83.8	81.2	82.5	79.2	75.1	77.1
Cassia (R)	86.0	85.9	85.9	84.2	84.1	84.1	80.9	79.6	80.2
Parthenium (L)	81.2	80.3	80.7	78.6	69.2	73.9	64.2	61.1	62.6
Parthenium (R)	83.8	82.1	82.9	81.6	78.2	79.9	72.0	69.2	70.6
Clerodendron (L)	82.6	81.3	81.9	80.1	73.5	76.8	67.1	64.2	65.6
Clerodendron (R)	83.3	83.1	83.2	81.6	79.6	80.6	75.6	70.1	72.8
Control	87.8	87.8	87.8	87.0	87.0	87.0	85.3	85.3	85.3
	SEm±	CD 5%		SEm±	CD 5%		SEm±	CD 5%	
For comparing species (S)	0.111	0.314		0.084	0.239		0.081	0.231	
For comparing concentrations (C)	0.042	0.119		0.032	0.090		0.031	0.087	
Interaction (S X C)	0.157	0.445		0.119	0.337		0.115	0.326	

L = Leaf extract DAS - Days after spraying

R = Root extract

RWC was observed in control (87%). Leaf extracts recorded significantly lower RWC as compared to root extract and the effect was more with parthenium followed by clerodendron, lantana, marigold and sunflower.

Increasing concentration of extracts decreased the RWC significantly. At 10 per cent concentration of leaf extracts, RWC reduced significantly to a greater extent as compared to root extracts. Higher concentration of leaf extract (10%) significantly reduced the RWC and lower values were recorded with parthenium (80.3%) followed by clerodendron (81.3%), lantana (82.7%), marigold (84.8%), cassia (85.8%), sunflower (85.6%) and paddy (85.9%). The interaction effects were also significant.

The observations at 10 DAS showed significant differences due to various species and concentrations. All the extracts significantly reduced the RWC and it was lowest with parthenium (73.9%) followed by clerodendron leaf extract (76.8%) and the highest was in control (87.0%). Leaf extracts recorded significantly lower RWC as compared to root extracts.

With an increase in the concentration of extract from 5 to 10%, there was a significant decrease in RWC . At 10 per cent concentration of leaf extracts, RWC was reduced to a greater extent as compared to root extracts. Higher concentration of leaf extracts significantly reduced the RWC and lower values were recorded with parthenium (69.2%) followed by clerodendron (73.5%), lantana (76.2%), marigold (78.2%) sunflower (80.1%), cassia (81.2%) and paddy (85.9%). The interaction effects were also found significant.

Significant differences due to various species and concentrations were noticed at 15 DAS. All the extracts significantly reduced the RWC and it was lowest with parthenium leaf extract (62.6%) followed by clerodendron (65.6%) and the highest in control (85.3%). Leaf extracts recorded significantly lower RWC as compared to root extracts.

Increasing concentrations of extract (5 to 10%), decreased the RWC significantly and at 10% concentration of leaf extract, the RWC was reduced to a greater extent as compared to root extracts. Lower RWC values were recorded with parthenium (61.1%), clerodendron (64.2%), lantana (68.2%), marigold (71.6%), sunflower (74.6%), cassia (75.1%) and paddy (76.3%).

4.1.3.2 Transpiration rate (μ g H_2O / m^2/s)

The data on transpiration rate in *Chromolaena odorata* leaves at different stages as influenced by various crop/weed extracts indicated a decrease in transpiration rate from 5 to 15 DAS (Table 10) and the decrease was more between 10 to 15 DAS. At 5, 10 and 15 DAS, the differences in the transpiration rate were noticed due to various species and concentrations. All the extracts significantly reduced the transpiration rate and it was lowest with parthenium (8.3), followed by clerodendron (8.6) and the highest in control (12.1). Leaf extracts recorded significantly lower transpiration rate as compared to root extracts at all the stages studied and at 5 DAS, with leaf extracts, the reduction was higher with parthenium followed by clerodendron and lantana.

With an increase in the concentration of extracts from 5 to 10 per cent, the rate of transpiration decreased significantly at all the stages. Higher concentration of leaf extract (10%) significantly reduced the transpiration rate and the lower values were recorded with parthenium (8.1) followed by clerodendron (8.5) and lantana (8.8).

At 10 DAS, all the extracts significantly reduced the transpiration rate and it was lowest with parthenium (6.6) followed by clerodendron (6.9) and the highest with control (10.9). Increasing concentrations of leaf extracts reduced the transpiration rate and lower values were observed in parthenium (6.4) followed by clerodendron (8.6) and lantana (7.2).

At 15 DAS, all the extracts significantly reduced the transpiration rate and it was lowest with parthenium (4.05) followed by clerodendron (4.2), and the highest with control (9.6). Increasing concentration of leaf extracts decreased the rate of transpiration and the lower values were recorded with clerodendron (3.6), followed by parthenium (3.7) and lantana (4.1).

4.1.3.3 Photosynthetic rate (μ mol CO_2/dm^2/s)

The effects of crop/weed extracts on photosynthetic rate in *Chromolaena odorata* leaves at different stages indicated a decrease in the photosynthetic rate from 5 to 15 days after spraying (DAS) and the decrease was more between 5 to 15 DAS (Table 11). The

Table 10. Effect of crop/weed extracts on transpiration rate (µg H_2O m^{-2} s^{-1}) at different stages in *Chromolaena odorata* leaves

Treatments	5 DAS			10 DAS			15 DAS		
	Concentrations (per cent)								
	5	10	Mean	5	10	Mean	5	10	Mean
Paddy (L)	10.9	9.9	10.4	10.1	9.3	9.7	7.6	7.1	7.3
Paddy (R)	11.3	10.2	10.7	10.6	9.5	10.0	8.5	8.3	8.4
Sunflower (L)	9.8	9.2	9.5	9.0	8.2	8.6	6.3	5.1	5.7
Sunflower (R)	10.2	9.4	9.8	9.2	8.6	8.9	6.8	6.6	6.7
Lantana (L)	9.2	8.2	9.0	8.1	7.2	7.6	5.2	4.1	4.6
Lantana (R)	9.7	9.2	9.4	8.6	8.0	8.3	5.8	4.4	5.1
Marigold (L)	9.9	9.8	9.8	8.2	7.6	7.9	5.6	4.6	5.1
Marigold (R)	10.2	10.6	10.4	8.9	7.8	8.3	5.8	4.9	5.3
Cassia (L)	9.9	9.3	9.6	9.1	8.3	8.7	6.2	5.2	5.7
Cassia (R)	10.1	9.5	9.8	9.3	8.6	8.9	6.7	6.3	6.5
Parthenium (L)	8.6	8.1	8.3	6.9	6.4	6.6	4.4	3.7	4.0
Parthenium (R)	8.8	8.4	8.6	7.2	6.5	6.8	4.6	4.2	4.4
Clerodendron (L)	8.7	8.5	8.6	7.2	6.6	6.9	4.9	3.6	4.2
Clerodendron (R)	8.9	8.6	8.7	7.8	7.0	7.4	5.1	4.3	4.7
Control	12.1	12.1	12.1	10.9	10.9	10.9	9.6	9.6	9.6
	SEm±	CD 5%		SEm±	CD 5%		SEm±	CD 5%	
For comparing species (S)	0.058	0.164		0.059	0.168		0.058	0.165	
For comparing concentrations (C)	0.022	0.062		0.022	0.064		0.022	0.062	
Interaction (S X C)	0.082	0.232		0.084	0.238		0.082	0.234	

L = Leaf extract DAS - Days after spraying

R = Root extract

Table 11. Effect of crop/weed extracts on photosynthetic rate (µmol CO_2 dm^2/s) at different stages in *Chromolaena odorata* leaves

Treatments	5 DAS			10 DAS			15 DAS		
	Concentrations (per cent)								
	5	10	Mean	5	10	Mean	5	10	Mean
Paddy (L)	10.8	9.2	10.0	9.2	7.8	8.5	8.6	7.2	7.9
Paddy (R)	11.6	9.8	10.7	9.6	8.6	9.1	9.0	7.6	8.3
Sunflower (L)	6.7	5.3	6.0	6.1	5.0	5.5	5.7	4.1	4.9
Sunflower (R)	8.1	7.0	7.5	6.9	6.2	6.5	6.2	4.6	5.4
Lantana (L)	6.2	4.8	5.5	5.0	3.2	4.1	3.9	2.2	3.0
Lantana (R)	7.6	5.2	6.4	5.6	3.8	4.7	4.6	2.1	3.8
Marigold (L)	5.2	4.6	4.9	4.8	3.6	4.2	4.2	3.0	3.6
Marigold (R)	6.0	5.1	5.5	5.2	4.2	4.7	4.8	3.6	4.2
Cassia (L)	7.2	5.8	6.5	7.1	5.1	6.1	5.6	4.3	4.9
Cassia (R)	9.2	8.2	8.7	8.0	7.6	7.8	6.6	4.7	5.6
Parthenium (L)	2.9	1.4	2.1	2.0	1.2	1.6	1.6	1.1	1.3
Parthenium (R)	2.7	1.8	2.2	2.3	1.6	1.9	1.9	1.3	1.6
Clerodendron (L)	4.1	3.2	3.6	3.0	2.1	2.5	2.8	1.8	2.3
Clerodendron (R)	4.2	3.8	4.0	3.6	3.0	2.3	3.1	2.2	2.6
Control	13.6	13.6	13.6	12.2	12.2	12.2	12.0	12.0	12.0
	SEm±	CD 5%		SEm±	CD 5%		SEm±	CD 5%	
For comparing species (S)	0.038	0:107		0.055	0.155		0.043	0.121	
For comparing concentrations (C)	0.014	0.041		0.021	0.058		0.016	0.046	
Interaction (S X C)	0.053	0.152		0.077	0.219		0.061	0.172	

L = Leaf extract DAS - Days after spraying

R = Root extract

observation at 5, 10 and 15 DAS showed significant differences due to various species and concentrations. All the extracts significantly reduced the photosynthetic rate at all the stages. At 5 DAS, the rate of photosynthesis was lowest with parthenium (2.1) followed by clerodendron (3.6) and the highest in control (13.6). Leaf reduced the photosynthetic rate more as compared to root extracts at all the stages.

