CHAPTER 11

ALLELOPATHIC EFFECTS OF WEEDS ON TEA SEED GERMINATION

One needs his own space for survival. Equally, plants need to have their own space, too. The environment, shared by all, contains limited resources and less-than-ideal growth conditions. All living things have strategies to thrive in this intense struggle for life. There are not a lot of clear winners or losers, but many survivors. Man or other animals can walk away or shut the door in front of the invaders, but plants can not do the same to save their space for survival as they can't walk or run away. Plants have a different way of acquiring or protecting their own space. They use **Allelopathy**, which means, **"Power"**

11.1 WHAT IS ALLELOPATHY?

Allelopathy is a chemical process that a plant uses to keep other plants from growing too close to it.

The term "*Allelopathy*" is from Greek meaning "to suffer from each other." The word derived from two separate words: *allelon* which means 'of each other', and *pathos* which means, 'to suffer'. Allelopathy has traditionally been considered only the negative chemical warfare or chemical inhibition of one species by another. Modern researches suggest that allelopathic effects can be of both positive and negative, depending upon the doses and organisms involved.

Allelopathy denotes that body of scientific knowledge which concerns the production of specific biomolecules by one plant, mostly secondary metabolites, that can induce suffering in, or give benefit to, another plant. This concept suggests that biomolecules (specifically termed as '*allelochemicals*') produced by a plant escape into the environment and subsequently influence the growth and development of other neighbouring plants.

Allelopathic chemicals can be present in any part of the plant like leaves, flowers, roots, fruits or stems. They can also be found in the surrounding soil. Target species are affected by these toxins in many different ways. The toxic chemicals may inhibit shoot/ root growth, they may inhibit nutrient uptake, or they may attack a naturally occurring symbiotic relationship thereby destroying the plant's usable source of a nutrient.

In 1996, *International Allelopathic Society* broadened its definition that allelopathy refers to any process involving secondary metabolites produced by plants, microorganisms, viruses and fungi that influence the growth and development of Agricultural and Biological Systems.

Different types of plants grow at a place forming an association. But in such association different species of plants are not completely harmless to other species. Even in cultivated fields, weeds of different nature grow among the crop plants and plants growing along the boundaries of the crop fields also having some effects on cultivation. It has been observed that the residual parts of many species of plants exude some chemicals which inhibit or promote the growth of associated plants. Any direct or indirect inhibitory or stimulatory effect of one plant (including microorganisms) on another through the production of chemical compounds that escape into the environment has been defined as *Allelopathy* by Rice (1984).

11.2 History

Theophrastus (ca. 300 B.C.), a student and successor to Aristotle, wrote about allelopathic reactions in his botanical works. He has been referred as the "father of Botany", and wrote how chickpea "exhausts" the soil and destroys weeds.

In 1 C.E., Gaius Plinius Secundus, a roman scholar and naturalist, wrote about how chick pea and barley "scorch up" corn land. He also mentioned that Walnut trees are toxic to other plants.

In 1832, Augustin Pyramus de Candolle, a botanist and naturalist, suggested that chemicals released by the crop caused soil sickness.

In 1907 – 1909, two researchers, Schreiner and Reed investigated leading to the isolation of a number of phytotoxic chemicals from plants and soils.

The term 'Allelopathy' was first coined by Prof. Hans Molisch, a German Plant Physiologist in 1937 who referred it as biochemical interactions between all types of plants including microorganisms. With this terminology, he covered both harmful and beneficial reciprocal biochemical interactions. Molisch's definition has been invariably followed by most of the investigators in Asia and Europe.

Thereafter, worldwide, a lot of allelopathic research was conducted in various fields of Agricultural and Biological Sciences.

Allelopathic effects of weeds on different crops/ crop varieties were reported by Tukey (1969), Whittaker (1971), Alsaadawi & Rice (1982a), Tripathi *et al* (1984), Rice (1984) and Pellisier (1993). Tukey (1970) stated that the most physiological and biochemical processes of plants have been reported to be adversely affected by the allelochemicals on addition to the soil or growth medium in the form of ground leaf litter, leaf leachates or extracts of plants and plant parts. Khailov (1974) mentioned that the effect of any given compound might be 'inhibitory' or 'stimulatory' which, in tern, depends on the concentration of the compounds in the surrounding medium. Del Moral & Cates (1971) defined allelopathy as the inhibitor of germination, growth and metabolism of one plant due to the release of organic chemicals by another. According to Putnam & Duke (1978), allelopathy may be a habitat factor in enhancing dominance by certain weeds in a variety of agro-ecosystems. Harper (1977) proposed the blanket term *'interference'*, comprising all chances in the environment, brought about by the proximity of the individuals and also includes 'the production of toxins'. Salisbury (1957) certainly indicated the presence of allelopathic reaction when he mentioned that anything that prevents a seed from sprouting and discourages a species from thriving must have a powerful influence on the composition of the plant community.

According to Rice (1984), Theophrastus (Ca 300 BC) observed and described similar inhibitory effects of crop plants on other crops over 2000 years ago. Later on, no scientific research was done to verify such observations until early part of the twentieth century. Since the turn of the century allelopathic research has been mainly restricted on well documented over the past few decades particularly in relation to its significance in both natural and agro-ecosystems [Rakhteenko *et al.*, 1973; Rice, 1976, 1979; Putnam & Duke, 1978; Rieeta 1981 and Bhowmik & Doll, 1982]. In agricultural ecosystems there are many agrestals whose allelopathic influences also have been proved in the laboratory [Giimmer & Beyer, 1960; Martin & Rademacher, 1960 and Welbank, 1960; Grodzinskiy, 1965].

The ecological significance of allelopathic influence has been pointed out by Whittaker & Feeney (1971), Datta & Sinha Roy (1974), Chatterji (1975) and Lodhi (1975a). Muller (1966, 1969, 1970, 1974) demonstrated the significance of allelopathy in relation to environmental complex and threw light on the allelopathic mechanism for a dominant vegetation. In forestry, the importance of allelopathic research on herbaceous or woody seed plants, ferns as well as mycorrhizae and other microorganisms can be ascertained. Moreover, allelopathy has also been implicated in many fields of plant sciences.

Rice (1984) mentioned the effects of weed interference of crop yields, effect of crop plants on other crop plants and effect of crop plants on weeds. In the field of forestry the importance of the studies of an allelopathic effect of woody seed plants or herbaceous angiosperms, ferns, as well as micorrhizae and other microorganisms can be realized. Allelopathy has also been implicated in case of plant pathology. In the last three decades, allelopathic research has been mainly carried out in the United States in general and

California and Oklahoma in particular. Both these states belong to the semi-arid climatic zone, there being very little or no information from the humid or sub-humid region, though the latter areas are covered with luxuriant vegetation and offered an excellent aspect for plant ecologists to do their work (Chou, 1977).

At present, considerable information are available on the role of allelopathy in cultivated and natural ecosystems. This phenomenon was studied in the last few decades in an extensive and critical way by a large number of workers in different parts of the world including Bonner & Galston (1944), Bonner(1950), Evenari (1961), Muller (1965, 1969), Rice (1967, 1972, 1976), Groner (1974, 1975), Newman & Rovira (1975), Al-Naib & Al-Mousawi (1976), Gliessman (1976, 1978), Lodhi (1976, 1978), Ballester *et al.* (1977), Newman & Miller (1977), Weaver & Klarich (1977). Fisher *et al.* (1978), Bell & Klikoff (1979), Lodhi & Killingbeck (1980), Stachon & Zimdahi (1980), Lovett & Jackson (1980), Younger *et al.* (1980), Lovett & Duffield (1981), Jobidon & Thibault (1982).

In India Datta & Sinha-Roy (1973, 1974, 1975, 1983), Sarma (1974a, 1974b), Datta & Chakraborty (1975, 1978, 1982a, 1982b), Pandya (1975, 1976, 1977), Murthy & Ravindra (1975), Murthy & Nagodra (1977), Ashraf & Sen (1978), Datta & Chatterjee (1980a, 1980b, 1980c), Datta & Bandyopadhyay (1981, 1989), Datta & Ghosh (1982, 1987, 1988), Datta & Dasmahapatra (1984, 1988), Gautam & Bishnoi (1990), Sundaramoorthy & Kalra (1991), Acharia & Sinha (1992), Agarwal & Anand (1992), Kohli & Batish (1994), Prasad (1995), Kalita & Dey (1998), Acharyya (1998), Kalita (1999), Sinha & Deo (1999), Kadir (2001), Agarwal *et al.* (2002), Goyal & Singh (2003), and Lama (2004) demonstrated allelopathic influences of some weedy species of plants of natural and cultivated vegetations.

11.3 Are all plants Allelopathic?

All the plants are not allelopathic. Some, though exhibit these allelopathic tendencies, may actually be displaying aggressive competition of a non-chemical form. Much of the controversy surrounding allelopathy is in trying to distinguish the type of competition being displayed. In general, if it is of a chemical nature, then the plant is considered allelopathic.

11.4 How Does Allelopathy Work?

Allelopathy is a chemical process that a plant uses to keep other plants out of its space. There are four general ways by means of which toxic metabolites get out of plants, these are weathering, leaching, exudation and volatilization (Tukey, 1969; Datta & Sinha Roy, 1974; Datta & Chatterjee, 1980a).

- Plants release chemicals that affect other plant's growth from their roots into the ground. The plants trying to grow near the allelopathic plant absorb those chemicals from the soil and are unable to live.
- Some plants release chemicals from their roots that will slow down or stop the process of photosynthesis of others. The chemicals actually change the amount of chlorophyll the plant produces. This affects the amount of food the plant can make. If a plant can't make food, naturally, it will die.
- Sometimes plants release chemicals in the form of gasses. These gasses are released through the small pores in the plant's leaves. Other plants absorb the gas and are stunted or die.

11.5 Nature's Impact:

Competition is used by both plants and animals to assure a place in nature. Plants will compete for sunlight, water, nutrients etc. and like animals, for territory. Competition, like parasitism, disease and predation, influences distribution and amount of organisms in an ecosystem. The interactions of ecosystems define an environment. When organisms compete with one another, they create the potential for resource limitations and possible extinctions. Allelopathy is a form of chemical competition. The allelopathic plant is competing through 'interference' chemicals and prevents other plants from using the available resources and thus influence the evolution and distribution of other species. One might say that allelopathic plants control the environments in which they live.

As for example, some pine trees are allelopathic. When their needles fall onto the ground and decompose, those release some acids or produce acid during decomposition, which goes into the soil. The soil absorbs acid from the decomposing needles. This acid doesn't hurt the pine tree, but discourages or kills other plants growing near it. This acid in the soil keeps unwanted plants from growing near the pine tree. Some other plants are also known to use allelopathic weapon to assure their space in nature.

Chemical signals are very common in many organisms. Both plants and animals use odours and scents as communication mechanisms. For example, in the animal kingdom insects use chemical signals as sex attractants, trail markers, and alarm calls. Among plants, many of the angiosperms (flowering plants) use strong floral scents to attract potential pollinators. And some organisms (both plants and animals) use airborne chemical compounds to discourage the presence of other organisms. Scientists use the term allelopathy to refer the biochemical interactions between different plants. The term usually implies that one plant produces one or more chemicals that have an inhibitory effect on nearby plants, but allelopathy may also include stimulatory effects.

