Allelopathic Effects of Some Dominant Weeds on Seed Germination and Seedling Growth of Tea

Chandra Ghosh, Kishor Biswas and A. P. Das

Research Journal of Agricultural Sciences
An International Journal

P- ISSN: 0976-1675
E- ISSN: 2249-4538

Volume: 12
Issue: 05

Res Jr of Agril Sci (2021) 12: 1733–1741

CARAS

Res. Jr. of Agril. Sci. (Sep-Oct 2021) 12(5): 1733–1741
www.rjas.org

Full Length Research Article

Allelopathic Effects of Some Dominant Weeds on Seed Germination and Seedling Growth of Tea

Chandra Ghosh[1], Kishor Biswas*[2] and A. P. Das[3]

Received: 31 May 2021 | Revised accepted: 04 Sep 2021 | Published online: 02 Oct 2021

ABSTRACT

The allelopathic effect of different concentration of leachates and extracts of six dominant weed species was studied on seed germination and early seedling growth of tea plants [*Camellia sinensis* (L.) Kuntze]. Almost in all the cases of leachates and extracts, the highest concentration (1:2.5) showed inhibitory effect on germination of seeds and subsequent seedling growth of tea. 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. The leachates or/and extracts of those test species having no major effect on seed germination, affect seedling elongation especially the root elongation. The inhibitory or stimulatory effect of a test plant leachate or/and extract depends on the concentrations. The study also suggests further allelopathic investigation, isolation and identification of active allelochemicals as well as their potential uses as growth and yield promoting agents.

***Key words*:** Leachate, Extract, *Camellia sinensis,* Root length, Shoot length

Allelopathy is a form of competition that works through interfering chemicals to prevent other plants from using the available resources and ultimately to keep other plants out of its space and thus influence the evolution and distribution of other species including microorganisms. Generally, the toxic chemical substances from allelopathic plants which are known as allelochemicals, escaped into the environment in four different ways – weathering, leaching, exudation and volatilization and subsequently influence the growth and development of other neighbouring plants [1-3]. Target species are affected by these toxins in different ways. They may affect germination of seeds, inhibit shoot and/or root growth, nutrient uptake, or may attack a naturally occurring symbiotic relationship thereby destroying the usable source of nutrient of the Plants. Modern research suggests that allelopathy may exert both positive and negative effects depending upon the concentration of allelochemicals and organisms involved [4-9].

One of the most worked out aspects of allelopathy in manipulated ecosystems is its role in agriculture, and the effects of weeds on crops, impacts of crops on weeds and effect of crops on some other crops have been invariably emphasized. Scientific investigation also revealed the prospect and possibility of using allelochemicals as growth regulators and natural pesticides [10-11] and thus sustainable agriculture may be promoted by replacing or at least reducing the uses of synthetic and harmful pesticides (including weedicides, insecticides, nematicides, fungicides etc.) which are the continuous sources of innumerable hazards viz., development of resistance in organisms, environmental pollution, toxicity related health hazards in humans and livestock etc. So, for the sustainability of agriculture as well as pollution free environment it is urgent need to minimize their uses and to take advantages of allelopathic strategies for pest management. Tea [*Camellia sinensis* (L.) Kuntze] is one of the important crops which plays major role in the economy and development of North Bengal as well as the country. Major parts of Northern Bengal is occupied by tea gardens and diverse group of weeds in and around the gardens create different forms of hazards including outbreak of pests and pathogens, increasing cultivation cost, hampering the quality and quantity of tea etc [12]. On the other hand, no such information is there regarding the allelopathic effects of common weeds on tea and no such study has been undertaken by any other worker. Therefore, the present investigation was carried out to evaluate the impacts of dominants weeds on seed germination and early growth of tea seedling.