With an increase in the concentration of extracts from 5 to 10 per cent, photosynthetic rate decreased significantly at all the growth stages. At 5 DAS, higher concentration of leaf extract significantly reduced the photosynthetic rate and the lower values were recorded with parthenium (1.4), followed by clerodendron (3.2) and marigold (4.6).

At 10 DAS, the rate of photosynthesis was lowest with parthenium (1.6) followed by clerodendron (2.5) and the highest in control (12.2). Higher concentration of leaf extracts significantly reduced the photosynthetic rate and the lower values were found with parthenium (1.2), followed by clerodendron (2.1) and lantana (3.2).

At 15 DAS, the rate of photosynthesis was lowest with parthenium (1.3), followed by clerodendron (2.3) and the highest in control (12.0). Higher concentration of leaf extract significantly reduced the photosynthetic rate and the lower values were recorded with parthenium (1.1) followed by clerodendron (1.8) and lantana (2.2).

4.1.3.4 Stomatal resistance (R, s cm^{-1})

The effect of crop/weed extracts on stomatal resistance (R) in *Chromolaena odorata* leaves at different stages indicated an increase in the stomatal resistance from 5 to 15 DAS and the increase was more between 10 and 15 DAS (Table 12).

The observations at 5, 10 and 15 DAS showed significant differences due to various species and concentrations. All the extracts significantly increased the stomatal resistance at all the stages and at 5 DAS, the stomatal resistance was highest with parthenium extracts (15.2) followed by clerodendron (14.9) and the lowest in control (9.6). Leaf extracts resulted in significantly higher stomatal resistance as compared to root extracts at all the stages.

Table 12. Effect of crop/weed extracts on stomatal resistance (S cm^{-1}) at different stages in *Chromolaena odorata* leaves

Treatments	5 DAS			10 DAS			15 DAS		
	Concentrations (per cent)								
	5	10	Mean	5	10	Mean	5	10	Mean
Paddy (L)	10.2	10.6	10.4	11.1	11.5	11.3	13.5	14.1	13.8
Paddy (R)	9.7	9.8	9.7	10.2	10.8	10.5	12.8	13.3	13.0
Sunflower (L)	12.6	13.2	12.9	13.8	14.6	14.2	15.8	16.0	15.9
Sunflower (R)	12.1	12.6	12.3	13.2	14.1	13.6	14.6	15.1	14.8
Lantana (L)	13.6	13.8	13.7	15.3	15.5	15.4	17.5	17.9	17.7
Lantana (R)	13.4	13.6	13.5	14.2	14.3	14.2	17.0	17.3	17.1
Marigold (L)	12.6	13.0	12.8	14.6	14.8	14.7	16.2	16.8	16.5
Marigold (R)	12.0	12.4	12.2	14.0	14.4	14.2	16.0	16.6	16.3
Cassia (L)	12.8	13.3	13.0	13.9	14.7	14.3	15.7	16.1	15.9
Cassia (R)	12.2	12.4	12.3	13.3	14.0	13.6	14.8	15.0	14.9
Parthenium (L)	15.0	15.4	15.2	15.2	16.8	16.5	18.6	18.5	18.5
Parthenium (R)	14.3	14.7	14.5	14.8	15.2	15.0	17.9	18.3	18.1
Clerodendron (L)	14.6	15.2	14.9	16.0	15.8	15.9	18.0	18.2	18.1
Clerodendron (R)	14.2	14.8	14.5	14.7	15.1	14.9	17.2	17.8	17.5
Control	9.6	9.6	9.6	11.2	11.2	11.2	12.1	12.1	12.1
	SEm±	CD 5%		SEm±	CD 5%		SEm±	CD 5%	
For comparing species (S)	0.062	0.174		0.074	0.209		0.069	0.195	
For comparing concentrations (C)	0.023	0.006		0.028	0.079		0.026	0.074	
Interaction (S X C)	0.087	NS		0.104	0.295		0.097	NS	

L = Leaf extract DAS - Days after spraying

R = Root extract

Increase in the concentration of extracts (5 to 10%), increased the stomatal resistance at all the stages. At 5 DAS, higher concentration (10%) of leaf extracts significantly increased the stomatal resistance and the values were highest with parthenium (15.4) followed by clerodendron (15.2), lantana (13.8) and cassia (13.3). At 10 DAS, the stomatal resistance was significantly highest with parthenium (16.5) followed by clerodendron (15.9), and the lowest in paddy root extract (10.5).

At higher concentration of leaf extracts, the stomatal resistance increased significantly and the values were more with parthenium (16.8) followed by clerodendron (15.8) and lantana (15.5). At 15 DAS, the stomatal resistance was significantly higher with parthenium (18.5) followed by clerodendron (18.1) and the lowest in control (12.1). With an increase in concentration of leaf extracts, stomatal resistance increased significantly. .pl47

4.1.3.5 Leaf temperature (°C)

The effect of crop/weed extracts on leaf temperature in *Chromolaena odorata* leaves at different stages indicated an increase in the leaf temperature from 5 to 15 DAS (Table 13). The observation at 5, 10 and 15 DAS showed significant differences due to various species and concentrations. All the extracts significantly increased the leaf temperature at all the growth stages. At 5 DAS, the leaf temperature was significantly more with parthenium (32.15) followed by clerodendron (31.68) and the lowest in control (29.2). Leaf extracts recorded significantly higher leaf temperature as compared to root extracts at all the stages. At 10 DAS, the leaf temperature increased significantly and it was more with parthenium (32.5) followed by clerodendron (32.35) and the lowest in control (30.0). At 15 DAS, leaf extracts significantly increased the leaf temperature and it was higher with parthenium (34.0) followed by clerodendron (33.65) and the lowest in control (30.6).

With an increase in concentration of extracts from 5 to 10 per cent, the leaf temperature increased significantly at all the stages. Higher concentration of leaf extract significantly increased the leaf temperature and higher values were recorded with parthenium (34.2) followed by clerodendron (34.2) and lantana (33.9).

Table 13. Effect of crop/weed extracts on leaf temperature (°C) at different stages in *Chromolaena odorata* leaves

Treatments	5 DAS			10 DAS			15 DAS		
	Concentrations (per cent)								
	5	10	Mean	5	10	Mean	5	10	Mean
Paddy (L)	29.9	30.1	30.0	30.9	31.3	31.1	31.6	31.9	31.8
Paddy (R)	29.5	29.7	29.6	30.5	30.7	30.6	30.9	31.3	31.1
Sunflower (L)	30.6	30.8	30.7	31.6	31.4	31.5	32.2	32.9	32.6
Sunflower (R)	29.9	30.0	29.9	30.9	31.2	31.0	30.9	31.6	31.3
Lantana (L)	31.0	29.9	30.4	32.1	32.6	32.3	33.0	33.9	33.5
Lantana (R)	30.6	30.1	30.3	31.6	31.8	31.7	32.8	32.8	32.8
Marigold (L)	29.8	30.2	30.0	32.0	30.8	31.4	32.9	33.4	33.2
Marigold (R)	29.6	29.6	29.6	31.6	31.2	31.4	32.6	33.2	32.9
Cassia (L)	30.5	30.1	30.3	30.8	31.6	31.2	32.0	33.0	32.5
Cassia (R)	29.8	29.9	29.8	29.8	30.1	29.9	31.6	32.6	31.9
Parthenium (L)	32.1	32.2	32.1	32.6	32.4	32.5	33.8	34.2	34.0
Parthenium (R)	31.9	32.0	31.9	32.1	32.0	32.0	32.9	33.6	33.2
Clerodendron (L)	31.5	31.8	31.7	32.2	32.5	32.3	33.1	34.2	33.6
Clerodendron (R)	31.6	31.8	31.7	32.0	32.0	33.1	33.0	33.8	33.4
Control	29.2	29.2	29.2	30.0	30.0	30.0	30.6	30.6	30.6
	SEm±	CD 5%		SEm±	CD 5%		SEm±	CD 5%	
For comparing species (S)	0.035	0.155		0.082	0.232		0.050	0.142	
For comparing concentrations (C)	0.021	NS		0.031	NS		0.019	0.054	
Interaction (S X C)	0.078	0.220		0.116	0.328		0.071	0.201	

L = Leaf extract DAS - Days after spraying

R = Root extract

4.2 EXPERIMENT II : USE OF ADDITIVES TO INCREASE THE EFFICACY OF HERBICIDES IN EUPATORIUM (*Chromolaena odorata*)

4.2.1 MORPHOLOGICAL CHARACTERS

4.2.1.1 Plant height (cm)

The effect of herbicides and additives on plant height in *Chromolaena odorata* is presented in Table 14. The data on plant height indicated significant differences due to treatments at 15 DAS. Among the treatments significantly lower plant height was recorded in glyphosate + ammonium sulphate followed by 2,4-D + ammonium sulphate as compared to all other treatments and control. The plant height reduced significantly due to herbicide treatments. However, the maximum plant height was recorded in control (71.6). Among the 2,4-D treatments, lower plant height was recorded in 2,4-D (4000 ppm) followed by 2,4-D (2000 ppm) + $(NH_4)_2$ SO_4, (1%), 2,4-D (3000 ppm), 2,4-D (2000 ppm) + Urea (1%), 2,4-D (2000 ppm) + KNO_3 (1%) and 2,4-D (2000 ppm) as compared to control.