Allelopathy is understood to mean the influence exerted by vegetable products (fruits) on other plants or plants of the same species through the gases they give off, such as carbon dioxide (CO_2), ethylene (ethane, C_2H_4) and aromatic substances, which reach their peak in particular at the climacteric (= time of maximum respiration). Due to this reason the fruit and vegetable species are not stored together. On the other hand, allelopathy may be used to advantage in ripening warehouses to bring about ripening at the desired time by exposure to ethylene.

There is convincing evidence that allelopathic interactions between plants play a crucial role in natural as well as in manipulated ecosystems:

1. The credit for a specific vegetation pattern has mostly been given to the competition. However, in recent times evidence is accumulating that all types of plants, viz. herbs, shrubs and trees, allelopathically affect the patterning of vegetation, largely in their immediate vicinity.
2. One of the most worked out aspects of allelopathy in manipulated ecosystems is the role of allelopathy in agriculture. In this, the effects of weeds on crops, crops on

weeds and crops on crops have been invariably emphasized. In addition, the possibility of using allelochemicals as growth regulators and natural pesticides (number of them are either commercially available or in the process of large-scale manufacture) promotes sustainable agriculture.

3. Allelopathic interactions have been demonstrated to play a crucial role in natural as well as man-made forests. Such interactions are pivotal in determining the composition of the vegetation growing as under-storey and in understanding the forest regeneration problems. Results obtained so far have shown that almost all types of plants (viz. angiosperms, gymnosperms, lower plants like ferns and micro-organisms, including mycorrhizae) present in forests indulge in allelopathic interactions.
4. Some of the recent findings have demonstrated that tree-crop interactions may have significant bearings on the total productivity of an agroforestry system (simultaneously or sequentially combined production of crops and forest plants). Therefore, it seems essential that the allelopathic compatibility of crops with trees should be checked before being introduced to an agroforestry system.

The above-quoted examples are some of the major aspects of allelopathic interactions in natural and manipulated ecosystems. Scientists study allelopathy and use their research to find natural, healthier herbicides and pesticides to stunt or kill specific unwanted plants and insects, but not to kill our desired plants.

In the next Millennium, worldwide there will be increase in demand for better quality food and in large quantity due to increased human population. Therefore, for sustainability of Agriculture, we need to minimize the use of presently marketed pesticides (like weedicides, insecticides, nematicides, fungicides) in crop production through the use of allelopathic strategies for pest management. The present pesticides used for control of agricultural pests have caused many problems, viz., development of resistance in organisms, environmental pollution, toxicity related health hazards in humans and livestock. Studies have shown a great potential of allelochemicals in pest- control, thereby, these may minimize or eliminate the use of present day pesticides.

Besides, allelopathy has many applications in agroecosystems and thus provides basis to Sustainable Agriculture. Therefore, it becomes a priority area of multidisciplinary research in developed countries and currently research is being conducted in most of the countries. To provide clean environment to our future generations, to avoid health hazards in human and livestock and for sustainability of agriculture, adoption of allelopathic strategies in farming is essential.

No allelopathic study on tea caused by weed residue has been undertaken earlier by any worker. Therefore the present investigation was carried out to determine the presence of any allelopathic effect of the associate plants of Tea, on its seeds germination and on the early growth of seedlings.

Taking all the above aspects in mind, the present work is restricted only on the effects of leachets and extracts of aerial parts of six commonly associated weed species to test their probable allelopathic effects upon a certified cultivar of TEA (TS $_{520}$). All these weeds are dicotyledonous *viz. Drymaria villosa* , *Galinsoga parviflora, Persicaria runcinata* were selected from the high altitude tea gardens and other three *viz. Ageratum conyzoides, Borreria latifolia* and *Mikania micrantha* were selected from the Tea Gardens of Terai-Duars regions.

In the present investigation, the effect of derived concentrations (i.e. 1:2.5, 1:5, 1:10 and 1:20) of leachets and extracts individually of aerial parts of test plants i.e. stem, leaves and inflorescence have been studied. For each desired concentration of leachets or extracts and for control (i.e. with distilled water) two replicates each with 10 seeds of tea and 25 ml of solution has been used.

Observations analyzed on the percentage of seed germination, percentage of inhibition or stimulation of germination, percentage of non-viability, percentile of viability, mean root length, mean shoot length, mean seedling length, percentage of inhibition or stimulation of root, shoot and seedling length, shoot vigour index, root vigour index, seedling vigour index and shoot: root ratio of seedling under different treatments. The Materials and methods used for this work have been detailed in Chapter-5.

11.6 Results and Discussion: Effects of Leachates

In this investigation leachates of six associated species of *Camellia sinensis* namely, *Ageratum conyzoides* L., *Borreria latifolia* (Aublet) Schumann, *Drymaria villosa* Chamisso et Schlechtendal, *Galinsoga parviflora* Cavanilles, *Mikania micrantha* Kunth, *Persicaria runcinata* (D. Don) H. Gross were tested for their allelopathic effects on the germination of seeds and seedling growth of *Camellia sinensis* and the results of those experiments are presented below.

11.6.1 Effects of Leachates of *Ageratum conyzoides* L. on Seed Germination and Seedling Growth of *Camellia sinensis* (L.) O. Kuntze

Table-11.1 and Plate-**XIV** exhibit the effect of leachates of aerial parts of *Ageratum conyzoides* on seed germination and seedling growth of *Camellia sinensis*. Results reveal that higher concentration leachates of 1:2.5 and 1:5 dilutions exhibited 15.96 % and 15.96 % inhibition on seed germination (71.43 %) as against control (85 %), whereas with the dilution of leachates at 1:10 and 1:20 the percentage of germination was increased to 85.71 and 100 respectively showed 0.84 % and 17.65 % stimulation on seed germination. The Leachates concentration of 1:20 showed no effect on seed germination in comparison with control. Increase in concentration of the leachates (i.e. 1:20, 1:10, 1:5 and 1:2.5) led to decline of the percentile of viability (100.00, 85.71, 71.43 and 71.43 respectively). In this investigation it was observed that the highest concentration of leachates of 1:2.5 showed delayed germination and it took 7 days to germinate the first seed. Afterwards with the decreasing concentration (1:5, 1:10 and 1:20) it was first and took 4 days to germinate the first seed. While in control the first seed germinated after 4 days.

The seedling growth of *Camellia sinensis* was affected variably in different concentrations of Leachates of *Ageratum conyzoides*. Maximum shoot length was recorded at 1:10 concentration of leachate (1.28 cm). The higher concentration of leachates i.e. 1:2.5 and 1:5; and lowest dilution of leachets 1: 20 caused 39.62, 19.81 and 15.09 % inhibition in shoot length, respectively when compared to control. But the diluted leachate at 1:10 level showed stimulatory effect caused 20.75 % stimulation in shoot length as against the control.

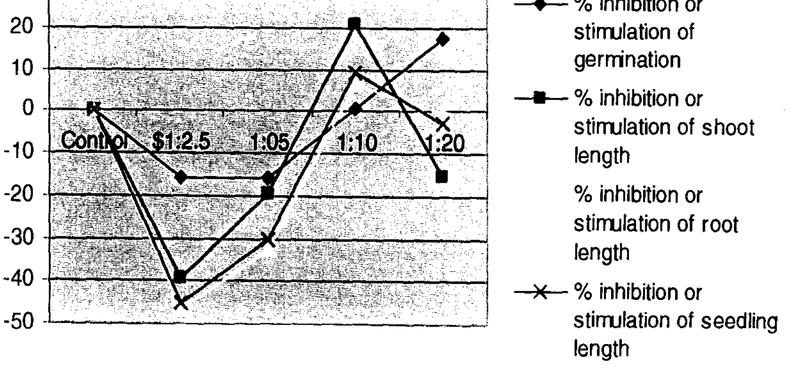
Table 11.1. Effect of leachates of aerial parts of *Ageratum conyzoides* L. on seed germination and seedling growth of *Camellia sinensis* (L.) O. Kuntze

PARAMETERS	CONCENTRATION OF SOLUTIONS				
	Control	1:2.5	1:5	1:10	1:20
Germination percentage	85.00	71.43	71.43	85.71	100
Germination % inhibition or stimulation	00.00	- 15.96	- 15.96	+0.84	+ 17.65
Percentile of viability	85.00	71.43	71.43	85.71	100
Nonviable Percentage	15.00	28.57	28.57	14.29	00.00
Mean shoot length (cm) per seedling	1.06	0.64	0.85	1.28	0.9
Percentage of inhibition or stimulation of shoot length	00.00	- 39.62	- 19.81	+ 20.75	- 15.09
Mean root length (cm) per seedling	4.74	2.53	3.2	5.05	4.73
Percentage of inhibition or stimulation of root length	00.00	- 46.62	- 32.49	+ 6.54	- 0.21
Mean total length (cm) per seedling	5.8	3.17	4.05	6.33	5.63
Percentage of inhibition or stimulation of seedling length	00.00	- 45.34	- 30.17	+ 9.14	- 2.93
Shoot vigour index	90.1	45.72	60.72	109.71	90.0
Root vigour index	402.9	180.72	228.58	432.84	473.0
Seedling vigour index	493.0	226.44	289.3	542.55	563.0
Shoot / Root ratio	0.22	0.25	0.27	0.25	0.19

+ / - Signs indicates stimulatory / inhibitory effect of Leachates.

On the other hand, the leachates of *Ageratum conyzoides* showed strong inhibitory effect on root growth of *Camellia sinensis* at the higher concentration i.e. 1:2.5 and 1:5 exhibited 46.62 and 32.49 % inhibition in root length, respectively, as compared to control. Although with the dilution of leachates the inhibitory effect in root length was decreased. At the lower concentration of leachates i.e. 1:10 showed slight 6.54 % stimulation and whereas 1:20 dilution level exhibited least 0.21 % inhibition in root length as compared to control, respectively. In spite of that root hairs were seen at 1:5 concentration and lateral roots were also developed at lower concentrations of 1:10. In control there was no development of root hairs or the initiation lateral roots.

Fig. 11.1: Effect of leachates of *Ageratum conyzoides*



Moreover, compared to the control (5.8 cm), the total length of seedling of *Camellia sinensis* was appreciably smaller in all concentrations of leatchates except 1:10 dilution. At the concentrations of 1:2.5, 1:5 and 1:20 levels exhibited 45.34, 30.17 and 2.93 % inhibition whereas lower dilution 1:10 caused 9.14 % stimulation of seedling length.

In this study it was seen that the shoot vigour index was more at concentration of 1:10 but seedling vigour index and root vigour index were more in all diluted concentrations of Leachates (1:10 and 1:20) in comparison with the control. With 1:2.5, 1:5 and 1:10 dilutions the shoot: root ratio of seedling was higher (0.25, 0.27 and 0.25, respectively) than that of the control (0.22) indicating more inhibition of root growth as compared to that of shoot.