* Kishor Biswas
✉ kbiswas83@gmail.com

[1] Department of Tea Science, University of North Bengal, Darjeeling - 734 013, West Bengal, India

[2] Department of Botany, Darjeeling Government College, Darjeeling - 734 101, West Bengal, India

[3] Department of Botany, Rajiv Gandhi University, Rono Hills, Doimukh - 791 112, Arunachal Pradesh, India

MATERIALS AND METHODS

For determination of allelopathic effect of dominant weeds on tea, six common dicotyledonous weeds with higher Importance Value Indices were selected as test plants. *Drymaria villosa* Schltdl. & Cham., *Galinsoga parviflora* Cav. and *Persicaria runcinata* (Buch.-Ham. *ex* D.Don) H.Gross were selected from tea gardens of Hilly area of Darjeeling district and other three viz. *Ageratum conyzoides* L., *Spermacoce alata* Aubl. and *Mikania micrantha* Kunth from Terai tea gardens. Entire aerial parts of different test species were collected from the fields in air-tight polythene bags, brought to the laboratory, washed thoroughly in running tap water and then in distilled water and then used for preparation of leachate and extracts. Mature seeds of TS_{520} cultivar of tea were collected from the *seed-bari* [demarcated good seed producing part of a Tea Garden] of Terai tea gardens and stored at 4º C in brown paper envelopes and used for different sets of experiment during the month of December and January. The procedures described by Putnam and Duke [13]; Kadir [14]; Datta and Ghosh [15] were followed for this work.

Preparation of extracts and leachates

The aerial parts of all the collected test plants were separately washed thoroughly in distilled water to remove adhering particles and the leachate were obtained by soaking 100g of fresh material in distilled water for 72 hours. The leachate were then filtered through Whatman (No.1) filter paper and the volume of the filtrate was made to 250 ml by adding distilled water to make the stock solution of leachate and was expressed by the ratio 1:2.5.

To prepare the stock solution of extract of the same strength (1:2.5) 100g of plant material was grinded into fine paste using a Bajaj Mixture Machine, filtered through Whatman (No.1) filter paper and the volume of the filtrate was made to 250 ml by adding distilled water. Then the desired concentrations of 1:5, 1:10, 1:20 of both the leachate and extracts were prepared consequently from the stock by subsequent dilution with distilled water.

Germination tests

Viable tea seeds were surface sterilized with 0.1% $HgCl_2$ solution for 3 minutes and transferred to 1% silver nitrate solution to remove the $HgCl_2$ and thoroughly washed in sterile distilled water. 10 healthy seeds were placed in a sterile plastic bowls [Diameter 12.2 cm, Depth 4 cm] lined with a layer of absorbent cotton moistened sufficiently by adding 25 ml of the test solutions whereas 25 ml of distilled water in case of control set. The plastic bowls were lined with aluminium foil and kept under 20°C. Two sets of replica for each test solution were made. Emergence of radicle was considered as criteria for seed germination. The germinated seeds were counted daily and the linear lengths of roots, shoots and seedlings were measured after 15 days of sowing. Root hairs, lateral roots and leaf initiation were also observed and recorded. Collected data was used to calculate the percentage of seed germination, percentage of inhibition or stimulation of germination, percentage of viability and non-viability, 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.

Data analysis

For the analysis of recorded data following formulae were used and presented in tabular forms.

1. Germination Percentage = (Number of seeds germinated/Number of seeds sown) × 100
2. Percentage of Inhibition or Stimulation of Germination; Saxena *et al.* [16]
   = [Germination % in desired solution – Germination % in control) / Germination % in control] × 100
3. Percentage of Viability = (Number of viable seeds/Number of seed sown) × 100
4. Percentage of Non – viability = (Number of non-viable seeds / Number of seed sown) × 100
5. Percentile of Viability = (% of viability at observed dilution / Maximum % of viability) × 100
6. Percentage of inhibition or stimulation of shoot Length = [(shoot length in desired solution – shoot length in control)/shoot length in control] × 100
7. Percentage inhibition or stimulation of root Length = [(root length in desired solution – root length in control) / Root length in control] × 100
8. Percentage inhibition or stimulation of seedling Length = [(seedling length in desired solution – seedling length in control) / Seedling length in control] × 100
9. Shoot and Root Vigour Index: Shoot and root Vigour Index was calculated following the formula described by Thind and Malick [17].
   Shoot Vigour Index = Germination percentage × Shoot Length
   Root Vigour Index = Germination percentage × Root Length
   Seedling Vigour Index = Germination percentage × Seedling Length
10. Shoot-Root Ratio: The formula of Bajpai *et al.* [18] was used for the calculation of the shoot-root ratio.
   Shoot: Root = length of Shoot/length of Root