The glyphosate treatments recorded lower plant height and it was lowest in Glyphosate (2000 ppm) + $(NH_4)_2$ SO_4 (1%) followed by Glyphosate (4000 ppm), Glyphosate (2000 ppm) + Urea (1%), Glyphosate (2000 ppm) + KNO_3 (1%) and Glyphosate (3000 ppm).

The effect of herbicides on dry matter of leaves and stem in *Chromolaena odorata* presented in Table 14, indicated significant differences due to various treatments. The leaf dry matter was significantly lowest in glyphosate (2000 ppm) + $(NH4)_2$ SO_4 (1%) (3.5 g/plant) followed by glyphosate (4000 ppm) (4.2 g/plant) and was highest in control (14.5 g/plant). The effect of glyphosate treatments was more than 2,4-D treatment combinations in reducing the leaf dry matter accumulation. Among glyphosate treatments, Glyphosate (2000 ppm) + $(NH_4)_2$ SO_4 (1%) was superior and reduced leaf dry matter significantly as compared to control. In 2,4-D combinations, significantly lowest leaf dry matter was recorded in 2,4-D (4000 ppm) which was on par with 2,4-D (2000 ppm) + $(NH_4)_2$ SO_4 (1%) as compared to control.

Table 14. **Effect of herbicides and additives on plant height (cm) and dry matter accumulation (g/plant) in *Chromolaena odorata* at 15 Days after spraying (DAS)**

Treatments	Plant height (cm)	Leaf dry matter (g)	Stem dry matter (g)
Control	71.60	14.5	43.7
2,4-D (2000 ppm) + Urea (1%)	69.20	6.1	28.8
2,4-D (2000 ppm) + KNO_3 (1%)	69.50	7.1	30.2
2,4-D (2000 ppm) + $(NH_4)_2SO_4$ (1%)	68.20	5.5	22.7
2,4-D (2000 ppm)	69.90	8.2	30.7
2,4-D (3000 ppm)	68.70	5.9	28.1
2,4-D (4000 ppm)	67.60	5.2	22.5
Glyphosate (2000 ppm) + Urea (1%)	67.45	5.3	22.3
Glyphosate (2000 ppm) + KNO_3 (1%)	67.90	5.8	26.9
Glyphosate (2000 ppm) + $(NH_4)_2SO_4$ (1%)	66.70	3.5	20.3
Glyphosate (2000 ppm)	68.50	6.9	29.3
Glyphosate (3000 ppm)	68.40	4.8	27.9
Glyphosate (4000 ppm)	67.90	4.2	21.9
SEm±	0.25	0.11	0.06
CD at 5%	0.73	0.32	0.19

DAS - Days after spraying

The stem dry matter decreased significantly due to herbicides and additives treatments. The lowest stem dry matter was recorded in Glyphosate (2000 ppm) + $(NH_4)_2$ SO_4) (1%) and was highest in control (43.75). Among glyphosate treatments, the stem dry matter was significantly lowest in Glyphosate (2000 ppm) + $(NH_4)_2$ SO_4 (1%) followed by Glyphosate (4000 ppm), Glyphosate (2000 ppm) + Urea (1%), Glyphosate (2000 ppm) + KNO_3 (1%), Glyphosate (3000 ppm) and Glyphosate (2000 ppm) as compared to control. Among 2,4-D herbicide combinations, the stem dry matter was significantly lowest in 2,4-D (4000 ppm) followed by 2,4-D (2000 ppm) + $(NH_4)_2$ SO_4 (1%), which were on par with each other as compared to control.

4.2.2 BIOCHEMICAL PARAMETERS

4.2.2.1 Chlorophyll a content (mg g fresh wt^{-1})

Chlorophyll a content decreased from 2 DAS to 6 DAS in all the treatments and there was a significant decrease in chlorophyll a content due to herbicides and additives as compared to control (Table 15). At 2 DAS, the chlorophyll a content declined to almost half in herbicide treatments as compared to control and the similar trend continued even at later samplings. Among the herbicide treatments, 2,4-D (2000 ppm) + KNO_3 (1%) recorded significantly lower chlorphyll a content at all the stages. Similarly, the maximum chlorophyll a content was recorded in 2,4-D (3000 ppm) 2,4-D (2000 ppm) at all the stages. However, no significant differences were observed between 2,4-D (2000 ppm) + $(NH_4)_2$ SO_4 (1%) and 2,4-D (4000 ppm), Glyphosate (2000 ppm) + KNO_3 (1%), Glyphosate (2000 ppm) + $(NH_4)_2$ SO_4 and Glyphosate (2000 ppm) at 2 DAS. Glyphosate (2000 ppm) + Urea (1%), Glyphosate (2000 ppm) + $(NH_4)_2$ SO_4 (1%), Glyphosate (2000 ppm), 2,4-D (2000 ppm) + KNO_3 (1%) and 2,4-D (3000 ppm) at 4 DAS and Glyphosate (2000 ppm), Glyphosate (3000 ppm), 2,4-D (4000 ppm) and 2,4-D (2000 ppm) + KNO_3 (1%) at 6 DAS were at par with each other.

4.2.2.2 Chlorophyll b (mg g fresh wt^{-1})

Chlorophyll b content also declined from 2 DAS to 6 DAS and differed significantly at all the stages. It was further observed that there was a significant decrease in chlorophyll b content due to herbicides and additives as compared to control at all the stages.

Table 15. Effect of herbicides and additives on chlorophyll content (mg g fresh wt^{-1}) in *Chromolaena odorata*

Treatments	Chlorophyll a			Chlorophyll b			Total Chlorophyll		
	2 DAS	4 DAS	6 DAS	2 DAS	4 DAS	6 DAS	2 DAS	4 DAS	6 DAS
Control	0.810	0.790	0.800	1.496	1.520	1.490	2.306	2.310	2.309
2,4-D(2000 ppm)+Urea (1%)	0.461	0.420	0.398	1.170	1.025	0.906	1.631	1.445	1.346
2,4-D(2000 ppm)+KNO_3 (1%)	0.429	0.389	0.368	1.156	1.004	0.896	1.585	1.393	1.306
2,4-D(2000 ppm)+$(NH_4)_2SO_4$ (1%)	0.456	0.448	0.416	1.178	1.023	0.911	1.634	1.471	1.374
2,4-D(2000 ppm)	0.490	0.485	0.489	1.165	1.132	0.918	1.655	1.616	1.481
2,4-D(3000 ppm)	0.469	0.463	0.459	1.153	1.125	0.889	1.622	1.586	1.436
2,4-D(4000 ppm)	0.441	0.428	0.390	1.149	1.225	0.876	1.590	1.566	1.364
Glyphosate(2000 ppm)+Urea (1%)	0.473	0.468	0.439	1.112	0.989	0.985	1.585	1.457	1.435
Glyphosate(2000 ppm)+KNO_3 (1%)	0.456	0.439	0.405	1.114	0.983	0.968	1.570	1.425	1.396
Glyphosate(2000 ppm)+$(NH_4)_2SO_4$ (1%)	0.481	0.469	0.455	1.120	0.996	0.966	1.601	1.465	1.440
Glyphosate(2000 ppm)	0.478	0.469	0.452	1.115	0.987	0.963	1.593	1.456	1.431
Glyphosate(3000 ppm)	0.463	0.458	0.451	1.020	0.965	0.951	1.483	1.424	1.411
Glyphosate(4000 ppm)	0.451	0.396	0.390	0.989	0.976	0.946	1.440	1.372	1.349
SEm±	0.003	0.004	0.002	0.001	0.025	0.005	0.003	0.006	0.031
CD at 5%	0.008	0.011	0.007	0.004	0.072	0.016	0.001	0.017	0.090

At 2 DAS, among herbicide treatments 2,4-D (2000 ppm) + $(NH_4)_2$ SO_4 (1%) and 2,4-D (2000 ppm) + KNO_3 (1%), Glyphosate (4000 ppm) recorded significantly higher and lower chlorophy.b contents respectively. However, the treatments Glyphosate (2000 ppm) + KNO_3 (1%) and Glyphosate (2000 ppm) + $(NH_4)_2$ SO_4 (1%) were at on par with each other. At 4 DAS, the treatment 2,4-D (4000 ppm) among the herbicide combinations recorded significantly higher chlorophyll b content, whereas Glyphosate (3000 ppm) had significantly lower chlorophyll "b" content. However, the treatment 2,4-D (2000 ppm) + Urea (1%), and 2,4-D (2000 ppm) + $(NH_4)_2$ SO_4 (1%) ; Glyphosate (2000 ppm) + Urea (1%), Glyphosate (2000 ppm) + KNO_3 (1%), Glyphosate (2000 ppm) + $(NH_4)_2$ SO_4 (1%), Glyphosate (2000 ppm) and Glyphosate (4000 ppm) did not differ significantly among themselves and where at on par with each other.