11.6.2 Effects of Leachates of *Borreria alata* (Aublet) chumann on Seed Germination and Seedling Growth of *Camellia sinensis* (L.) O. Kuntze

Table-11.2 and Plate XIV exhibits the effects of leachates of aerial parts of *Borreria alata* on seed germination and seedling growth of *Camellia sinensis*. Results revealed that leachates at the concentration of 1:2.5 exhibited 32.78 % strong inhibition on seed germination (57.14 %) as against control (85 %), whereas with the dilution of leachates at 1:5, 1:10 and 1:20 the percentage of germination was increased to 71.43, 71.43 and 85.71, respectively. At the concentration of 1:5, 1:10 exhibited the same inhibition rate i.e. 15.96%. But, the lowest concentration 1:20 showed least stimulatory effect and caused 0.84 % stimulation on seed germination in comparison with control. Increase in concentration of the leachates (i.e. 1:20, 1:10, 1:5 and 1:2.5) led to decline of the percentile of viability (100.00, 83.34, 83.34 and 66.67 respectively). The highest concentration of leachates of 1:2.5 showed delayed germination and it took 11 days to germinate the first seed. Afterwards with the decreasing concentration (1:5, 1:10 and 1:20) it was fast and took only 4 days to germinate the first seed. While in control the first seed germinated after 4 days. Development of root hairs was seen at 1:2.5 and 1:5 concentrations, but lateral root initiation was prohibited. Whereas in control there was no initiation of root hairs or lateral roots.

The leachates of *Borreria alata* showed strong inhibitory effect on shoot growth of *Camellia sinensis*. Maximum shoot length was recorded at 1:20 concentration of leachate (1.17 cm) and thereafter it started declining with increasing concentrations. The higher concentration of leachates i.e. 1:2.5, 1:5 and 1:10 showed strong inhibitory effect on shoot growth of *Camellia sinensis*. Although with the dilution of leachates the inhibitory effect in shoot length was decreased (48.11, 43.40 and 36.79 % inhibition) as compared to control. But the diluted leachates at 1:20 level showed stimulatory effect that caused 10.38 % stimulation in shoot length as against control. On the other hand, the leachates of *Borreria alata* showed variable effect on root growth of *Camellia sinensis* in different concentrations. At the concentrations of leachates of 1:2.5 and 1:10 showed inhibitory effect on root growth, resulting (13.50 and 2.32 % inhibition) as compared to control, respectively. Whereas with the dilution of leachates at 1:5 and 1:20 showed stimulatory effect that caused 0.21 and 8.23 % stimulation in root elongation as against the control. The seedling growth of *Camellia sinensis* was affected variably in different concentrations of leachate of *Borreria alata*. Moreover, as compared to the control (5.8 cm), the total length of seedling of *Camellia sinensis* was smaller in higher concentrations of leatchates of 1:2.5, 1:5 and 1:10 (i.e. 4.65, 5.35, and 5.3 cm). But the diluted leachates at 1:20 level showed stimulatory effect caused 8.62 % stimulation in seedling length as against control.

Table 11.2. Effect of leachates of aerial parts of *Borreria alata* (Aublet) Schumann on seed germination and seedling growth of *Camellia sinensis* (L.) O. Kuntze

PARAMETERS	CONCENTRATION OF SOLUTIONS				
	Control	1:2.5	1:5	1:10	1:20
Germination percentage	85.0	51.14	71.43	71.43	85.71
Germination % inhibition or stimulation	00.00	- 31.78	- 15.96	- 15.96	+ 0.84
Percentile of viability	99.17	66.67	83.34	83.34	100.0
Nonviable Percentage	15.0	42.86	28.57	28.57	14.29
Mean shoot length (cm) per seedling	1.06	0.55	0.6	0.67	1.17
Percentage of inhibition or stimulation of shoot length	00.00	- 48.1	- 43.4	- 36.79	+ 10.38
Mean root length (cm) per seedling	4.74	4.10	4.75	4.63	5.13
Percentage of inhibition or stimulation of root length	00.00	- 13.5	+ 0.21	- 2.32	+ 8.23
Mean total length (cm) per seedling	5.8	4.65	5.35	5.3	6.3
Percentage of inhibition or stimulation of seedling length	00.00	- 19.83	- 7.76	- 8.62	+ 8.62
Shoot vigour index	90.1	31.43	42.86	47.86	100.28
Root vigour index	402.9	234.27	339.29	330.72	439.69
Seedling vigour index	493.0	265.7	382.15	378.58	539.97
Shoot / Root ratio	0.22	0.13	0.13	0.14	0.23

+ / - Signs indicates stimulatory / inhibitory effect of Leachates.

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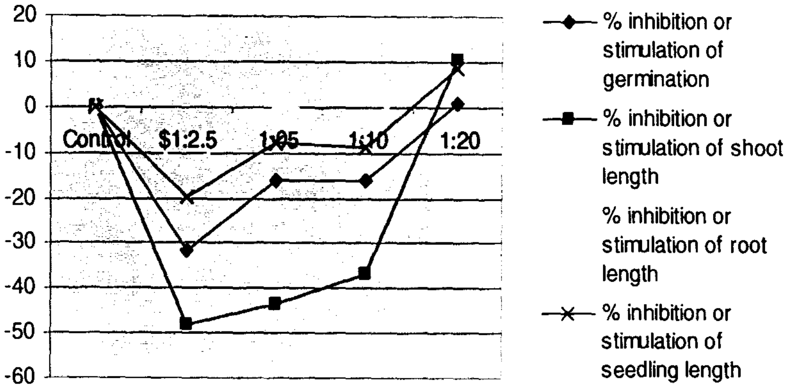
Fig. 11.2: Effect of leachates of *Borreria alata*



In this study it was seen that the shoot vigour index, root vigour index, and seedling vigour index were less at higher concentrations of leachets of 1:2.5, 1:5, 1:10 level. But at 1:20 concentration of leachates shoot vigour index, root vigour index, and seedling vigour index were more in comparison to the control. The shoot: root ratio followed a similar pattern of response. The shoot: root ratio of seedlings was slightly affected (0.13, 0.13, and 0.14) at all the higher concentrations of Leachates in comparison to control (0.22). But in lowest concentration of 1:20 it was increased (0.23) indicating more inhibition of shoot length than that of root length.

11.6.3 Effects of Leachates of *Drymaria villosa* Chamisso et Schlechtendal on Seed Germination and Seedling Growth of *Camellia sinensis* (L.) O. Kuntze

Table-11.3 exhibit the effect of leachates of aerial parts of *Drymaria cordata* on seed germination and seedling growth of *Camellia sinensis.* Results reveal that leachates at the concentration of 1:2.5 and 1:10 exhibited 15.96 % and 15.96 % caused 71.43 % inhibition on seed germination as against 85 % in control; whereas at the concentrations 1:5 and 1:20 exhibited the same percentage of germination was increased to 85.71. At the lowest concentration of 1:5 and 1:20 showed least stimulatory effect and caused only 0.84 % stimulation on seed-germination when compares to the control. Increase in concentration of the leachates (i.e. 1:20, 1:10, 1:5 and 1:2.5) led to decline of the percentile of viability (100.00, 83.34, 100.00 and 83.34 respectively). All the concentrations of leachates except 1:20 level took 4 days to germinate the first seed. Diluted concentration of leachets 1:20 showed delayed germination and took 7 days to germinate the first seed. While in control the first seed germinated after 4 days. In spite of that lateral roots were also developed at the lower concentration (1:10). Whereas in control there was no initiation of root hairs or lateral roots.

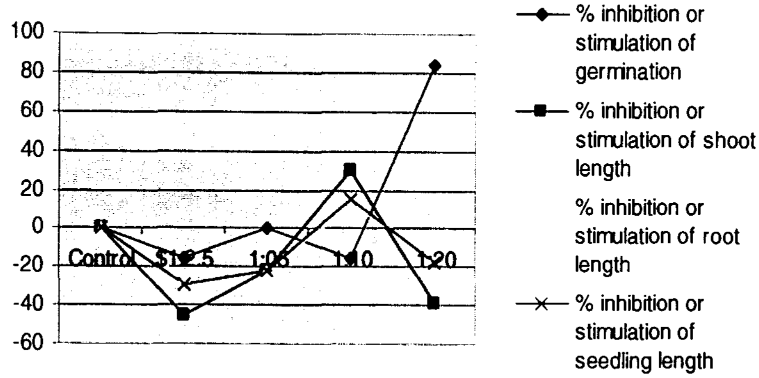
Table 11.3. Effect of leachates of aerial parts of *Drymaria villosa* Chamisso et Schlechtendal on seed germination and seedling growth of *Camellia sinensis* (L.) O. Kuntze

PARAMETERS	CONCENTRATION OF SOLUTIONS				
	Control	1:2.5	1:5	1:10	1:20
Germination percentage	85.0	71.43	85.71	71.43	85.71
Germination % inhibition or stimulation	00.00	- 15.96	+ 0.84	- 15.96	+ 84.0
Percentile of viability	99.17	83.34	100	83.34	100
Nonviable Percentage	15.0	28.57	14.29	28.57	14.29
Mean shoot length (cm) per seedling	1.06	0.58	0.83	1.38	0.65
Percentage of inhibition or stimulation of shoot length	00.00	- 45.28	- 21.70	+30.19	- 38.68
Mean root length (cm) per seedling	4.74	3.55	3.68	5.3	4.12
Percentage of inhibition or stimulation of root length	00.00	- 25.11	- 22.36	+ 11.81	- 13.08
Mean total length (cm) per seedling	5.8	4.13	4.51	6.68	4.77
Percentage of inhibition or stimulation of seedling length	00.00	- 28.79	- 22.24	+ 15.17	- 17.76
Shoot vigour index	90.1	41.43	71.14	98.57	55.71
Root vigour index	402.9	253.58	315.41	378.58	353.13
Seedling vigour index	493.0	295.01	386.55	477.15	408.84
Shoot / Root ratio	0.22	0.16	0.23	0.26	0.16

+ / - Signs indicates stimulatory / inhibitory effect of Leachates.

The leachates of *Drymaria cordata* showed strong inhibitory effect on shoot growth of *Camellia sinensis*. Maximum shoot length was recorded at 1:10 concentration of leachate (1.38 cm) and thereafter it started declining with the increase of concentrations. All the concentration of leachates showed strong inhibitory effect on shoot growth except the 1:10 concentration. Although with the dilution of leachates the inhibitory effect in shoot length was decreased and caused (45.28, 21.70 and 38.68 % inhibition) as compared to control, respectively. But the diluted leachates at 1:10 level showed more stimulatory effect caused 30.19 % stimulation in shoot length as against control. On the other hand, the leachates of *Drymaria cordata* showed variable effect on root growth of *Camellia sinensis* in different concentrations. At the concentrations of leachates of 1:2.5, 1:5 and 1:20 showed inhibitory effect on root growth of *Camellia sinensis*, resulting 25.11, 22.36 and 13.08 % inhibition, as compared to control, respectively. Whereas with the dilution of leachates at 1:10 showed 11.81% stimulation in root length as against the control.