RESULTS AND DISCUSSION

In the present investigation leachates and extracts of six associated species of tea were tested for their allelopathic effects on seed germination and seedling growth of tea plant and the results are presented below (Table 1-12; ± sign in the table indicates stimulatory / inhibitory effect)

Effects of Ageratum conyzoides

Leachate: Present study reported both inhibitory and stimulatory effect of different concentrations of leachate of *A. conyzoides* on tea seed germination and seedling growth and are represented in (Table 1). Higher concentrations of leachate of 1:2.5 and 1:5 exhibited 15.96% and 15.96% inhibition on seed germination whereas with the dilution of leachates at 1:10 and 1:20 the percentage of germination was increased to 85.71 and 100 respectively showing 0.84% and 17.65% stimulation of seed germination. Germination was delayed by 3 days at the highest concentration of leachate of 1:2.5 as it took 7 days to germinate the first seed as compared to the control in which the first seed was germinated in the 4th day as in lower concentrations (1:5, 1:10 and 1:20).

Strong inhibitory effect on root growth were also noted at the higher concentration of leachate of 1:2.5 and 1:5 and inhibitory effect were estimated to be 46.62 and 32.49% respectively, as compared to control and it was decreased with the gradual dilution of leachate. Root hairs and lateral roots were developed at 1:5 concentrations as well as at lower concentrations of 1:10 but not in control solution.

Table 1 Effect of *Ageratum conyzoides* leachate on seed germination and seedling growth of tea

Parameters	Concentration of solutions				
	Control	1:2.5	1:5	1:10	1:20
Germination percent	85.00	71.43	71.43	85.71	100
Germination inhibition/ stimulation percent	00.00	- 15.96	- 15.96	+0.84	+ 17.65
Percentile of viability	85.00	71.43	71.43	85.71	100
Non-viability percent	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
Percent of inhibition/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
Percent of inhibition/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
Percent of inhibition/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

Increased shoot vigour index was noted at lower concentration of leachates and maximum value was recorded at the concentration of 1:10. Seedling vigour index and root vigour index were also increased by the lower concentrations of leachates. 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.

Extract: Extract of *Ageratum conyzoides* also showed its allelopathic effect on tea seed germination and seedling growth (Table 2) but it was more prominent than that of leachate. 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 and 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. Seed under all the treatment 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 5th day.

All the shoot, root and seedling length was considerably inhibited in almost all concentrations except 1:20 dilution in which the root length and seedling length were slightly stimulated by 12.24 and 9.83% respectively over the control. Application of highest concentration (1:2.5) of extract caused strong toxic effects in all the cases like shoot, root and seedling length of 33.96%, 42.19%, and 40.69% respectively and that was parallel with that of leachate. However, root hairs were seen in all the concentrations of extract but lateral roots were initiated only at the lowest concentrations of 1:20 level. Whereas in control there was no initiation of root hairs or lateral roots as in case of leachate.

Table 2 Effect of extracts of *Ageratum conyzoides* on seed germination and seedling growth of tea

Parameters	Concentration of solutions				
	Control	1:2.5	1:5	1:10	1:20
Germination percent	85.0	57.14	71.43	71.43	85.71
Germination inhibition/ stimulation percent	00.00	- 32.78	- 15.96	- 15.96	+ 0.84
Percentile of viability	99.17	66.67	83.34	83.34	100.0
Non-viability percent	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
Percent of inhibition/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
Percent of inhibition/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
Percent of inhibition/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

Effects of Spermacoce alata

Leachate: Leachate of *Spermacoce alata* at the highest concentration of 1:2.5 exhibited 51.14% of seed germination against control where germination percentage was 85 and thus strong inhibition of germination by 31.78 % were reported. By the dilutions of leachate of 1:5 and 1:10 the percentage of germination was increased to 71.43, 71.43 respectively thus gradually decreased the percentage of inhibition and ultimately the seed germination was stimulated slightly by 0.84% at the lowest concentration (Table 3). Germination was delayed in the highest concentration of leachate of 1:2.5 and took 11 days to germinate the first seed whereas in lower concentrations (1:5, 1:10 and 1:20) as well as in control it took only 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 and lateral roots.