4.2.2.3 Total chlorophyll content (mg g fresh wt^{-1})

The data on total chlorophyll content indicated that it significantly decreased due to herbicides and additives at all the stages (Table 15). However, the total chlorophyll content declined from 2 to 6 DAS, in all the treatments except in control, where there was a slight increase as compared to the previous stages. Among various treatment combinations, 2,4-D (3000 ppm), 2,4-D (2000 ppm) recorded significantly higher total chlorophyll content at all the stages. Whereas, significantly lower total chlorophyll content was recorded in (Glyphosate (4000 ppm) at all the stages.

The treatment Glyphosate (2000 ppm) + KNO_3 (1%) and Glyphosate (4000 ppm), Glyphosate (2000 ppm) + Urea (1%) and Glyphosate (2000 ppm) were at on par with each other at 4 DAS. Whereas at 6 DAS, treatments 2,4-D (2000 ppm) + $(NH_4)_2$ SO_4 (1%), 2,4-D (4000 ppm), Glyphosate (2000 ppm) + KNO_3 (1%) ; 2,4-D (4000 ppm) 2,4-D (3000 ppm), Glyphosate (2000 ppm) + Urea (1%), Glyphosate (2000 ppm) + $(NH_4)_2$ SO_4 (1%), Glyphosate (2000 ppm) and Glyphosate (3000 ppm) are did not differ significantly among themselves.

4.2.2.4 Total soluble sugars (mg g dry wt^{-1})

The data on total solable sugars in *chromolaena odorata* presented in Table 16 revealed significant differences due to various herbicides and additives treatments at all the

Table 16. Effect of herbicides and additives on total soluble sugar content in (mg g dry wt^{-1}) *Chromolaena odorata*

Treatments	2 DAS	4 DAS	6 DAS
Control	23.6	23.8	23.9
2,4-D (2000 ppm) + Urea (1%)	20.7	20.2	18.1
2,4-D (2000 ppm) + KNO_3 (1%)	20.9	20.6	18.4
2,4-D (2000 ppm) + $(NH_4)_2SO_4$ (1%)	19.4	17.2	15.8
2,4-D (2000 ppm)	22.2	21.5	20.7
2,4-D (3000 ppm)	20.3	19.8	17.3
2,4-D (4000 ppm)	18.6	17.0	15.6
Glyphosate (2000 ppm) + Urea (1%)	20.1	18.6	17.5
Glyphosate (2000 ppm) + KNO_3 (1%)	20.6	18.9	17.8
Glyphosate (2000 ppm) + $(NH_4)_2SO_4$ (1%)	18.2	17.3	15.6
Glyphosate (2000 ppm)	22.2	19.6	18.8
Glyphosate (3000 ppm)	21.8	19.3	18.5
Glyphosate (4000 ppm)	19.0	17.5	15.8
SEm±	0.280	0.074	0.091
CD at 5%	0.840	0.216	0.264

stages and it decreased from 2 DAS to 6 DAS. Significantly higher total soluble sugars was recorded in control at all the stages. At 2 DAS, among Glyphosate treatments, total soluble sugar content was lowest in Glyphosate (2000 ppm) + $(NH_4)_2 SO_4$ (1%) followed by Glyphosate (4000 ppm) as compared to control. The treatments with 2,4-D and additives resulted in a significant decrease in total soluble sugars. Among 2,4-D treatments, the lowest sugar content was recorded in 2,4-D (4000 ppm) followed by 2,4-D (2000 ppm) + $(NH_4)_2 SO_4$ as compared to control. The similar trend was observed at 4 DAS and 6 DAS in all the herbicide treatments. There was a significant reduction in total soluble sugars due to the combination of additives with different herbicides.

4.2.2.5 Total free phenols (mg g dry wt^{-1})

Total free phenol content in *Chromolaena adorata* leaves as influenced by herbicides with additives are given in Table 17. The data on phenol content indicated significant differences due to treatments at all the stages except at 2 DAS. There was a significant increase in total free phenols due to some herbicides and significant decrease in some herbicides as compared to control.

At 2 DAS, the maximum phenol content was observed in 2,4-D (4000 ppm) and was minimum in Glyphosate (4000 ppm). At 4 DAS, the treatment Glyphosate (2000 ppm) + $(NH_4)_2 SO_4$ (1%) recorded significantly higher phenols over all other treatments including control. Similarly significant lower phenol content was recorded in 2,4-D (2000 ppm) + $(NH_4)_2 SO_4$ (1%). However, the treatments 2,4-D (2000 ppm) + Urea (1%), 2,4-D (4000 ppm), Glyphosate (3000 ppm) and Glyphosate (4000 ppm); 2,4-D (2000 ppm) + KNO_3 (1%), 2,4-D (2000 ppm) + $(NH_4)_2 SO_4$, and Glyphosate (2000 ppm) + KNO_3 (1%) ; 2,4-D (3000 ppm), Glyphosate (3000 ppm) and Glyphosate (4000 ppm) did not differ significantly among themselves.

At 6 DAS, significantly higher total free phenol content was recorded in Glyphosate (4000 ppm) as compared to all other treatments including control. Significantly lower phenol content was observed in Glyphosate (2000 ppm) + KNO_3 (1%). However 2,4-D (2000 ppm) + KNO_3 (1%), 2,4-D (2000 ppm) + $(NH_4)_2 SO_4$ (1%), and Glyphosate (2000 ppm) + KNO_3 (1%) ; 2,4-D (2000 ppm) + Urea (1%), 2,4-D (3000 ppm), Glyphosate (2000 ppm) + Urea (1%), and Glyphosate (2000 ppm) + $(NH_4)_2 SO_4$ (1%) were at on par with each other.

Table 17. Effect of herbicides and additives on total free phenols (mg g dry weight^{-1})*Chromolaena odorata*

Treatments	2 DAS	4 DAS	6 DAS
Control	8.78	10.60	10.90
2,4-D (2000 ppm) + Urea (1%)	7.56	8.68	8.03
2,4-D (2000 ppm) + KNO_3 (1%)	7.70	7.33	6.30
2,4-D (2000 ppm) + $(NH_4)_2SO_4$ (1%)	7.35	7.13	6.35
2,4-D (2000 ppm)	8.00	8.10	7.04
2,4-D (3000 ppm)	7.80	8.25	7.56
2,4-D (4000 ppm)	8.50	8.65	7.25
Glyphosate (2000 ppm) + Urea (1%)	7.85	9.25	8.15
Glyphosate (2000 ppm) + KNO_3 (1%)	8.20	7.15	6.30
Glyphosate (2000 ppm) + $(NH_4)_2SO_4$ (1%)	7.45	10.40	8.20
Glyphosate (2000 ppm)	7.68	7.80	7.85
Glyphosate (3000 ppm)	7.83	8.40	9.15
Glyphosate (4000 ppm)	5.35	8.25	10.25
SEm±	0.610	0.146	0.042
CD at 5%	NS	0.427	0.123

4.2.3 BIOPHYSICAL PARAMETERS

4.2.3.1 Relative water content (%)

The data on relative water content (RWC, %) revealed a decreasing trend from 2 DAS to 6 DAS (Table 18). The various herbicide treatments significantly reduced the RWC at all the stages studied (2,4 and 6 DAS). Among glyphosate treatments, RWC was less in (Glyphosate (2000 ppm) + $(NH_4)_2$ SO_4 (1%) and Glyphosate (4000 ppm) which were on par with each other followed by Glyphosate (2000 ppm) + Urea (1%) and Glyphosate (2000 ppm) + KNO_3 (1%). The treatments with 2, 4-D combinations resulted in significant reduction in RWC and it was lowest in 2,4-D (4000 ppm) and 2,4-D (2000 ppm) + $(NH_4)_2$ SO_4 (1%) which were on par with each other as compared to control.

4.2.3.2 Photosynthetic rate (µmol CO2 dm^2/s)

The effect of herbicides and additives on photosynthetic rate in *Chromolaena odorata* leaves at different stages is presented in Table 19.

The rate of photosynthesis decreased from 2 DAS to 6 DAS. Various herbicide treatments significantly reduced the photosynthetic rate at all the stages as compared to control. Among the Glyphosate treatments, the lowest photosynthetic rate was recorded in Glyphosate (2000 ppm) + $(NH_4)_2$ SO_4 (1%) followed by Glyphosate (4000 ppm) which were on par with each other as compared to control. The herbicide 2,4-D and additive treatments also decreased photosynthetic rate significantly. The rate of photosynthesis was lowest in 2,4-D (4000 ppm) followed by 2,4-D (2000 ppm) + $(NH_4)_2$ SO_4 (1%) which were on par with other.