Fig. 11.3: Effect of leachates of *Drymaria villosa*

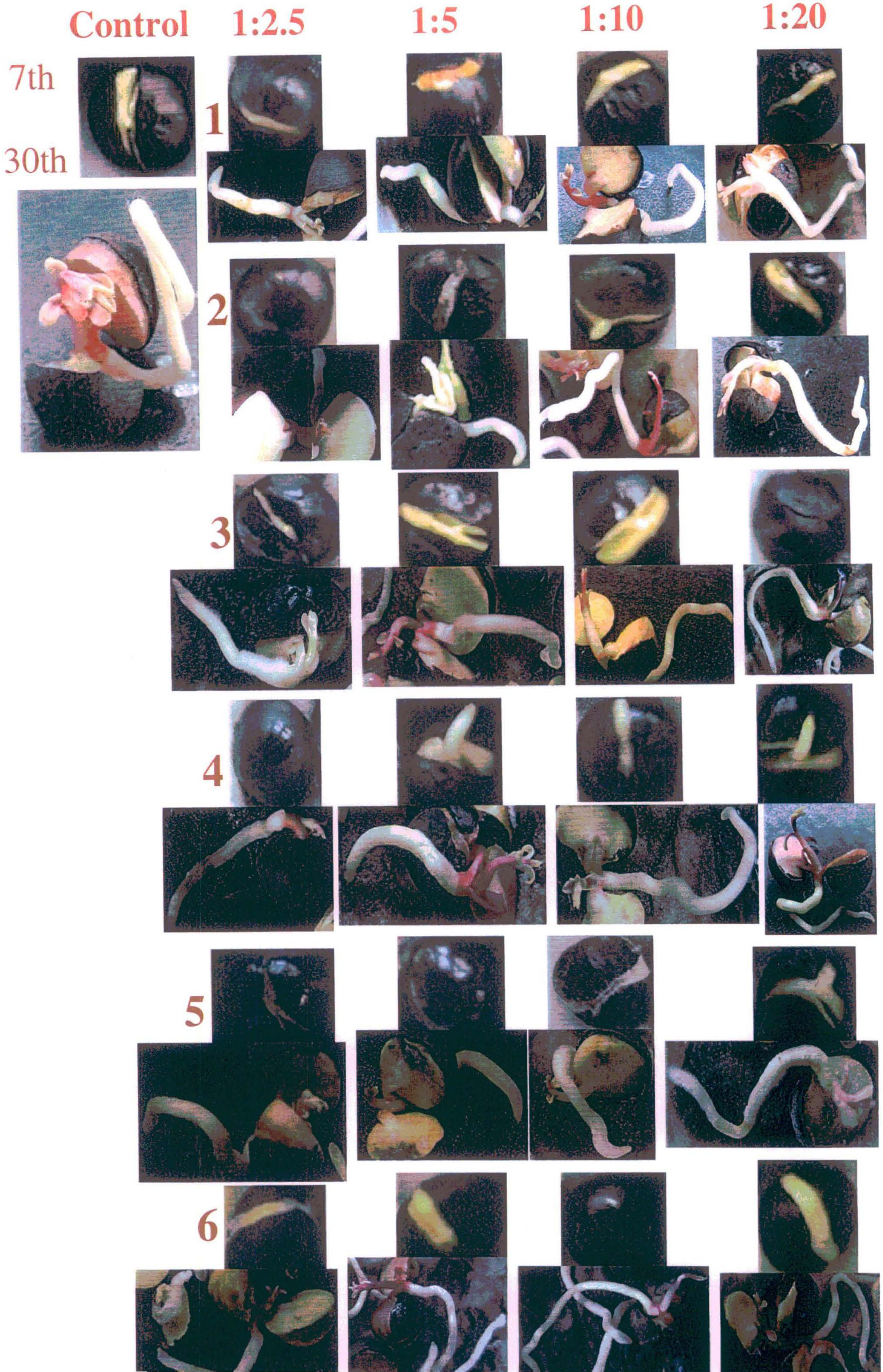


The seedling growth of *Camellia sinensis* was affected variably in different concentrations of leachates of *Drymaria cordata.* Moreover, as compared to the control (5.8 cm), the total length of seedling was smaller in all the concentrations of leatchates except in 1:10. At the concentrations 1:2.5, 1:5 and 1:20 showed 28.79, 22.24 and 17.76 % inhibition as compared to control, respectively. But the diluted leachates at 1:10 level showed stimulatory effect and caused 15.17 % stimulation in seedling growth as against control.

In this study it was seen that the shoot vigour index was more at the 1:10 dilution only and less in other concentrations but seedling vigour index and root vigour index were less in all the concentrations of leachates in comparison to the control. The shoot: root ratio of seedlings was slightly affected (0.16) at 1:2.5 and 1: 20 concentrations of leachates respectively in comparison to control (0.22). But in concentrations of 1: 5 and 1:10 it was increased (0.23 and 0.26) indicating more stimulation of shoot elongation than that of root elongation.

11.6.4 Effects of Leachates of *Galinsoga parviflora* Cavanilles on Seed Germination and Seedling Growth of *Camellia sinensis* (L.) O. Kuntze

Data on seed germination and seedling growth of *Camellia sinensis* in response to leachate treatments of aerial parts of *Galinsoga parviflora* have been recorded in Table-11.4. During this investigation it was observed that treatment with highest concentration of leachates (1:2.5) showed only inhibitory effects on seed germination, achieved 71.43 % of seed germination resulted in 15.96 % inhibition as compared to control (85 %). Thereafter, germination percentage increased linearly with decreasing concentration of leachates reaching a maximum of 100.00 % with the


Control
1:2.5
1:5
1:10
1:20
7th
30th
1
2
3
4
5
6

dilutions of 1:10 and 1:20 levels. In spite of that, application of 1:5, 1:10 and 1:20 levels caused 0.84, 17.65 and 17.65 % stimulation in seed germination, respectively, as against control. Moreover all the concentration of Leachates took same time to initiate the germination i.e. 4 days to germinate the first seed. While in control also the first seed was germinated after 4 days. In addition to that root hairs were developed at the lowest concentration of 1:20 only and prohibited lateral roots initiation. Whereas in control there was no initiation of root hairs or lateral roots.

The growth of seedlings was also noticed to be influenced under different concentration of leachates (Plate-**XIV**'). The seedling length was progressively decreased by increasing concentration of leachates and the decrease reached a maximum (2.58 cm) in 1:2.5 level of concentration and showed vigorous inhibition (50.86 %) as against control (5.8 cm). But the diluted leachates at 1:10 and 1:20 levels showed 5 and 14.83 % stimulation in seedling elongation as against the control.

Leachate treatments tremendously retarded the growth of shoot at 1:2.5, 1:5 and 1:10 levels caused 79.25, 10.38, and 0.94 % inhibition in shoot length as compared to control, respectively. Whereas, the rate of shoot growth was slightly increased at 1:20 level of dilution. The 1:20 dilution of leachate showed least stimulatory effect that caused 15.09 % stimulation in shoot length as against the control. Although with the further dilution of leachates the inhibitory effect in root length was decreased. At higher concentration of 1:2.5 and 1: 5 level showed 44.51 and 27.22 % inhibition as compared to control, respectively. But the diluted leachates at 1:10 and 1:20 level showed stimulatory effect causing 6.33 and 14.77 % stimulation in root length as against control.

Table 11.4. Effect of leachates of aerial parts of *Galinsoga parviflora* Cavanilles on seed germination and seedling growth of *Camellia sinensis* (L.) O. Kuntze

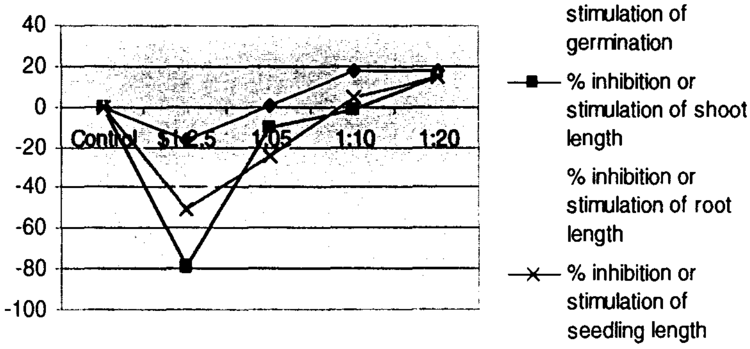
PARAMETERS	**CONCENTRATION OF SOLUTIONS**				
	Control	**1:2.5**	**1:5**	**1:10**	**1:20**
Germination percentage	85.0	71.43	85.71	100.0	100.0
Germination % inhibition or stimulation	00.00	- 15.96	+ 0.84	+ 17.65	+ 17.65
Percentile of viability	85.0	71.43	85.71	100.0	100.0
Nonviable Percentage	15.0	28.57	14.29	00.00	00.00
Mean shoot length (cm) per seedling	1.06	0.22	0.95	1.05	1.22
Percentage of inhibition or stimulation of shoot length	00.00	- 79.25	- 10.38	- 0.94	+ 15.09
Mean root length (cm) per seedling	4.74	2.63	3.45	5.04	5.44
Percentage of inhibition or stimulation of root length	00.00	- 44.51	- 27.22	+ 6.33	14.77
Mean total length (cm) per seedling	5.8	2.85	4.4	6.09	6.66

Percentage of inhibition or stimulation of seedling length	00.00	- 50.86	- 24.14	+ 5.0	+ 14.83
Shoot vigour index	90.1	15.71	81.42	105.0	122.0
Root vigour index	402.9	187.86	295.7	504.0	544.0
Seedling vigour index	493.0	203.57	377.12	609.0	666.0
Shoot / Root ratio	0.22	0.08	0.28	0.21	0.22

+ / - Signs indicates stimulatory / inhibitory effect of Leachates.

In spite of that seedling vigour index, shoot vigour index and root vigour index were lower in higher concentration of Leachates and higher in all diluted leachets as compared to control.

Fig. 11.4: Effect of leachates of *Galinsoga parviflora*



In the present investigation it was observed that the shoot: root ratio of seedling was higher (0.28) at the concentrations of 1:5 only, over the control (0.22), which indicated more inhibition of growth of root system of seedlings. Besides, under the concentration of 1:2.5, 1:10 and 1:20 the shoot: root ratios were 0.08, 0.21, and 0.22 respectively.