The study also reported reduced shoot vigour index, root vigour index and seedling vigour index at concentrations of leachate of 1:2.5, 1:5 and 1:10. But in contrast, at 1:20 concentration all the shoot vigour index, root vigour index, and seedling vigour index were increased 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) by all the higher concentrations of leachate in comparison to control (0.22) indicating more inhibition of shoot length than that of root length.

Extract: Extract of *Spermacoce alata* in contrast with the leachate showed only inhibitory effect on seed germination and seedling growth of tea and the germination percentage decreased along with the increase of concentrations of extract solutions (Table 4). Higher concentration of extract of 1:2.5 showed 32.78% of inhibitory effect on germination. On the other hand, dilutions of 1:5, 1:10 and 1:20 exhibited same degree of inhibition (15.96%). All the concentrations of extract took same time to germinate the first seed i.e., 4 days as in the control, except the dilution of 1:10 which delayed the germination by 3 days as the first seed was germinated on the 7th day after sowing.

Shoot length was inhibited by all the concentrations of extract and the inhibition % was comparatively higher than leachate lowest concentration of which had some stimulatory effect. But the root length and seedling length were both inhibited and stimulated by higher and lower concentrations of extract respectively, and it was more prominent than that of leachate. In contrast to leachate, root hairs were seen at 1:10 concentration only. Like leachate in control there was no initiation of root hairs or lateral roots.

Table 3 Effect of leachate of *S. alata* on seed germination and seedling growth of tea

Parameters	Concentration of solutions				
	Control	1:2.5	1:5	1:10	1:20
Germination percent	85.0	51.14	71.43	71.43	85.71
Germination inhibition/ stimulation percent	00.00	- 31.78	- 15.96	- 15.96	+ 0.84
Percentile of viability	99.17	66.67	83.34	83.34	100.0
Non-viability percent	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
Percent of inhibition/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
Percent of inhibition/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
Percent of inhibition/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

Table 4 Effect of extracts of *S. alata* on seed germination and seedling growth of tea

Parameters	Concentration of solutions				
	Control	1:2.5	1:5	1:10	1:20
Germination percent	85.0	57.14	71.43	71.43	71.43
Germination inhibition/ stimulation percent	00.00	- 32.78	- 15.96	- 15.96	- 15.96
Percentile of viability	100.0	67.22	84.04	84.04	84.04
Non-viability percent	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
Percent of inhibition/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
Percent of inhibition/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
Percent of inhibition/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

Effects of Drymaria villosa

Leachate: Leachate of *D. villosa* at the concentration of 1:2.5 and 1:10 inhibited the seed germination by 15.96% whereas the germination was slightly promoted by both 1:5 and 1:20 dilution by 0.84% (Table 5). Diluted concentration of leachate of 1:20 showed delayed germination and took 7 days to germinate the first seed. While in control the first seed germinated after 4 days. Lateral roots were developed at the lower concentration (1:10) whereas in control no root hairs or lateral roots were initiated. The study also marked the increase in shoot vigour index only at 1:10 dilution and decreased the same at other concentrations. Seedling vigour index and root vigour index were lesser in all the concentrations of leachate than the control solution. The shoot-root ratio of seedlings was least affected (0.16%) at 1:2.5 and 1:20 concentrations. Leachate of 1: 5 and 1:10 concentration increased the ratio by 0.23 and 0.26% respectively indicating more stimulation of shoot elongation than that of root.

Extract: Application of different concentrations of extract of *D. villosa* also exerted both the inhibitory and stimulatory impact like leachate (Table 6). But the percentage of inhibition was quite high in case of extract.

Shoot length and seedling length were inhibited and promoted by the higher and lower concentration of extracts whereas the root length was only inhibited. There was no initiation of root hairs or lateral roots in control but lateral root initiation was found at a later stage only at 1:5 dilution. All the shoot vigor index, root vigor index, seedling vigor index as well as the shoot-root ratio were decreased by higher concentrations of extract and increased at lower concentration. It indicated more inhibition of soot length than that of root and thus differed from that of leachate.