At 4 DAS, the Glyphosate and additive treatments significantly decreased the photosynthetic rate as compared to control. The lowest values of the photosynthetic rate were observed in Glyphosate (2000 ppm) + $(NH_4)_2$ SO_4 (1%) followed by Glyphosate (4000 ppm) which were on par with each other as compared to control. Whereas, the 2,4-D treatments significantly decreased the photosynthetic rate and the lower values were observed in 2,4-D (4000 ppm) followed by 2,4-D (2000 ppm) + $(NH_4)_2$ SO_4 (1%) which were on par with each other as compared to control. At 6 DAS, the Glyphosate and additive treatments significantly decreased the photosynthetic rate as compared to control. The lowest values of the

Table 18. **Effect of herbicides and additives on relative water content (RWC, %) in *Chromolaena odorata***

Treatments	2 DAS	4 DAS	6 DAS
Control	84.4	84.3	83.5
2,4-D (2000 ppm) + Urea (1%)	75.2	69.1	62.4
2,4-D (2000 ppm) + KNO_3 (1%)	76.1	70.2	63.8
2,4-D (2000 ppm) + $(NH_4)_2SO_4$ (1%)	73.2	66.1	58.8
2,4-D (2000 ppm)	76.3	73.7	64.6
2,4-D (3000 ppm)	73.3	68.6	61.3
2,4-D (4000 ppm)	71.3	65.9	57.6
Glyphosate (2000 ppm) + Urea (1%)	71.8	66.5	60.9
Glyphosate (2000 ppm) + KNO_3 (1%)	72.5	67.3	61.2
Glyphosate (2000 ppm) + $(NH_4)_2SO_4$ (1%)	70.4	62.9	53.2
Glyphosate (2000 ppm)	73.1	68.9	63.9
Glyphosate (3000 ppm)	72.6	68.2	62.9
Glyphosate (4000 ppm)	70.7	63.9	54.5
SEm±	0.72	0.39	0.49
CD at 5%	2.11	1.14	1.44

Table 19. Effect of herbicides and additives on photosynthetic rate in *Chromolaena odorata* ($\mu mol\ CO_2\ dm^{-2}\ s^{-1}$)

Treatments	2 DAS	4 DAS	6 DAS
Control	6.12	6.10	6.00
2,4-D (2000 ppm) + Urea (1%)	3.42	2.05	1.45
2,4-D (2000 ppm) + KNO_3 (1%)	3.63	2.66	2.13
2,4-D (2000 ppm) + $(NH_4)_2SO_4$ (1%)	2.23	1.00	1.00
2,4-D (2000 ppm)	4.46	3.06	2.80
2,4-D (3000 ppm)	2.46	1.35	1.10
2,4-D (4000 ppm)	1.43	1.00	0.80
Glyphosate (2000 ppm) + Urea (1%)	1.42	1.10	0.80
Glyphosate (2000 ppm) + KNO_3 (1%)	1.61	1.20	0.90
Glyphosate (2000 ppm) + $(NH_4)_2SO_4$ (1%)	1.06	0.80	0.56
Glyphosate (2000 ppm)	3.10	1.81	1.22
Glyphosate (3000 ppm)	2.50	1.45	1.10
Glyphosate (4000 ppm)	1.10	0.88	0.67
SEm±	0.45	0.42	0.38
CD at 5%	0.93	0.96	0.97

photosynthetic rate were observed in Glyphosate (2000 ppm) + $(NH_4)_2 SO_4$ (1%) followed by Glyphosate (4000 ppm) which were on par with each other as compared to control. Whereas in 2,4-D and additives treatments, the photosynthetic rate significantly decreased as compared to control. The lower values of photosynthetic rate was recorded in 2,4-D (4000 ppm) followed by 2,4-D (2000 ppm) + $(NH_4)_2 SO_4$ (1%) which were on par with each other as compared to control.

4.2.3.3 Stomatal conductance (cm s^{-1})

The effect of herbicides on stomatal conductance in *Chromolaena odorata* presented in Table 20 indicated taht it decreased from 2 DAS to 6 DAS.

At 2 DAS, the stomatal conductance was reduced significantly due to herbicide treatments and it was highest in control. The glyphosate and additive treatments significantly decreased the stomotal conductance as compared to control. The lowest values of the stomatal conductance were observed in Glyphosate (2000 ppm) + $(NH_4)_2 SO_4$ (1%) followed by Glyphosate (4000 ppm) which were on par with each other as compared to control. 2,4-D and additive treatments significantly decreased the stomatal conductance. The lower values were observed in 2,4-D (2000 ppm) + $(NH_4)_2 SO_4$ (1%) followed by 2,4-D (4000 ppm) and were on par with each other as compared to control. However at 4 DAS and 6 DAS, the stomatal conductance values were non significant due to various treatments. The stomatal conductance was less in herbicide treatments as compared to control.

4.2.3.4 Leaf temperature (°C)

The leaf temperature did not differ significantly at various stages due to treatments (Table 21). At 2 DAS, the leaf temperature ranged from 29.1 °C (Glyphosate, 4000 ppm) to (31.6°C) Glyphosate (3000 ppm). At 4 DAS, the higher leaf temperature was recorded in 2,4-D (2000 ppm) + Urea (1%) and the lowest in Glyphosate (2000 ppm) + Urea (1%) ; Whereas at 6 DAS, the leaf temperature varied from 30.7°C (2,4-D 2000 ppm) + KNO_3 (1%) to 34.0°C (2,4-D, 4000 ppm).

Table 20. Effect of herbicides and additives on stomatal conductance (cm s^{-1}) on *Chromolaena odorata*

Treatments	2 DAS	4 DAS	6 DAS
Control	2.70	2.43	2.30
2,4-D (2000 ppm) + Urea (1%)	0.52	0.43	0.31
2,4-D (2000 ppm) + KNO_3 (1%)	0.61	0.50	0.46
2,4-D (2000 ppm) + $(NH_4)_2SO_4$ (1%)	0.37	0.33	0.22
2,4-D (2000 ppm)	0.70	0.63	0.52
2,4-D (3000 ppm)	0.40	0.36	0.30
2,4-D (4000 ppm)	0.36	0.30	0.22
Glyphosate (2000 ppm) + Urea (1%)	0.86	0.46	0.43
Glyphosate (2000 ppm) + KNO_3 (1%)	0.90	0.36	0.33
Glyphosate (2000 ppm) + $(NH_4)_2SO_4$ (1%)	0.56	0.43	0.31
Glyphosate (2000 ppm)	1.20	0.40	0.33
Glyphosate (3000 ppm)	0.92	0.66	0.51
Glyphosate (4000 ppm)	0.70	0.46	0.38
SEm±	0.24	0.18	0.21
CD at 5%	0.71	NS	NS

Table 21. Effect of herbicides and additives on leaf temperature (°C) on *Chromolaena odorata*

Treatments	2 DAS	4 DAS	6 DAS
Control	29.4	33.0	31.2
2,4-D (2000 ppm) + Urea (1%)	29.5	32.7	31.8
2,4-D (2000 ppm) + KNO_3 (1%)	30.5	32.3	30.6
2,4-D (2000 ppm) + $(NH_4)_2SO_4$ (1%)	30.2	32.5	31.6
2,4-D (2000 ppm)	30.8	32.3	31.6
2,4-D (3000 ppm)	30.5	32.0	34.0
2,4-D (4000 ppm)	30.6	32.0	32.6
Glyphosate (2000 ppm) + Urea (1%)	30.7	31.8	32.1
Glyphosate (2000 ppm) + KNO_3 (1%)	30.2	31.9	31.9
Glyphosate (2000 ppm) + $(NH_4)_2SO_4$ (1%)	31.0	32.0	31.9
Glyphosate (2000 ppm)	30.9	32.0	31.8
Glyphosate (3000 ppm)	31.6	31.9	32.0
Glyphosate (4000 ppm)	29.1	32.3	32.4
SEm±	5.843	6.046	0.623
CD at 5%	NS	NS	NS

DISCUSSION

V. DISCUSSION

Chromolaena odorata L. (K and R) is the most trouble some and obnoxious weed. It is perennial in nature and produces many suckers from the underground rhizomes and also produce millions of seeds, which can travel any distance in the air and can establish in uninfested areas. Several efforts have been made to combat the menace and its aggression in several areas, but no conclusive evidences have been drawn so far with respect to its eradication.

The integrated method of weed control is a comprehensive method, which includes both theoretical and practical aspects. Since, *Chromolaena odorata* grows on a variety of soils and climatic conditions, no single method can eradicate this noxious weed. The integrated approach includes methods like cultural, chemical and biological approach. The biological method of weed control refers to use of insects, nematodes, plant pathogens, viruses, and competing plants etc. The term allelopathy refers to the detrimental effects of one plant species on the germination, growth and development of another species, (Narwal, 1994).

In recent days, the use of plants/plant parts with allelopathic potential for the control of noxious weeds is gaining more importance . The allelopathic effect is due to the presence of various allelochmicals. The extracts from several plant species have been tried for the control of *Chromolaena odorata,* but not much progress has been made in this direction.

The herbicides interfere with several metabolic pathways. It has long been known that the efficacy of herbicides could be increased by mixing with compatible carriers. Lot of work has been done on these aspects in several problematic weeds, but not much work has been reported in *Chromolaena odorata*. The use of plants with allelopathic potential and the use of herbicides lead to several physiological and biochemical changes and thus can effectively suppress the growth, development and reproductive efficiency of *Chromolaena odorata*.

With this background, experiments were conducted with seven different species having allelopathic potential and to study the effect of leaf and root extracts on physiological, biophysical, biochemical and seed germination parameters in *Chromolaena odorata*. In another experiment, investigations were carried out to study the influence of herbicides alone and with additives on morpho physiological, biochemical and bio physical changes in *Eupatorium*. The results obtained are discussed in this chapter.