11.6.5 Effects of Leachates of *Mikania micrantha* Kunth on Seed Germination and Seedling Growth of *Camellia sinensis* (L.) O. Kuntze

Results of treatments with the leachates of aerial parts of *Mikania micrantha* on different parameters of germination and seedling growth of *Camellia sinensis* are given in Table - 11.5. From the perusal of the results, it is apparent that there was deleterious effect on the percentage of germination in all dilutions of leachates which exhibited firm and inhibitory toxic effect. At the concentration of 1:2.5, 1:5 and 1:10 levels of Leachates exhibited 66.39, 32.78 and 15.96 % inhibition on seed germination (28.57, 57.14 and 71.43 % respectively) as against control (85 %). Although at lower concentrations of 1:20 germination exhibited very low (0.84 %) stimulatory effect as compare to control. However, the effect of leachates of *Mikania micrantha* on seed germination of *Camellia sinensis* was inhibitory. All the concentration of Leachates, except 1: 5 dilution, took 4 days to germinate the first seed. Whereas at concentration of leachets 1: 5 showed delayed germination and it took 11 days to germinate the first seed. While in control the first seed germinated after 4 days. In spite of that root hairs were also developed at lower concentrations of 1:10 and prohibited lateral roots initiation. Whereas in control there was no initiation of root hairs or lateral roots.

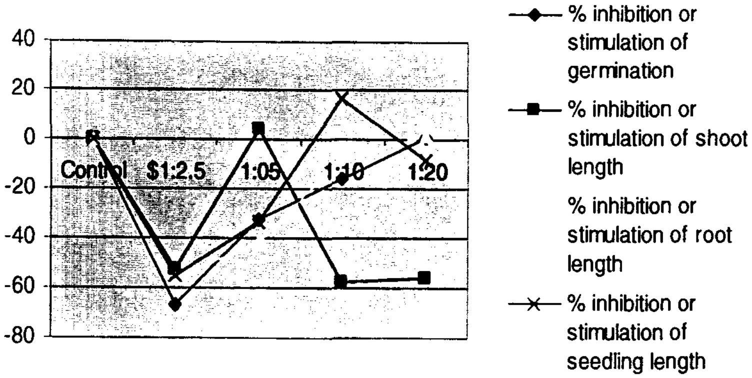
In this investigation it was seen that there was detrimental effect on the growth of seedling of *Camellia sinensis* with the leachates of *Mikania micrantha* in all concentrations. The seedling growth increased linearly with decreasing concentration of Leachates. At concentrations of 1:2.5, 1:5, 1:10 and 1:20 seedling growth was highly hindered and caused 55.17, 33.10, 16.38 and 8.62 % inhibition in seedling length, respectively, as compared with the control.

Table 11.5. Effect of leachates of aerial parts of *Mikania micrantha* Kunth on seed germination and seedling growth of *Camellia sinensis* (L.) O. Kuntze

PARAMETERS	CONCENTRATION OF SOLUTIONS				
	Control	1:2.5	1:5	1:10	1:20
Germination percentage	85.0	28.57	57.14	71.43	85.71
Germination % inhibition or stimulation	00.00	- 66.39	- 32.78	- 15.96	+ 0.84
Percentile of viability	99.17	33.33	66.67	83.34	100.0
Nonviable Percentage	15.0	71.43	42.86	28.57	14.29
Mean shoot length (cm) per seedling	1.06	0.5	1.1	0.45	0.47
Percentage of inhibition or stimulation of shoot length	00.00	- 52.83	+ 3.77	- 57.55	- 55.66
Mean root length (cm) per seedling	4.74	2.1	2.78	4.4	4.83
Percentage of inhibition or stimulation of root length	00.00	- 55.7	- 41.35	- 7.17	+ 1.90
Mean total length (cm) per seedling	5.8	2.6	3.88	4.85	5.3
Percentage of inhibition or stimulation of seedling length	00.00	- 55.17	- 33.10	16.38	- 8.62
Shoot vigour index	90.1	14.29	62.85	32.14	40.28
Root vigour index	402.9	60.0	158.85	314.29	413.98
Seedling vigour index	493.0	74.29	221.7	346.43	454.26
Shoot / Root ratio	0.22	0.24	0.4	0.10	0.10

+ / - Signs indicates stimulatory / inhibitory effect of Leachates.

Fig. 11.5: Effect of leachates of *Mikania micrantha*



Shoot vigour index, root vigour index and seedling vigour index were also low in viable concentrations. Only in diluted concentration (1:20) showed slightly higher root vigour index as compare to control. Besides, the shoot: root ratio of seedling was observed that the shoot: root ratio of seedling was higher (0.40) at the concentrations of 1:5 only over the control (0.22), which indicated more inhibition of growth of root system of seedlings. Besides, under the concentration of 1:2.5, 1:10 and 1:20 the shoot: root ratios were 0.24, 0.10 and 0.10 respectively.

11.6.6 Effects of Leachates of *Persicaria runcinata* (D. Don) H. Gross on Seed Germination and Seedling Growth of *Camellia sinensis* (L.) O. Kuntze OF *Camellia sinensis* (L.) O. Kuntze

Effects of different concentration of leachates of whole plant of *Polygonum runcinatum* on seed germination and seedling growth of *Camellia sinensis* are shown in Table-11.6 and Plate-XIV From the perusal of the data it is evident that highest concentration of leachates of 1:2.5 exhibited slight stimulatory effect (0.84 %) on germination percentage (85.71%) as against 85 % in control. Interestingly, at the concentration of leachates of 1: 5 exhibited inhibitory effect (15.96 %) on germination percentage (71.43) as against 85 % with control. Subsequently, diluted leachates of 1:10 and 1:20 improved the germination percentage to 85.71 and 85.71 respectively and showed least stimulatory effect (0.84 %) as compared to control. All the concentration of Leachates except 1: 10 took 4 days to germinate the first seed. Whereas 1: 10 concentration of leachets showed delayed germination and took 7 days to germinate the first seed.

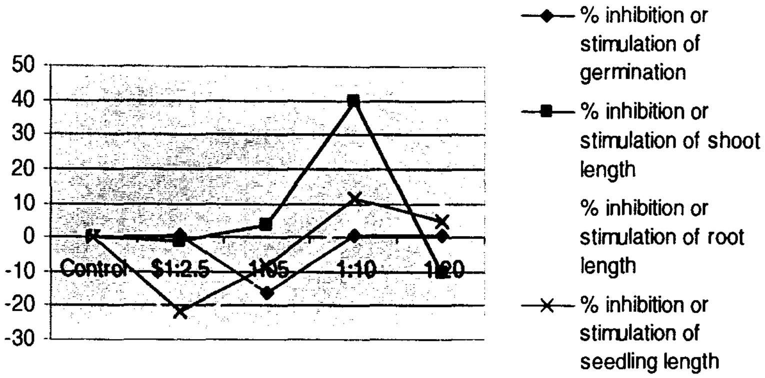
Seedling growth was also varied greatly under the influence of different concentrations of Leachates. Treatments with the dilutions of 1:5, 1:10 levels manifested 3.77 and 39.62 % more elongation of shoot length, respectively, over the control. Though the highest concentration of leachates (1:2.5) and lowest concentration of leachates (1:20) exhibited 0.94 and 10.38 % inhibition in shoot elongation. Moreover, it was observed that the tendency of root growth did not follow the similar trend as the shoot. It was usually inhibited at higher concentrations of 1:2.5 and 1:5 and was retarded through 26.16 and 11.39 % inhibition, respectively. But only at the lower 1:10 and 1:20 concentration showed 5.06 and 8.23 % stimulation, respectively in root elongation. There was also inhibition of root hair or lateral root initiation. The growth of seedlings was appeared to be promoted at the diluted concentration of Leachates. dilutions 1:10 and 1:20 showed 11.38 and 4.83 % stimulation respectively and at the higher concentration of Leachates (1:2.5 and 1:5) there was 21.55 and 8.62 % inhibition respectively over the control.

Table 11.6. Effect of leachates of aerial parts of *Persicaria runcinata* (D. Don) H. Gross on seed germination and seedling growth of *Camellia sinensis* (L.) O. Kuntze

PARAMETERS	**CONCENTRATION OF SOLUTIONS**				
	Control	**1:2.5**	**1:5**	**1:10**	**1:20**
Germination percentage	85.0	85.71	71.43	85.71	85.71
Germination % inhibition or stimulation	00.00	+ 0.84	- 15.96	+ 0.84	+0.84
Percentile of viability	99.17	100.0	83.34	100.0	100.0
Nonviable Percentage	15.0	14.29	28.57	14.29	14.29
Mean shoot length (cm) per seedling	1.06	1.05	1.1	1.48	0.95
Percentage of inhibition or stimulation of shoot length	00.00	- 0.94	+ 3.77	+ 39.62	- 10.38
Mean root length (cm) per seedling	4.74	3.5	4.2	4.98	5.13
Percentage of inhibition or stimulation of root length	00.00	- 26.16	- 11.39	+ 5.06	+ 8.23
Mean total length (cm) per seedling	5.8	4.55	5.3	6.46	6.08
Percentage of inhibition or stimulation of seedling length	00.00	- 21.55	- 8.62	+ 11.38	+ 4.83
Shoot vigour index	90.1	90.0	78.57	126.85	81.42
Root vigour index	402.9	299.99	300.01	426.84	439.69
Seedling vigour index	493.0	389.99	378.58	553.69	521.11
Shoot / Root ratio	0.22	0.3	0.26	0.3	0.19

+ / - Signs indicates stimulatory / inhibitory effect of Leachates.

Fig. 11.6: Effect of leachates of *Persicaria runcinata*



In the present investigation it was observed that the seedling vigour index and root vigour index were lower at concentrations of 1:2.5 and 1:5 but they were higher with 1:10 and 1:20 dilutions. Although the shoot vigour index was higher only at lowest concentration (1:10), but it was definitely lower with all other concentrations as against control. With 1:2.5, 1:5 and 1:10 dilutions the shoot: root ratio of seedling was higher (0.30, 0.26 and 0.30, respectively) than that of control (0.22) indicating more inhibition of root growth as compared to that of shoot.

11.7 RESULTS AND DISCUSSIONS: EFFECT OF EXTRACTS

In the present study extracts of six commonly associated species *viz. Ageratum conyzoides* L., ***Borreria alata* (Aublet) Schumann,** *Drymaria villosa* Chamisso et Schlechtendal, *Galinsoga parviflora* Cavanilles, *Mikania micrantha* Kunth, and *Persicaria runcinata* (D. Don) H. Gross were tested for their allelopathic effects on seed germination and seedling growth of *Camellia sinensis* (L.) O. Kuntze and the results of which are discussed below.

11.7.1 Effect of extracts of *Ageratum conyzoides* L. on Seed Germination and Seedling Growth of *Camellia sinensis* (L.) O. Kuntze

The effects of extracts of aerial parts of *Ageratum conyzoides* on different parameters of seed germination and seedling growth of *Camellia sinensis* are presented in Table 11.7.

Results reveal that the process of seed germination was observed to be affected by the treatment with the extract. The germination percentage showed decline along with the increase of concentration of extract solutions. Higher concentration of extract of 1:2.5 showed more inhibitory effect (32.78 %) on the percentage of germination as well as the percentile of viability. On the other hand, extracts of 1:5, 1:10 dilutions also exhibited inhibitory effect and caused 15.96 % and 15.96 % decline on seed germination and 1:20 dilution exhibited least stimulatory effect of 0.84 % as against 85.0 % with control. In this investigation it was observed that all the concentration of extracts took same time to germinate the first seed i.e. at the 5th day of sowing as same as control in which too first seed was germinated on the 4th day.