Table 5 Effect of leachate of *D. villosa* on seed germination and seedling growth of tea

Parameters	Concentration of solutions				
	Control	1:2.5	1:5	1:10	1:20
Germination percent	85.0	71.43	85.71	71.43	85.71
Germination inhibition/ stimulation percent	00.00	- 15.96	+ 0.84	- 15.96	+ 0.84
Percentile of viability	99.17	83.34	100	83.34	100
Non-viability percent	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
Percent of inhibition/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
Percent of inhibition/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
Percent of inhibition/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

Table 6 Effect of extracts of *D. villosa* on seed germination and seedling growth of tea

Parameters	Concentration of solutions				
	Control	1:2.5	1:5	1:10	1:20
Germination percent	85.0	57.14	71.43	71.43	85.71
Germination inhibition/ stimulation percent	00.00	- 32.78	- 15.96	- 15.96	+ 0.84
Percentile of viability	99.17	66.67	83.34	83.34	100
Non-viability percent	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
Percent of inhibition/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
Percent of inhibition/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
Percent of inhibition/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

Effects of Galinsoga parviflora

Leachate: Only the highest concentration of leachate (1:2.5) of *G. parviflora* showed 15.96% of inhibitory effects on germination whereas the further dilutions gradually promoted the rate of germination up to 17.65% (Table 7). There was no delay in the germination of seeds treated with different concentrations of leachate as it took 4 days to germinate the first seed as in control set. The 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. Shoot length and root length were inhibited by 79.25% and 44.51% respectively by the treatment with highest concentration of 1:2.5 and due to their cumulative effects, the seedling length was also inhibited by 50.86%. Similarly, all the shoot vigour index, root vigour index and seedling vigour index were decreased in higher concentrations of leachate and gradually increased with the increase in dilution of leachate concentration. The shoot-root ratio of seedling was higher (0.28) at the concentrations of 1:5 than the control (0.22) but lesser in other concentrations indicating more inhibition of growth of root system of seedlings in higher concentration. At 1:2.5, 1:10 and 1:20 concentrations of leachate the shoot-root ratios were 0.08, 0.21, and 0.22 respectively.

Extract: The higher concentrations of 1:2.5 and 1:5 resulted in 15.96 % decline in seed germination over the control (85.0 %) and the diluted extracts of 1:10 and 1:20 caused slight stimulation of 0.84% in seed germination (Table 8) and thus the extract intended to exert more inhibitory impact than the leachate. The delay in germination was more or less same as in leachate except at the lower dilution of 1:20 that showed delayed germination by 3 days. The length of seedling and root appeared to be promoted with the lower concentration of extract (1:20) by 6.72% and 8.44%. On the other hand, 1:2.5, 1:5 and 1:10 dilutions of extract showed inhibition in the elongation of seedling and root. Highest % of inhibition in seedling and root elongation was found in the highest concentration (1:2.5) of extracts by 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 (32.08%, 32.08% and 13.21%), 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 extract. Moreover, formation of root hairs and the initiation of lateral roots were inhibited in this treatment. Increase in shoot-root ratio except in lowest concentration of extract also suggested its harmful effect on root elongation which was quite irregular in case of leachate.

Table 7 Effect of leachates of *G. parviflora* on seed germination and seedling growth of tea

Parameters	Concentration of solutions				
	Control	1:2.5	1:5	1:10	1:20
Germination percent	85.0	71.43	85.71	100.0	100.0
Germination inhibition/ stimulation percent	00.00	- 15.96	+ 0.84	+ 17.65	+ 17.65
Percentile of viability	85.0	71.43	85.71	100.0	100.0
Non-viability percent	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
Percent of inhibition/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
Percent of inhibition/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
Percent of inhibition/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

Table 8 Effect of extracts of *G. parviflora* on seed germination and seedling growth of tea

Parameters	Concentration of solutions				
	Control	1:2.5	1:5	1:10	1:20
Germination percent	85.0	71.43	71.43	85.71	85.71
Germination inhibition/ stimulation percent	00.00	- 15.96	- 15.96	+ 0.84	+ 0.84
Percentile of viability	99.17	83.34	83.34	100	100
Non-viability percent	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
Percent of inhibition/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
Percent of inhibition/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
Percent of inhibition/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

Effects of Mikania micrantha

Leachate: All the dilutions of leachate of *M. micrantha* exhibited inhibitory effects on germination of tea seed and the inhibitory effect was estimated to be 66.39, 32.78 and 15.96% at the concentration of 1:2.5, 1:5 and 1:10 respectively. At the lowest concentrations of 1:20 germination percentage was stimulated by 0.84%. Only the leachate concentration of 1:5 delayed the germination by 7 days (germination started on 11th day) but at the other concentrations including control germination initiated at 4th day only. Root hairs were 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.