5.1 EXPERIMENT I : STUDIES ON THE ALLELOPATHIC EFFECTS OF CROP AND WEED EXTRACTS ON EUPATORIUM (*Chromolaena odorata*)

5.1.1 BIOCHEMICAL PARAMETERS

Chlorophyll a, Chlorophyll b, and total Chlorophyll contents decreased from 5 to 15 DAS and all aqueous extracts significantly reduced Chlorophyll a, Chlorophyll b, and total Chlorophyll. At all the stages studied, leaf extracts reduced Chlorophyll a, Chlorophyll b, and total Chlorophyll significantly as compared to control. Among the various plant extracts, parthenium, clerodendron and marigold were more effective in reducing the Chlorophyll content than other species. In general, leaf extracts were more deleterious for Chlorophyll content than the root extracts. Increasing concentration of extracts also significantly decreased the Chlorophyll a, Chlorophyll b, and total Chlorophyll contents. This suggest that, various extracts contain different allelochemicals and have impact on chlorophyll degradation and thus affect various metabolic activities. Mamata *et al.* (1992) reported that *Parthenium hysterophrus* contain allellochemicals like phenolic acid and 3- sesqueterprenes. Bikaram *et al*, (1992) reported that marigold contain allelochemicals like ocimenone, B-ocimene, dehydro tagetome, xanthophyll and carotenoids.

Ambica and Vidya (1994) have identified 20 phenolics and alkaloids from *Lantana camara*. Kohli *et al.* (1985) reported a reduction in chlorophyll content of rape seedlings due to parthenium extracts. Dharmaraj *et al.* (1994) reported a greater reduction in chlorophyll content of Trianthema species due to sunflower extracts.

The mean sugar content of *Eupatorium* decreased from 5 to 15 days after spraying. All the extracts significantly reduced the total sugar content and the reduction was more in leaf extracts than the root extracts at all the stages. Among the various crop/weed extracts, parthenium, clerodendron and lantana, significantly decreased the sugar content which indicated that these extracts were more deleterious for *Chromolaena odorata*.

Increasing concentrations of extracts resulted in a significant decrease of total sugar content, which may be attributed to higher amount of allelochemicals. The present study also suggested that, various extracts affect sugar metabolism in the sprayed plants. Ambika and Jayachandra (1980) and Doddamani (1992) also reported a reduction in sugar content due to allelochemicals of plant species, and suggested that the allelochemicals affect various biochemical pathways leading to distorted metabolic activities in the plants. Kohli *et al* (1985) reported a reduction in sugar content of crop plants viz., pigeonpea, lentil, mungbean and blackgram due to extracts of *Parthenium hysterophorus*.

The total free phenols increased from 5 to 15 DAS. All the extracts resulted in a significant decrease of total free phenol content at all the stages. Leaf extracts reduced total free phenols more than the root extracts, indicating greater effect of leaf allelochemicals in decreasing free phenol content. Among the various species, *Lantana camara, Cassia sericea* decreased the total free phenol content at 5 DAS, whereas, at 10 and 15 DAS, the extracts of marigold and sunflower significantly reduced the total phenol content. Increasing concentration of extracts decreased the total free phenols at all the stages. This data suggests that the allelochemicals of various plant extracts alter biochemical pathways in the plants and thus bring about alteration in enzymes and finally resulting in change of biochemical constituents. Ambica and Vidya (1994) reported that the *Lantana camara* extracts contain very high concentrations of various alkaloids and phenolics and affect plant metabolism. They further suggested that, *Lantana camara* contain nearly 20 phenolic compounds and alkaloids.

5.1.2 GERMINATION STUDIES

The seeds collected from sprayed plants showed significant differences in per cent germination on 10th day. The per cent germination was significantly reduced due to various weed extracts and leaf extracts were more effective in reducing the per cent germination than the root extracts. Among the various weed extracts, the germination was more affected by parthenium, clerodendron and lantana. At 10 per cent concentration of extracts of parthenium and clerodendron, the per cent germination was zero which indicates the highest inhibitory effect of these weeds on the germination of *Chromolaena odorata*. Increasing concentration of extracts, resulted in decreased seed germination suggesting a greater effect of allelochemials on the development of seed.

Similarly, Doddamani (1992) reported a greater decrease in the germination of *Chromolaena odorata* with *Lantana camara* extracts. Ambica and Vidya (1994) also reported a reduced germination of ragi seeds due to allelochemicals present in *Lantana camara*. Rao *et al.* (1977), Dube *et al.* (1979), Ambica and Jayachandran (1980), Kohli *et al.* (1985) and Srivastava *et al.* (1985) also reported a significant reduction in the germination of various crop seeds viz barley, wheat, sorghum, peas, rape seed, radish, cabbage, due to extracts of parthenium and they also suggested that the inhibitory effect of parthenium extracts was due to presence of inhibitors such as parthenin, coronopilin, caffeic acid, p-coumaric acid, sesequeterpene lactones in these extracts.

5.1.3 BIOPHYSICAL PARAMETERS

Various crop/weed extracts significantly reduced the relative water content of *Chromolaena odorata* leaves. The relative water content decreased from 5 to 15 DAS, which indicates that these extracts affect water balance in the plant system. Leaf extracts reduced RWC to a greater extent than root extract thereby indicating the greater presence of allelochemicals in leaf rather than roots. Similarly, several workers have reported deleterious effect of leaf extracts on several species Viz., in parthenium, (Mamata and Mahadevappa, 1992) in *Chromolaena odorata* (Doddamani, 1992). *Cyperus rotundes* (Uppar *et al.*, 1994). They also reported the presence of more allelochmeicals in leaves than in stem or roots. Among the various extracts, significantly greater decrease in RWC was observed at all the stages with parthenium followed by clerodendron and lantana.

Increasing concentration of extracts decreased RWC to a greater extent, which indicates that the extract concentration plays a very important role in determining the efficacy of allelochemicals. Similarly, Schon and Einhelling (1982) also reported that the leaf water potential in sorghum leaves decreased drastically due to sunflower leaf extracts. Dharmaraj *et al.* (1994) also reported a reduction in RWC of *Trianthema* species due to sunflower leaf extracts.

The photosynthetic rate decreased from 5 to 15 DAS. Rice (1984) indicated that allelopathic agents influence the plant growth by affecting various physiological processes like cell division, respiration and photosynthesis. Carbon assimilation is very important parameter which influence the biomass production. All the extracts resulted in a significant decrease of photosynthetic rate at all the stages, which suggested that allelochemicals directly affect photosynthetic rate and may be due to inhibition of photosynthetic enzymes.

Leaf extracts were more detrimental in reducing the rate of photosynthesis than root extracts probably due to presence of more allelochemicals in leaves. Among the various plant species tested, the extracts of parthenium, clerodendron and marigold, decreased the photosynthetic rate significantly. Increasing concentration of extracts significantly decreased the rate of photosynthesis. Similarly, Dharmaraj *et al.* (1994) reported a significant decrease in photosynthetic rate of Trianthema sps, due to extracts of sunflower. Doddamani (1992) reported that the extracts of *Chromolaena odorata* reduced the photosynthetic rate of several species. Mamata and Mahadevappa, (1992) reported a reduction in the photosynthetic rate of parthenium due to *Cassia sericea* extracts.

Rate of transpiration decreased from 5 DAS to 15 DAS and the various extracts resulted in a significant decrease of transpiration rate at all the stages. Leaf extracts reduced the rate of transpiration more than that of root extracts. Among the various extracts, parthenium, clerodendron and lantana resulted in a significant decrease in the rate of tmaspiration. Increasing concentration of extracts resulted in significant decrease in rate of transpiration. This data suggests that the allelochemicals of various species have impact on the mechanism of stomatal opening and bring about changes in guard cells resulting in decreased rate of transpiration.

Rice (1984) also suggested that the allelochemicals influence various physiological processes including stomatal regulation. Our results also indicated that the stomotal resistance was more with leaf extracts than with root extracts and was significantly higher in the extracts of parthenium, clerodendron and lantana, thereby indicating that the increase of stomatal resistance might have lead to decrease in transpiration rate. The reduction in the transpiration rate might also be due to a drastic reduction in the RWC,due to which there will be loss of cell turgidity thereby reducing the water availability.

Stomatal resistance increased from 5-15 DAS. The various extracts resulted in a significant increase in the stomatal resistance suggesting the importance of allelochemicals of various extracts on the mechanism of gaseous exchange and resistance mechanisms. Leaf extracts increased the stomatal resistance more than that of root extracts indicating the greater hindrance of gaseous exchange with leaf extracts. Among the various extracts, the effect was more significant with parthenium, clerodendron and lantana. Schon and Einhelling (1982) also reported increased diffusive resistance in sorghum leaves due to allelochemicals of sunflower leaves. Increasing concentration of extracts resulted in significant increase in stomatal resistance indicating higher resistance to gaseous movement at higher concentrations of extracts. This may be attributed to change in architecture of guard cells, intercellular changes due to change in metabolic activity of internal structures.

The various extracts resulted in increased leaf temperature at all the stages which may be attributed to reduced water content of leaves and more absorption of solar radiation due to less rate of transpiration. At 15 DAS, among various extracts parthenium, clerodendron and marigold resulted in significant increase in leaf temperature due to less relative water content in these treatments. Increasing concentrations of extracts resulted in increased leaf temperature suggesting more impact of allelochemicals on leaf temperature. This data suggests that allelochemicals play an important role in the regulation of leaf temperature through their influence on metabolic processes which might have impaired structure and function of plant organelles.

In general, it was observed that among all the species studied, parthenium (Plate 3) and Clerodendron (Plate 4) were found to be more effective in controlling Eupatorium and again the leaf extracts exhibited profound influence over root extracts.