The effect of extracts on the growth of seedlings revealed that all shoot, root and seedling length was considerably inhibited in almost all concentrations. Only the root length and seedling length were slightly stimulated (12.24 and 9.83 % respectively) over the control at 1:20 dilution of the extract. Whereas shoot, root and seedling length showed decline along with the increase of concentration of extracts. Application of highest concentration (1:2.5) caused strong toxic effects in all the cases like shoot, root and seedling length of 33.96%, 42.19%, and 40.69 % respectively as against control. However, root hairs were seen in all the concentrations of extract but lateral roots were initiated only at lower concentrations of 1:20 level. Whereas in control there was no initiation of root hairs or lateral roots.

Although seedilng vigour index, root vigour index and shoot vigour index were lower in all the concentrations of extracts except at 1:20 where root vigour index and seeding vigour index were more as compared to control. In this investigation it was observed that the shoot: root ratio of seedling in different concentration of extracts did not show any major dissimilarity. Although with the 1:2.5 dilution, the occurrences of higher shoot: root ratio 0.26 over the control (0.22) indicated more inhibition of root growth than that of the shoot.

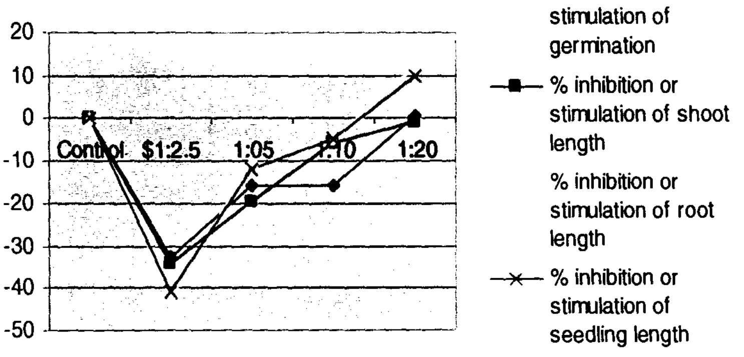
Table 11.7. Effect of extracts of aerial parts of *Ageratum conyzoides* L. on seed germination and seedling growth of *Camellia sinensis* (L.) O. Kuntze

PARAMETERS	CONCENTRATION OF SOLUTIONS				
	Control	**1:2.5**	**1:5**	**1:10**	**1:20**
Germination percentage	85.0	57.14	71.43	71.43	85.71
Germination % inhibition or stimulation	00.00	- 32.78	- 15.96	- 15.96	+ 0.84
Percentile of viability	99.17	66.67	83.34	83.34	100.0
Nonviable Percentage	15.0	42.86	28.57	28.57	14.29
Mean shoot length (cm) per seedling	1.06	0.70	0.85	1.00	1.05
Percentage of inhibition or stimulation of shoot length	00.00	- 33.96	- 19.81	- 5.66	- 0.94
Mean root length (cm) per seedling	4.74	2.74	4.27	4.53	5.32
Percentage of inhibition or stimulation of root length	00.00	- 42.19	- 9.92	- 4.43	+ 12.24
Mean total length (cm) per seedling	5.8	3.44	5.12	5.53	6.37
Percentage of inhibition or stimulation of seedling length	00.00	- 40.69	- 11.72	- 4.66	+ 9.83
Shoot vigour index	90.1	40	60.72	71.43	90
Root vigour index	402.9	156.56	305.01	323.58	455.98

Seedling vigour index	493.0	196.56	365.73	395.01	545.98
Shoot / Root ratio	0.22	0.26	0.20	0.22	0.20

+ / - Signs indicates stimulatory / inhibitory effect of extracts.

Fig. 11.7: Effect of extracts of *Ageratum conyzoides*



11.7.2 Effect of extracts of *Borreria latifolia* (Aublet) Schumann on Seed Germination and Seedling Growth of *Camellia sinensis* (L.) O. Kuntze

Effects of extracts of different concentration of aerial parts of *Borreria alata* on the germination of seeds and seedling growth of *Camellia sinensis* is shown in Table 11.8. In the present investigation it was observed that extracts of *Borreria alata* showed much inhibitory effect on seed germination and seedling growth of *Camellia sinensis*.

The germination percentage showed decline along with the increase of concentration of extract solutions. Higher concentration of extract at 1:2.5 showed more inhibitory effect (32.78 %) on the percentage of germination as well as on the percentile of viability. On the other hand, dilutions of 1:5, 1:10 and 1:20 exhibited same inhibitory effects on seed germination and caused 15.96 %, 15.96 % and 15.96 % decline as against 85.0 % with control, respectively. In this investigation it was observed that all the concentration of extracts took same time to germinate the first seed i.e. 4 days as it was also in the control, except at the dilution of 1:10 which was much delayed and took 7 days to germinate the first seed.

The effects of extracts on the growth of seedlings revealed that both shoot, root and seedling elongation was considerably inhibited in almost all concentrations. Only the growth of root and seedling were stimulated (20.25 % and 14.31 % respectively) at 1:20 dilution of the extract over the control. Application of highest concentration (1:2.5) showed vigorous toxic effects on shoot, root and seedling growth i.e. 52.83%, 55.06% and 54.66 % decline as against the control. However, no lateral roots were initiated. Only root hairs were seen at lower 1:10 concentrations. Whereas in control there was no initiation of root hairs or lateral roots.

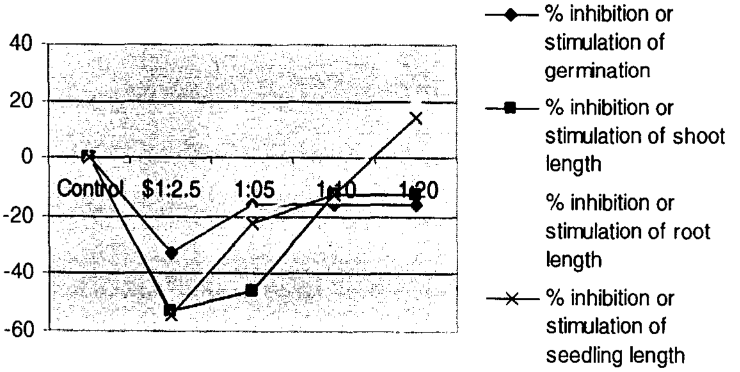
However, seeding vigour index, shoot vigour index and root vigour index were lower in almost all the concentrations of extracts over the control. But root vigour index were slightly more at the lower concentrations of 1:20 as compared to control. Though shoot: root ratio of seedling was influenced in all concentration of extracts and never showed any major dissimilarity. Highest shoot: root ratio of seedling was found at the concentration of 1:2.5 and 1:10 and those caused 0.23 over the control (0.22), indicating slight inhibition of root growth in comparison to shoot growth.

Table 11.8. Effect of extracts of aerial parts of *Borreria latifolia* (Aublet) Schumann on seed germination and seedling growth of *Camellia sinensis* (L.) O. Kuntze

PARAMETERS	CONCENTRATION OF SOLUTIONS				
	Control	1:2.5	1:5	1:10	1:20
Germination percentage	85.0	57.14	71.43	71.43	71.43
Germination % inhibition or stimulation	00.00	- 32.78	- 15.96	- 15.96	- 15.96
Percentile of viability	100.0	67.22	84.04	84.04	84.04
Nonviable Percentage	15.0	42.86	28.57	28.57	28.57
Mean shoot length (cm) per seedling	1.06	0.50	0.57	0.93	0.93
Percentage of inhibition or stimulation of shoot length	00.00	- 52.83	- 46.23	- 12.26	- 12.26
Mean root length (cm) per seedling	4.74	2.13	3.93	4.13	5.70
Percentage of inhibition or stimulation of root length	00.00	- 55.06	- 17.09	- 12.87	+ 20.25
Mean total length (cm) per seedling	5.8	2.63	4.5	5.06	6.63
Percentage of inhibition or stimulation of seedling length	00.00	- 54.66	- 22.41	- 12.76	+ 14.31
Shoot vigour index	90.1	28.57	40.72	66.43	66.43
Root vigour index	402.9	121.71	280.72	295.01	407.15
Seedling vigour index	493.0	150.28	321.44	361.44	473.58
Shoot / Root ratio	0.22	0.23	0.15	0.23	0.16

+ / - Signs indicates stimulatory / inhibitory effect of extracts.

Fig. 11.8: Effect of extracts of *Borreria alata*



11.7.3 Effect of extracts of *Drymaria villosa* Chamisso *et* Schlechtendal on Seed Germination and Seedling Growth of *Camellia sinensis* (L.) O. Kuntze

Table 11.9 presents the effects of extracts of whole plants of *Drymaria villosa* on seed germination and seedling growth of *Camellia sinensis*. Results revealed that extracts at different concentrations reduced the germination percentage in comparison to control.

In this investigation reciprocal relationship between reduction of germination percentage and extract concentration was observed. The application of 1:2.5, 1:5 and 1:10 dilutions caused 32.78 %, 15.96 % and 15.96 % inhibition in seed germination, respectively. Whereas in lowest concentration of extract of 1:20 exhibited least stimulation 0.84 % in seed germination as against 85.0 with control, respectively. It was noticed that only highest concentration of extracts of 1:2.5 showed delayed germination, which germinated the first seed at 8^{th} day after sowing. While with all the lower concentration of extracts took same time to germinate the first seed i.e. after 4 days as it is in control.

Results of the effects of extracts on seedling growth also showed similar effects as in case of germination. The length of root, shoot and seedlings reduced inversely under the influence of different dilutions of extract. Growth of root and shoot showed inhibitory effects in almost all the concentrations of extract except at lower dilution of 1:20 level where shoot growth showed stimulatory effect of 13.21 % over the control. Treatments with extract solutions, namely, 1:2.5, 1:5 and 1:10 resulted in 25.34 %, 19.66 % and 9.83 % decline whereas in diluted concentration of extract of 1:20 showed least 2.24 % stimulation in seedling length over the control, respectively. However, there was no initiation of root hairs or lateral roots in control. But lateral root initiation was found at a later stage only in 1:5 dilution.

Seedling vigour index, root vigour index and shoot vigour index were lower in all concentrations of extract except at the lowest dilution (1:20), where all these three are little higher than control. However, all the concentrations of extract shoot: root ratio of seedling was slightly influenced. Highest shoot: root ratio of seedling was found in lowest concentration of (1:20) caused 0.25 over the control (0.22) which indicates the inhibition of root growth in comparison to shoot growth.