Growth of seedling was also inhibited by *M. micrantha* leachate and the percentage of inhibition of seedling length was directly proportional to the concentration of leachate. Concentrations of 1:2.5, 1:5, 1:10 and 1:20 inhibited the seedling growth by 55.17, 33.10, 16.38 and 8.62%. Shoot vigour index, root vigour index and seedling vigour index were decreased except in 1:20 dilution where root vigour index was higher than the control. The shoot-root ratio of seedling was higher than the control at the concentrations of 1:2.5 and 1:5 (i.e., 0.24 and 0.40 respectively). Thus, it indicated high level of inhibition of the root system of seedlings than that of shoot at higher concentrations, whereas the prevention of shoot growth was more at lower concentrations.

Extract: Extract of different concentrations of this dominating associate also exerted the similar type of activity on germination and early growth of seedling of tea but the magnitude of inhibition was lesser than the leachate. Only the highest concentration of extract of 1:2.5 dilution, delayed the germination process by 7 days as in case of leachate. There was no initiation of lateral roots except at 1:5 where only root hairs were seen. The effect of extract on early growth of seedlings was also quite prominent as in case of germination. In contrast to leachate, it showed stimulation of seedling growth at lowest concentration. Like leachate, it also affected the shoot vigour index, root vigour index and seedling vigour index in the similar pattern i.e., decreased except in lowest concentration (1:20) where shoot root, and seedling vigour index were affected in an opposite way.

Extract showed the general pattern of increasing shoot-root ratio by inhibiting root growth except at 1:10 where it was just the opposite (decrease in the ratio and more inhibition of shoot). In this aspect the impact of extract differs from that of leachate which showed both the enhancement and reduction in the ratio.

Table 9 Effect of leachate of *M. micrantha* on seed germination and seedling growth of tea

Parameters	Concentration of Solutions				
	Control	1:2.5	1:5	1:10	1:20
Germination percent	85.0	28.57	57.14	71.43	85.71
Germination inhibition/ stimulation percent	00.00	- 66.39	- 32.78	- 15.96	+ 0.84
Percentile of viability	99.17	33.33	66.67	83.34	100.0
Non-viability percent	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
Percent of inhibition/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
Percent of inhibition/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
Percent of inhibition/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

Table 10 Effect of extracts of *M. micrantha* on seed germination and seedling growth of tea

Parameters	Concentration of Solutions				
	Control	1:2.5	1:5	1:10	1:20
Germination percent	85.0	57.14	57.14	71.43	85.71
Germination inhibition/ stimulation percent	00.00	- 32.78	-32.78	-15.96	+ 0.84
Percentile of viability	99.17	66.67	66.67	83.34	100
Non-viability percent	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
Percent of inhibition/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
Percent of inhibition/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
Percent of inhibition/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

Effects of Persicaria runcinata

Leachate: Treatment of tea seeds with different concentrations of leachate mildly stimulated the germination (0.84 %) except 1:5 concentration where inhibition of germination by 15.96% were noted (Table 11). All the concentrations of leachate except 1:10 took 4 days to germinate the first seed. Leachate of 1:10 concentration showed delayed germination and took 7 days to germinate the first seed.

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 at all other concentrations. 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.

Table 11 Effect of leachate of *Persicaria runcinata* on seed germination and seedling growth of tea

Parameters	Concentration of Solutions				
	Control	1:2.5	1:5	1:10	1:20
Germination percent	85.0	85.71	71.43	85.71	85.71
Germination inhibition/ stimulation percent	00.00	+ 0.84	- 15.96	+ 0.84	+0.84
Percentile of viability	99.17	100.0	83.34	100.0	100.0
Non-viability percent	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
Percent of inhibition/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
Percent of inhibition/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
Percent of inhibition/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

Extract: Increase in the concentration of the extracts led to decrease in the percentage of germination as well as percentile of viability whereas the lower concentration had some stimulatory impact (Table 12). All the concentrations of extract showed delayed germination and took 7 days to germinate the first seed except 1:20 at which first seed germinated on the 4th day as in control. Application of different concentrations of extract prevented the shoot and root growth in higher concentrations and promoted by lower concentrations. Promotion of root growth at 1:20 concentration was notably high but due to their cumulative effects growth of seedlings was inhibited in all the concentration of extract. In this regard the extract showed it differential impact from that of leachate of the same plant.