5.2 EXPERIMENT II : USE OF ADDITIVS TO INCREASE THE EFFICACY OF HERBICIDES IN EUPATORIUM (*Chromolaena odorata*)

It is well known that herbicides affect various morpho-physiological, biophysical and biochemical characters and thus affect various metabolic processes. Among the herbicides, the use of translocative type of herbicides such as 2,4-D and glyphosote are very effective in controlling the perennial weeds than the contact type of herbicides. It has long been known that, the efficacy of herbicides could be increased with the addition of additives. The additives help in better translocation of herbicides and improve the efficacy of applied herbicides. Hence, an attempt was made to study the effect of herbicides, 2,4-D and Glyphosate and the use of additives on the physiological aspects of *Chromolaena odorata*.

5.2.1 MORPHOLOGICAL CHARACTERS

The present investigation revealed that there was a significant reduction in plant height and partitioning of dry matter in leaf and stem due to various herbicide treatments. It was observed that among the Glyphosate combinations, lower plant height and leaf stem dry matter was recorded in Glyphosate (2000 ppm) + $(NH_4)_2 SO_4$ (1%), Glyphosate (4000 ppm) and were on par with each other, which indicated the greater effectiveness of these treatments for the control of *Chromolaena odorata*. Among 2,4-D combinations, the application of 2,4-D (2000 ppm) + $(NH_4)_2 SO_4$ (1%), 2,4-D (4000 ppm) were very effective and significantly reduced the plant height, leaf dry matter and stem dry matter.

The data also suggested that the application of additives resulted in higher efficacy of applied herbicides and increasing concentration of herbicides resulted in a greater decrease in plant height, leaf and stem dry matter. Similarly, Mumbareddy (1989), Doddamani (1992), Singh *et al.* (1992), and Mummigatti (1994) observed similar results and indicated that the herbicides affected apical and intercalary meristematic cells, reduced the internodal elongation and also affected various processes and functions, leading to decreased plant height and total dry matter production.

a. Leaf extract (5%)

b. Leaf extract (10%)

c. Root extract (5%)

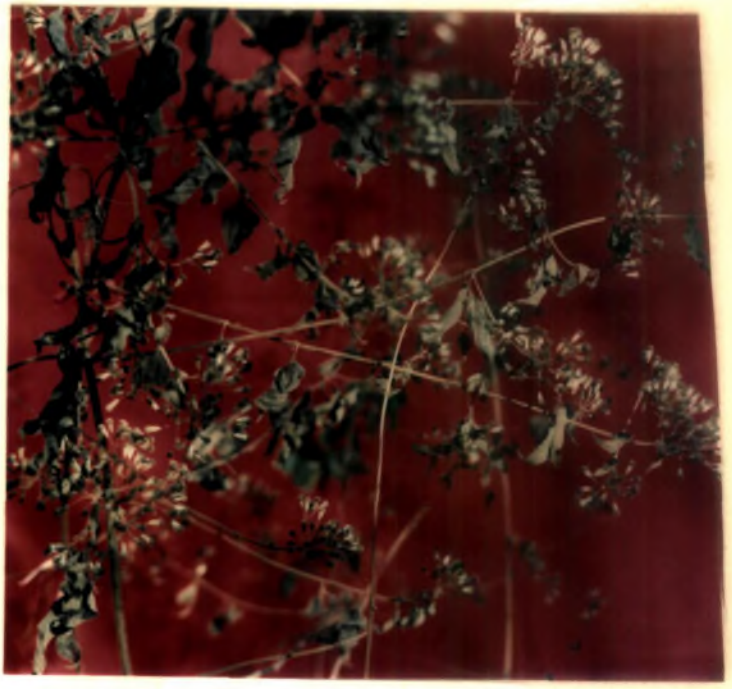
d. Root extract (10%)

PLATE 3. EFFECT OF PARTHENIUM LEAF AND ROOT EXTRACTS AT 5 AND 10% CONCENTRATION ON EUPATORIUM

a. Leaf extract (5%)

b. Leaf extract (10%)

c. Root extract (5%)



d. Root extract (10%)

PLATE 4. **EFFECT OF CLERODENDRON LEAF AND ROOT EXTRACTS AT 5 AND 10% CONCENTRATION O**
EUPATORIUM

e. Control (water spray)

Application of herbicides reduce the total dry matter through their effect on plant growth by way of blocking the electron transport chain, altering the membrane integrity, inhibition of photosynthesis, inhibition of protein synthesis and cell division (Halliwell, 1982). The herbicide 2,4-D enters the plant tissue through the cuticle by diffusion and moves inside the plant both apoplastically and symplastically, causing characteristic phytotoxic symptoms such as epinasty, swelling, twisting and bending of the treated parts and also distant parts as a result, plants stop growing, meristematic cells stop dividing, young leaves stop expanding and the mesophyll tissue stop developing.

Roots may loose their ability to absorb water and mineral nutrients and leaves may loose photosynthetic ability (Gruzdyer *et al.*, 1980). Glyphosate increased the PAL activity and reduced the protein synthesis through depletion of aromatic aminoacids pool as well as through the production of phytotoxic levels of aminoacids and secondary phenolics which affect the growth (Jaworski, 1972).

Maligeppagol (1990) and Patil (1990) reported a reduction in the foliage dry weight of *Cynodon dactylon* due to the spray of Glyphosate and 2,4-D mainly due to strong phytotoxic effect of these chemicals on the phenol metabolism.

5.2.2 BIOCHEMICAL PARAMETERS

Chlorophyll a, chlorophyll b and total chlorophyll contents decreased significantly due to herbicide treatments at all the growth stages. The chlorophyll a content was less as compared to chlorophyll b and the application of additives to herbicides decreased the chlorophyll to a greater extent. The mean chlorophyll a, chlorophyll b and total chlorophyll decreased from 2 DAS 6 DAS. Thus, the herbicides affect important photosynthetic pigments and result in decreased photosynthesis. The decrease in chlorophyll content was attributed to a decreased in RWC and disrupted cellular organelles, (Mummigatti, 1994).

The total soluble sugars decreased significantly due to various herbicide treatments at all the stages and the mean sugar content decreased from 2 DAS to 6 DAS. Among the glyphosate treatments, Glyphosate (2000 ppm) + $(NH_4)_2SO_4$ (1%), and Glyphosate (4000 ppm) significantly reduced the total soluble sugar content. The 2,4-D treatments like 2,4-D (2000 ppm) + $(NH_4)_2 SO_4$ (1%) and 2,4-D (4000 ppm) decreased the total soluble sugars to a greater extent. This decrease was mainly attributed to the utilization of carbohydrate reserves during the period when the demand is more and supply is less due to reduced photosynthetic activity (Trilica and Singh, 1979) and reduced chlorophyll content (Gruzdev et al., 1980 and Sharma *et al.*, 1986).

It was observed that the application of herbicides altered the metabolism of phenolic compounds thereby reduced the phenol content significantly and application of additives to herbicides further improved the efficacy of applied herbicides. The decrease in free phonol may be attributed to altered TAL, PAL activities (Mummigatti, 1994). Similarly, the total free phenol content also reduced due to the usage herbicides with additives (Smith *et al.*, 1977; Mummigatti *et al.*, 1994).

5.2.3 BIOPHYSICAL PARAMETERS

It was observed that relative water content (RWC) decreased significantly due to various herbicide treatments at all the stages and the mean RWC decreased from 2 DAS to 6DAS, which may be due to increased desication of plants. Among the glyphosate combinations, Glyphosate (2000 ppm) + $(NH_4)_2SO_4$ (1%) and Glyphosate (4000 ppm) reduced the RWC significantly at all the stages indicating higher efficacy of these treatments.

The 2,4-D treatments like 2,4-D (2000 ppm) + $(NH_4)_2 SO_4$ (1%) and 2,4-D (4000 ppm) reduced the relative water content significantly at all the stages. The data suggested that, the addition of Ammonium Sulphate increased the efficacy of herbicides. Similarly, Mummigatti (1994) observed a decreased RWC with 2,4-D and glyphosate treatments and noticed a reduction in the water balance.

Photosynthesis is the primary process which forms the base for total dry matter production. It was observed that the photosynthetic rate decreased significantly due to various herbicide treatments at all the stages and the mean Photosynthesis rate decreased from 2 DAs to 6 DAS which indicates the greater influence of herbicides on photosynthesis. Similar results were also observed by Pfister and Urabch (1983).

Among the glyphosate treatments, Glyphosate (2000 ppm) + $(NH_4)_2 SO_4$ (1%) and Glyphosate (4000 ppm) reduced the photosynthetic rate to a greater extent at all the stages indicating higher efficacy of the herbicides. The 2,4-D treatments like, 2,4-D (2000 ppm) + $(NH_4)_2 SO_4$ (1%) and 2,4-D (4000 ppm) decreased the photosynthetic rate to a greater extent as compared to control at all the stages. The data suggested that the additives increased the efficacy of herbicides and reduced the photosynthesis to a greater extent. Richardson (1977), Turner and Loader (1978) reported that the addition of ammonium sulphate, urea and KNO_3 increases the efficacy of herbicides like 2, 4-D and glyphosate.