Table 11.9. Effect of extracts of aerial parts of *Drymaria villosa* Chamisso et Schlechtendal on seed germination and seedling growth of *Camellia sinensis* (L.) O. Kuntze

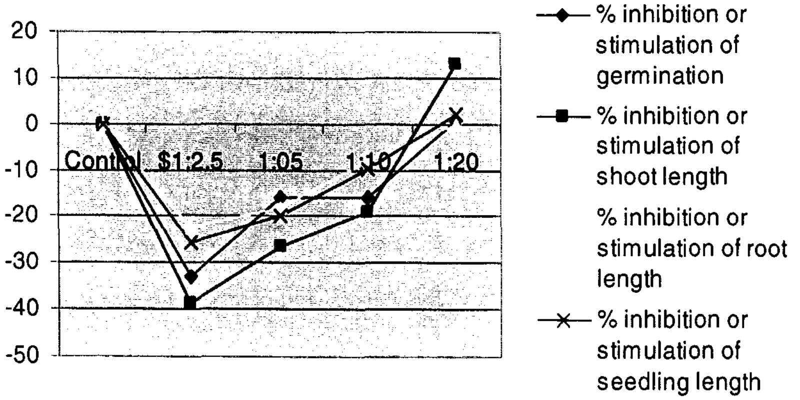
PARAMETERS	CONCENTRATION OF SOLUTIONS				
	Control	1:2.5	1:5	1:10	1:20
Germination percentage	85.0	57.14	71.43	71.43	85.71
Germination % inhibition or stimulation	00.00	- 32.78	- 15.96	- 15.96	+ 0.84


7th
30th
1
2
3
4
5
6

Percentile of viability	99.17	66.67	83.34	83.34	100
Nonviable Percentage	15.0	42.86	28.57	28.57	14.29
Mean shoot length (cm) per seedling	1.06	0.65	0.78	0.86	1.2
Percentage of inhibition or stimulation of shoot length	00.00	- 38.68	- 26.42	- 18.87	+ 13.21
Mean root length (cm) per seedling	4.74	3.68	3.88	4.37	4.73
Percentage of inhibition or stimulation of root length	00.00	- 22.36	- 18.14	- 7.81	- 0.21
Mean total length (cm) per seedling	5.8	4.33	4.66	5.23	5.93
Percentage of inhibition or stimulation of seedling length	00.00	- 25.34	- 19.66	- 9.83	+ 2.24
Shoot vigour index	90.1	37.14	55.72	61.43	102.85
Root vigour index	402.9	210.28	277.15	312.15	405.41
Seedling vigour index	493.0	247.42	332.87	373.58	508.26
Shoot / Root ratio	0.22	0.18	0.20	0.20	0.25

+ / - Signs indicates stimulatory / inhibitory effect of extracts.

Fig. 11.9: Effect of extracts of *Drymaria villosa*



11.7.4 Effect of extracts of *Galinsoga parviflora* Cavanilles on Seed Germination and Seedling Growth of *Camellia sinensis* (L.) O. Kuntze

Different parameters of seed germination and seedling growth of *Camellia sinensis* under the influence of extracts from aerial parts of *Galinsoga parviflora* are recorded in Table - 11.10.

Results reveal that the process of seed germination has been affected by the treatment of the extract. The higher concentrations of 1:2.5 and 1:5 resulted 15.96 % and 15.96 % decline in seed germination over the control (85.0 %). Besides diluted extracts of 1:10 and 1:20 caused least 0.84 % and 0.84 % stimulation in seed germination in comparison to control, which led to the increase of the percentile of viability (83.34 %, 83.34 %, 100 % and 100 % respectively) along with the increase in dilution. Moreover, in all the concentration of extracts time required for germination was same i.e. 4 days to germinate the first seed except at the lower dilution of 1:20 that showed delayed germination where first seed germinated after 7 days. In control the first seed germinated after 4 days.

The length of seedling and root appeared to be promoted with the lower concentration of extracts at 1:20 level. It was observed that there was 6.72 % and 8.44% stimulation in the elongation of seedling and root at 1:20 dilution of the extract over the control. On the other hand, the 1:2.5, 1:5 and 1:10 levels of dilution showed inhibition in the elongation of seedling and root. Highest inhibition in seedling and root elongation was found in the highest concentration (1:2.5) of extracts 34.48 and 49.37 %, respectively. The shoot growth was stimulated more in almost all the concentrations i.e. 1:2.5, 1:5 and 1:10 levels of dilution and exhibited 32.08 %, 32.08 % and 13.21 % stimulation, respectively except at 1:20 dilution level which showed the least inhibitory effect of 0.94 % as compared to control. So, totally opposite responses in the growth of shoot and root were shown in different concentrations of extracts. Moreover, formation of root hairs and the initiation of lateral roots were inhibited in this treatment.

Seedling and root vigour indices were higher at the dilution of 1:20 and lower at 1:2.5, 1:5 and 1:10 levels. However, shoot vigour index was higher in all the higher concentrations of extracts and for the lower concentration only 1:20 dilution exhibited similar shoot vigour index in comparison with the control. In this investigation it was observed that shoot: root ratio of seedlings was much influenced. At the lower level of concentration namely, 1:5, 1:10 and 1:20 shoot: root ratio of seedlings were 0.34, 0.28 and 0.20, respectively, caused better growth of shoot. But in the highest concentration (1:2.5) this ratio was increased (0.58) indicating more inhibition of root growth than shoot.

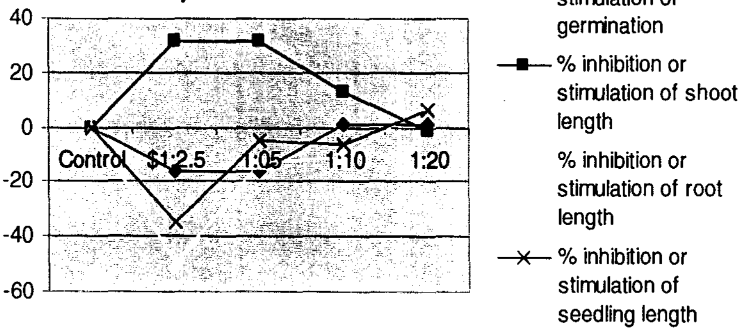
Table 11.10. Effect of extracts of aerial parts of *Galinsoga parviflora* Cavanilles on seed germination and seedling growth of *Camellia sinensis* (L.) O. Kuntze

PARAMETERS	CONCENTRATION OF SOLUTIONS				
	Control	1:2.5	1:5	1:10	1:20
Germination percentage	85.0	71.43	71.43	85.71	85.71
Germination % inhibition or stimulation	00.00	- 15.96	- 15.96	+ 0.84	+ 0.84
Percentile of viability	99.17	83.34	83.34	100	100
Nonviable Percentage	15.0	28.57	28.57	14.29	14.29
Mean shoot length (cm) per seedling	1.06	1.4	1.4	1.2	1.05
Percentage of inhibition or stimulation of shoot length	00.00	+32.08	+32.08	+ 13.21	- 0.94
Mean root length (cm) per seedling	4.74	2.4	4.12	4.22	5.14
Percentage of inhibition or stimulation of root length	00.00	- 49.37	- 13.08	- 10.97	+ 8.44
Mean total length (cm) per seedling	5.8	3.8	5.52	5.42	6.19
Percentage of inhibition or stimulation of seedling length	00.00	- 34.48	- 4.83	- 6.55	+ 6.72

Shoot vigour index	90.1	100.0	100.0	102.85	90.0
Root vigour index	402.9	171.43	294.29	361.70	440.55
Seedling vigour index	493.0	271.43	394.29	464.55	530.55
Shoot / Root ratio	0.22	0.58	0.34	0.28	0.20

+ / - Signs indicates stimulatory / inhibitory effect of extracts.

Fig. 11.10: Effect of extracts of *Galinsoga parviflora*



11.7.5 Effect of extracts of *Mikania micrantha* Kunth on Seed Germination and Seedling Growth of *Camellia sinensis* (L.) O. Kuntze

Effects of the extracts of whole plant of *Mikania micrantha* on different parameters of seed germination and seedling growth of *Camellia sinensis* are presented in Table - 11.11.

Both, germination and early growth of seedling were affected adversely by the effect of this dominating associate of tea. At the beginning, germination percentage decreased linearly against the increase of concentration of extracts. It was minimum (57.14 %) with the highest concentration (1:2.5) of extracts and showed 32.78 % inhibitory effect over control. Moreover, extract concentrations of 1:5 and 1:10 caused 32.78 % and 15.96 % decline and 1:20 dilution showed 0.84 % stimulation in seed germination, as against the control (85.0). When in 1: 2.5 dilution of extract 12 days was required for the germination of the first seed, it took only 5 days, like control, in other.

As it was in case of germination, the effect of extracts on early growth of seedlings was also quite prominent. With extracts treatment the growth of shoot, root and seedling were inhibited adversely and were always less than that of the control except in 1:20 dilution, where shoot and seedling growth enhanced to 20.75 % and 1.38 %. Treatments with extracts dilutions, namely, 1:2.5, 1:5, and 1:10 caused 15.09 %, 62.26 % and 1.89 % inhibition of shoot elongation and 77.22 %, 56.75 %, 29.75 % and 2.95 % inhibition in root elongation, respectively, over the control. It is clear that toxic effects on the growth of roots of new born seedlings were tremendous than that of shoot growth in different concentrations of extracts. Highest degree of inhibition (65.86%) of seedling growth was resulted in highest concentration 1:2.5 over the control. There was no initiation of lateral roots except at 1:5 dilution where only root hairs were seen.

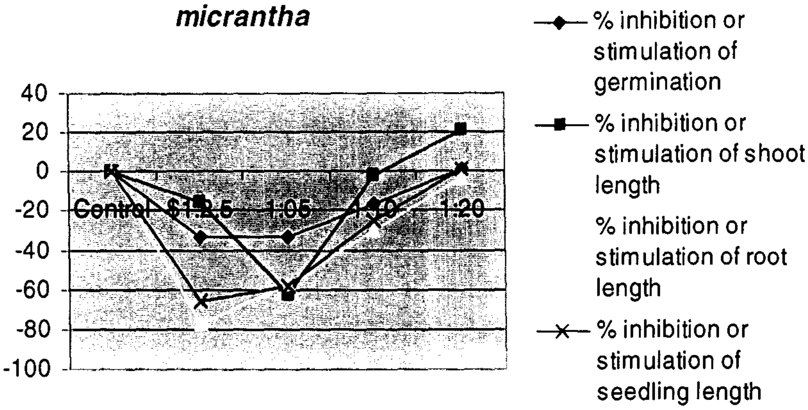
Moreover, the seedling vigour index, root vigour index and shoot vigour index, were always lower in all concentration of extracts, except at the 1:20 dilution where shoot and seedling vigour indices were little higher than that of control. In this investigation it was observed that the shoot: root ratio of seedling was affected considerably in different concentrations. Although with the 1:2.5 dilution, the occurrence of higher shoots: roots ratio (0.83) indicated more injurious and/or toxic inhibition of root growth than that of the shoot as compared to control (0.22).

Table 11.11. Effect of extracts of aerial parts of *Mikania micrantha* Kunth on seed germination and seedling growth of *Camellia sinensis* (L.) O. Kuntze

PARAMETERS	CONCENTRATION OF SOLUTIONS				
	Control	1:2.5	1:5	1:10	1:20
Germination percentage	85.0	57.14	57.14	71.43	85.71
Germination % inhibition or stimulation	00.00	- 32.78	-32.78	-15.96	+ 0.84
Percentile of viability	99.17	66.67	66.67	83.34	100
Nonviable Percentage	15.0	42.86	42.86	28.57	14.29
Mean shoot length (cm) per seedling	1.06	0.9	0.4	1.04	1.28
Percentage of inhibition or stimulation of shoot length	00.00	- 15.09	- 62.26	-1.89	+ 20.75
Mean root length (cm) per seedling	4.74	1.08	2.05	3.33	4.60
Percentage of inhibition or stimulation of root length	00.00	- 77.22	- 56.75	- 29.75	- 2.95
Mean total length (cm) per seedling	5.8	1.98	2.45	4.37	5.88
Percentage of inhibition or stimulation of seedling length	00.00	- 65.86	- 57.76	- 24.66	+ 1.38
Shoot vigour index	90.1	51.43	22.86	74.29	109.71
Root vigour index	402.9	61.71	117.14	237.86	394.27
Seedling vigour index	493.0	113.14	140	312.15	503.98
Shoot / Root ratio	0.22	0.83	0.20	0.31	0.28

+ / - Signs indicates stimulatory / inhibitory effect of extracts.

Fig. 11.11: Effect of extracts of *Mikania micrantha*



11.7.6 Effect of extracts of *Persicaria runcinata* (D. Don) H. Gross on Seed Germination and Seedling Growth of *Camellia sinensis* (L.) O. Kuntze

Different parameters of seed germination and seedling growth under the influence of extracts of aerial parts of *Persicaria runcinata* on *Camellia sinensis* have been presented in Table - 11.12.

In the present investigation it was found that the increase of the concentration of the extracts led to decrease in the percentage of germination as well as percentile of viability. The application of 1:2.5 and 1:5 dilutions of extracts caused 15.96 % and 15.96 % inhibition in seed germination respectively over the control, expressing clear decline of the percentile of viability. Moreover, lower concentrations of extracts i.e. 1:10 and 1:20 dilutions appeared to have 0.84 % and 17.65 % stimulatory effect in seed germination than that of the control (85.0 %). All the concentration of extracts except 1: 20 levels showed delayed germination and took 7 days to germinate the first seed. However, at 1: 20 concentration of extract showed first seed germination on the 4^{th} day.

The seedling growth was adversely affected in different concentrations of extracts. Roots of seedlings were more affected than that of shoots and only lateral root was initiated at the lower 1:20 level of dilution. However, control did not show any root hairs and lateral roots initiation within this period. Application of different concentrations of extracts, namely, 1:2.5, 1:5 and 1:20 caused 19.81 %, 15.09 % and 5.66 % inhibition whereas 1:10 dilution showed 22.64 % stimulation in shoot length. In case of root length, 1:2.5, 1:5 and 1:10 caused 40.93, 31.86 and 19.83 % reduction, when 1:20 dilution showed little stimulatory effect of 0.84 % in root elongation as compared to the control. Moreover, growth of seedlings was inhibited in all the concentration of extract. Highest inhibition of seedling growth resulted in strong concentration at 1:2.5 levels was 37.07 % as compared to control.

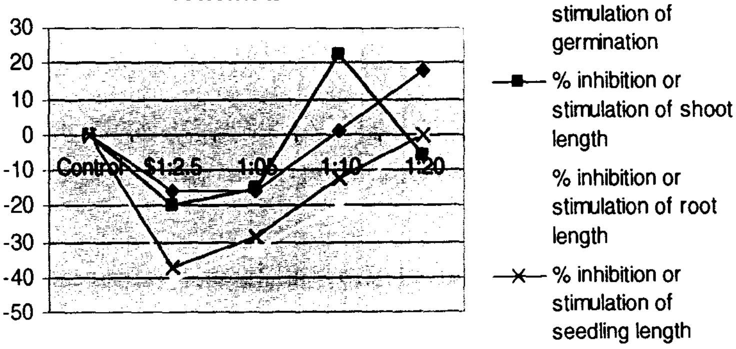
Shoot, root and seedling vigour indices were lower in almost all concentrations of diluted extracts except at the lower concentration of 1:20. In the present study it was also observed that the shoot: root ratios of seedlings were higher (0.30, 0.28 and 0.34) in 1:2.5, 1:5 and 1:10 concentrations respectively except the lower concentration of 1:20 that showed little less i.e. 0.21 than that of the control (0.22) causing more inhibition of the root growth than to the shoot.

Table 11.12. Effect of extracts of aerial parts of *Persicaria runcinata* (D. Don) H. Gross on seed germination and seedling growth of *Camellia sinensis* (L.) O. Kuntze

PARAMETERS	CONCENTRATION OF SOLUTIONS				
	Control	1:2.5	1:5	1:10	1:20
Germination percentage	85.0	71.43	71.43	85.71	100
Germination % inhibition or stimulation	00.00	- 15.96	- 15.96	+ 0.84	+ 17.65
Percentile of viability	85	71.43	71.43	85.71	100
Nonviable Percentage	15.0	28.57	28.57	14.29	00.00
Mean shoot length (cm) per seedling	1.06	0.85	0.9	1.3	1.00
Percentage of inhibition or stimulation of shoot length	00.00	-19.81	- 15.09	+ 22.64	- 5.66
Mean root length (cm) per seedling	4.74	2.8	3.23	3.8	4.78
Percentage of inhibition or stimulation of root length	00.00	- 40.93	- 31.86	- 19.83	+ 0.84
Mean total length (cm) per seedling	5.8	3.65	4.13	5.1	5.78
Percentage of inhibition or stimulation of seedling length	00.00	- 37.07	- 28.79	- 12.07	- 0.34
Shoot vigour index	90.1	60.72	64.29	111.42	100.0
Root vigour index	402.9	200.0	230.72	325.70	478.0
Seedling vigour index	493.0	260.72	295.01	437.12	578.0
Shoot / Root ratio	0.22	0.30	0.28	0.34	0.21

+ / - Signs indicates stimulatory / inhibitory effect of extracts.

Fig. 11.12: Effect of extracts of *Persicaria runcinata*



11.8 CONCLUSION

Results reveal that allelopathic experiments with the leachates and extracts of six dominant weed species on the germination and early seedling growth of tea (*Camellia sinensis*) are quite interesting which need further studies. Almost in all the cases of leachates and extracts at highest concentration (1:2.5) showed no promotory effect instead, high to complete inhibitory effects on the germination of seeds and subsequent seedling growth of *Camellia sinensis*. However, interestingly, it was noted that in case of *Persicaria runcinata* the highest concentration (1:2.5) of leachate showed slightly stimulatory effects on seed germination. However the leachates or extracts of all the test species had no major effect on seed germination. But, eirt allelopathic effects were noticed in seedling elongation, specially on the root elongation.

It is also noteworthy that in all the cases of leachates or extracts at lower *Camellia sinensis*. These data reflect that inhibitory or stimulatory effect of a given plant leachate or extract effects differentially under different concentrations. This agrees with the views of Rice (1984) who stated ".... apparently most, if not all, organic compounds that are inhibitory to the same process in very small concentrations" and also supports the views of Molisch (1937) who referred allelopathy as biochemical interactions detrimental as well as beneficial between all types of plants. The result suggests that the growth inhibitory compounds due to auto-toxic principles contained in the plant tissue are concentration rate dependent. At lower concentrations, with some species, these compounds did not inhibit the germination or seedling growth or rather tended to stimulate, whereas at higher concentrations they inhibited the germination and seedling growth of *Camellia sinensis*.

The observation showed that *Mikania micrantha* was a highly toxic plant, which strongly inhibited not only the germination of seeds but also the seedling growth of *Camellia sinensis* in both leachates and extracts under use. It indicates the presence of potent germination and growth-retarding factors of allelopathic implication for *Camellia sinensis* in the commonly associated species. So an intensive study of the plant communities in relation to *Mikania micrantha* might be of great practical value for understanding the allelochemic interactions between the plant associations.

However the results of the use of leachates or extracts of *Borreria alata* and *Ageratum conyzoides* individually showed the inhibitory effects to the germination as well as seedling growth of *Camellia sinensis* at higher concentrations. Interestingly, its allelopathic effect was noticed much in seedling elongation, specially on the elongation of root mainly in extract solution. It may be inferred that these plants not only compete with *Camellia sinensis* but also interact quite effectively to some extent by retarding its post-germination aspects due to their allelopathic potentialities. This type of differential behavior of delayed emergence and the inhibition of seedling growth in different species of plants has been reported by different authors. In this respect, Klein & Schusta (1930) have reported high content of a water-soluble alkaloid that have found fatal in high concentration.

Similarly, at lower concentrations of *Ageratum conyzoides, Borreria alata, Galinsoga parviflora, Drymaria villosa* and *Persicaria runcinata* stimulated seedling growth of *Camellia sinensis* but none of them at highest concentration showed any promotory effect. This is in conformity with the observation made by Chatterji (1975) where aqueous extracts of *Crotalaria medicagenea* in lower concentration stimulated the growth of hypocotyl and radicle of the seedling of *Calligonum polygonoides* while the highest concentration was inhibitory.

Furthermore, all the lower dilutions of leachate and extract of *Galinsoga parviflora* showed stimulatory effect on seed germination and seedling growth and interestingly shoot length was much stimulated in higher concentrations of extract.

Finally, it was observed that in almost all the cases biochemical interactions are to be inhibitory than stimulatory between weeds and crop plant like TEA and moreover the rate of inhibition of extract solutions were more than respective leachate solutions. It suggests that some compounds of plants do not leach out and / or the compounds in the test solutions are higher in extracts than in the leachates. Since the effects of leachates or extracts were variable with the variation of concentration of solutions, the compounds responsible for inhibition or stimulation are supposed to be water soluble in nature. It is likely that these compounds leach out from the plants during the season or during decomposition of residues and then get absorbed into the soil. Thereafter the moisture in the soil dilutes the released compounds to cause auto-toxicity in field conditions. Schreiner & Reed (1908) reported that all the allelopathics are water-soluble compounds, mostly phenolic in nature. Phenolic compounds may be in effective, inhibitory or stimulatory in their biological activities (Kefeli & Kadyrov 1971).

From the above findings it is concluded that in an intermixed community of weed and crop plants (TEA), the more aggressive species usually dominates and this aggressiveness is associated with favorable contrasting growth habits and above these factors, there are some weeds which supplement aggressiveness by the release of growth inhibiting substances or allelochemicals, get released into the soil as root exudates or leachates of their dead and decaying vegetative matter or both, are inhibitory or stimulatory to seed germination, growth and development of seedlings of *Camellia sinensis.* Thereby reducing or eliminating the competitiveness of crop plants as well as of other weed species.

It has also been observed by several workers that, crops too have allelopathic effects on weeds and such growth inhibitory phytotoxic compounds might act as natural herbicides (Bell & Koeppe, 1972). Though a considerable amount of information related to allelopathy has accumulated in scientific literature, its significance to agriculture and particularly, to weed science is yet to be fully recognized to evaluate its effective use.