The stomatal conductance reduced significantly due to herbicide treatments at 2 luction in stomatal conductance was more in 2,4-D (2000 ppm) + $(NH_4)_2SO_4$

(1%), 2,4-D (4000 ppm), Glyphosate (2000 ppm) + $(NH_4)_2SO_4$ (1%) and glyphosate (4000 ppm) indicating the greater efficacy of these treatments on stomatal conductance. The stomotal conductance is directly related to the rate of photosynthesis, which also reduced considerably due to herbicides. The decreased stomatal conductance is due to altered anatomy of mesophyll cells and cellular constituents (Nobel *et al.*, 1975). The leaf temperature did not show any definite trend due to the application of herbicides.

Based on the above discussion, the following conclusions could be drawn,

The various plant species extracts affected physiological, biophysical and biochemical parameters and seed germination in *Chromolaena odorata*. All the extracts significantly reduced RWC, Chlorophyll a, chlorophyll b total chlorophyll, sugar content, rate of photosynthesis, rate of transpiration and seed germination. The leaf extracts significantly reduced all the parameters more than root extracts. Increasing concentration of extracts, decreased all the above parameters.

However, the various extracts resulted in increase of total free phenol content, stomatal conductance and leaf temperature. Among the various species, the leaf extract from parthenium, clerodendron and lantana showed greater effect in that order and significantly reduced the RWC, Chlorophyll a, chlorophyll b and total chlorophyll content, sugar content, rate of transpiration, seed germination and increased total free phenol content, stomatal resistance and leaf temperature, Thus it is inferred that the extracts of parthenium and clerodendron are more effective in controlling *Chromolaena odorata*.

The herbicide treatments significantly reduced the plant height, stem dry matter, leaf dry matter, RWC, rate of photosynthesis, stomatal conductance, chlorophyll a, chlorophyll b, total chlorophyll, total soluble sugars and total free phenol content. The use of 2,4-D and glyphosate with additives increased the efficacy of herbicides. Among glyphosate and 2,4-D combinations, Glyphosate (2000 ppm) + $(NH_4)_2SO_4$, Glyphosate (4000 ppm), 2,4-D (2000 ppm) + $(NH_4)_2SO_4$, and 2,4-D (4000 ppm) were more effective in controlling *Chromalaena odorata*. The application of Glyphosate (2000 ppm) + $(NH_4)_2SO_4$, or 2,4-D (2000 ppm) + $(NH_4)_2SO_4$, can be recommended for effective control of *Chromolaena odorata*.

5.3 FUTURE LINE OF WORK

1. Use of some mroe plant species with high allelopathic potential and at higher concentrations may be tried for thier efficacy in controlling Eupatorium.
2. Avenues may be found out to decrease the weed seed banks (*Chromolaena odorata*) in soil either through their decay using microbial toxins as adsorbents or stimulation of their seed germination.
3. Possibilities of using certain allelochemicals from plants or microbes (bacteria, fungi, etc) as herbicides or as structural models for herbicide development to controlling the Eupatorium may be explored.
4. Studies are needed on factors affecting inactivation and effectiveness of allelocheicals, after their release from donor plants. Very little is known concerning the binding of these chemicals in the soil and the effects of their binding on their activity. In addition, virtually nothing is known concerning the role of soil texture in the accumulatin of allelochemicals to physiologically active concentrations.
5. Temperature stress markedly accentuates the allelopathic effects of some allelochemicals on the growth of weeds and hence a detailed study is needed on this aspect.
6. Mechanism of action of different allelochemicals is not clear and hence a detailed study can be made on such aspects.
7. Seed production potential and viability of seeds as affected by various herbicides may be studied to understand the control of seed spread in Eupatorium.
8. The regeneration capacity, if any, may be tried after the appliction of various herbicides to understand the mechanism of action and to eradicate this noxious weed effectively.
9. In the present ivestigation, only limited additives have been used that to at a fixed concentration. It is worth trying several other inexpensive and easily available additives for increasing the herbicidal efficiency.
10. It is also necessary to find out the effect of increasing concentration of additives for effective control of Eupatorium so as to reduce the concentration of herbicides.
11. The cost:Benefit ratio of using the herbicides and additives at different concentrations and to find out its relationship with the per cent Control of Eupatorium has to be worked out.

SUMMARY

VI. SUMMARY

The present investigation was aimed in finding out the allelopathic effect of crop/weed extracts and their concentrations on the growth, development and reproductive efficiency of Eupatorium. It was also intended to find out the effect of additives in increasing the efficacy of herbicides. To achieve the objectives,two experiments were conducted at Department of Farm Forestry, University of Agricultural Sciences, Dharwad during 1995-96. To study the effect of aqueous extracts of various plant species on physiological, biophysical and seed germination characters, a naturally grown eupatorium in the open field was used. The second experiment was conducted in pots to study the use of herbicides, glyphosate and 2,4-D and their combinations with additives (Urea, KNO_3, $(NH_4)_2SO_4$) for effective control of Eupatorium. The results obtained are summarized in this chapter.

1. The relative water content (RWC) decreased significantly due to various plant extracts. RWC decreased from 5 to 15 DAS and leaf extracts reduced RWC to a greater extent than root extracts. Among the species, parthenium, clerodendron and lantana were more effective in reducing the RWC.

2. Decrease in various biochemical parameters viz., Chlorophyll a, Chlorophyll b, total Chlorophyll and sugar content was noticed with an increase in the concentration of extracts. Among them, the extent of decrease was more in parthenium followed by clerodendron and Lantana leaf extracts rather than their respective root extracts.

3. The total free phenol content increased significantly at 5 to 15 DAS and the increase was more in leaf extracts than in root extracts. At 5 DAS, Lantana and Cassia leaf extracts decreased the phenol content considerably. Whereas at 10-15 DAS, sunflower and marigold leaf extracts were more effective in decreasing the phenol content. Higher the concentration of extracts, more was the reduction of phenol content in Eupatorium leaves at all the stages.

4. There was a decrease in the photosynthetic rate and transpiration rate at 5 to 15 DAS and the decrease was more in leaf extracts as compared to root extracts. Increasing concentration of leaf extracts decreased the transpiration rate in parthenium, clerodendron and lantana leaf extracts.

5. Stomatal resistance and leaf temperature decreased from 5 to 15 DAS and the decrease was observed in all the extracts. However, it was more in parthenium followed by clerodendron and lantana.

6. Increase in the concentration of leaf extracts significantly decreased the seed germination per cent in parthenium, clerodendon and lantana. At higher concentration (10%), the per cent germination, BRI, GRI, GR were zero in parthenium and clerodendron leaf extracts.

7. The foliar spray of herbicides with additives decreased the plant height, stem and leaf dry matter accumulation in Eupatorium. Among various herbicides with additives concentrations, the decrease was more in combination of Glyphosate + Ammonium sulphate, 2,4-D + Ammonium sulphate and 2,4-D and Glyphosate at higher concentrations.

8. The relative water content was found to be least in Glyphosate in combination with Ammonium sulphate and higher concentrations of Glyphosate and 2,4-D alone.

9. Photosynthetic rate, stomatal conductance decreased with an increase in the concentration of herbicides with the combination of additives.

10. Decrease in various biochemical parameters like Chlorophyll a, Chlorophyll b, Total Chlorophyll, Total soluble sugars, Total free phenol contents was noticed with an increase in the concentration of herbicides and in combination with additives. Among them, the extent of decrease was more in Glyphosate + Ammonium sulphate, 2,4-D + Ammonium sulphate and higher concentrations of Glyphosate and 2,4-D alone.

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PHYSIOLOGICAL BASIS OF BIOLOGICAL AND CHEMICAL CONTROL OF EUPATORIUM (*Chromolaena odorata* K & R)

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ABSTRACT

Field experiments were conducted on the naturally grown Eupatorium at the Farm Forestry Department, University of Agricultural Sciences, Dharwad during 1995 and 1996 to find out the allelopathic effect of crop and weed extracts on growth, development and reproductive efficiency of Eupatorium and the effect of additives to increase the efficacy of herbicides. The first experiment consisted of twenty nine treatment combinations having leaf and root extracts of two crop species (Paddy and Sunflower) and five weed species (Lantana, Marigold, Cassia, Parthenium and Clerodendron) both at 5 and 10% concentrations. The treatments were imposed by preparing aqueous extracts of crop and weed extracts before the full bloom stage (approximately 90 days old seedlings). The second experiment consisted of thirteen treatment combinations comprising different concentrations of 2,4-D and Glyphosate (2000, 3000 and 4000 ppm) along with the additives urea, KNO_3 and Ammonium sulphate at 1% concentration. The treatments were imposed at 60 days old plants.

Results revealed that with an increase in the concentration of extracts, there was a decrease in photosynthetic rate, transpiration rate, chlorophyll content, sugar content, stomatal resistance, leaf temperature and relative water content. However, there was a significant increase in the total free phenols due to the application of extracts. It was further observed that the effect was more with leaf extracts than with the root extracts. Among different species, parthenium followed by clerodendron and lantana were more effective in bringing a desirable change for controlling growth and development of Eupatorium as compared to other crop and weed extracts.

In the second experiment, relative water content was found to be least in Glyphosate in combination with Ammonium Sulphate and higher concentrations of Glyphosate and 2,4-D alone. Photosynthetic rate and stomatal conductance decreased with an increase in the concentration of herbicides with the combination of additives. Decrease in various biochemical parameters like chlorophyll a, chlorophyll b and total chlorophyll was noticed with an increase in the concentration of herbicides and in combination with additives. Among them, the extent of decrease was more in Glyphosate+Ammonium sulphate, 2,4-D + Ammonium sulphate and higher concentrations of Glyphosate and 2,4-D alone.