All shoot, root and seedling vigor index were reduced by the higher concentration of extract but increased at lower concentration. Like leachate, the extract solutions also affected the shoot-root ratio in the same way.

Table 12 Effect of extracts of *Persicaria runcinata* on seed germination and seedling growth of tea

Parameters	Concentration of Solutions				
	Control	1:2.5	1:5	1:10	1:20
Germination percent	85.0	71.43	71.43	85.71	100
Germination inhibition/ stimulation percent	00.00	- 15.96	- 15.96	+ 0.84	+ 17.65
Percentile of viability	85	71.43	71.43	85.71	100
Non-viability percent	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
Percent of inhibition/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
Percent of inhibition/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
Percent of inhibition/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

The observation showed *Mikania micrantha* as a highly toxic plant, which strongly inhibited not only the germination of seeds but also the seedling growth of *Camellia sinensis* by both leachate and extract under use. It indicates the presence of potent germination and growth-retarding factor(s) of allelopathic implication for *Camellia sinensis* in this 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 among the plant association.

However, the leachates or extracts of *S. alata* and *A. 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, especially on the elongation of root mainly in extract solution. It may be inferred that these plants not only compete with tea but also interact quite effectively to some extent by retarding its post-germination aspects due to their allelopathic potentialities.

Similarly, at lower concentrations of *A. conyzoides, S. alata, G. parviflora, D. villosa* and *P. runcinata* stimulated seedling growth of tea but none of them at highest concentration showed any promotory effect. Furthermore, all the lower dilutions of leachate and extract of *G. 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 were inhibitory than stimulatory between weeds and crop plant like tea and moreover the rate of inhibition by 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 different seasons 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.

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. 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 leachate of their dead and decaying vegetative matter or both, are inhibitory or stimulatory to seed germination, growth and development of seedlings of tea. Thereby reducing or eliminating the competitiveness of crop plants as well as of other weed species.

CONCLUSION

The germination of tea seeds and growth of the seedlings showed differential response depending on the species of weed, type of treatment solution i.e., leachate and extract and the concentrations of treatment solution. In most of the cases impacts of the weed species was directly proportionate to the concentration. The weeds showing inhibitory effect on germination and seedling growth may have some impact on growth and development of mature tea plants and ultimately, they may affect the yield and quality of tea. That should be kept in mind during the weed management as well as the plant having stimulatory effects may be investigated for exploitation to promote the growth and yield. The study also suggests further allelopathic investigation both in field and laboratory condition, isolation and identification of active allelochemicals and their potential uses as growth and yield promoting agents.

LITERATURE CITED

1. Tukey HB. 1970. The leaching of substances from plants. *Ann. Rev. Plants Physiology* 21: 305-324.
2. Datta SC, Sinha-Roy SP. 1974. Allelopathy and Inhibitors. *Science and Culture* 40: 47-59.
3. Datta SC, Chatterjee AK. 1980. Allelopathy in *Polygonum orientale*: Inhibition of seed germination and seedling growth of mustard. *Crop. Physiol. Ecology* 5: 54-59.
4. Rice EL. 1976. Allelopathy and grassland improvement. *In*: *The Grasses and Grassland of Oklahoma*. (Eds) J. R. Estes and R. J. Tyri) Noble Foundation. Ardmore Oklahoma. pp 90-111.
5. Gliessman SR. 1978. Allelopathy as a potential mechanism of dominance in the humid tropics. *Trop. Ecology* 19: 200-208.
6. Lodhi MAK. 1978. Allelopathic effects of decaying litter of dominant trees and their associated soil in a lowland forest community. *Am. Jr. Botany* 65: 340-344.
7. Ballester A, Albo JM, Vieitez E. 1977. The allelopathic potential of *Erica scoparia* L. *Oecologia* 30: 55-61.
8. Fisher RF, Woods RA, Glavicic MR. 1978. Allelopathic effects of goldenrod and aster on young sugar maple. *Can. Jr. For Research* 8: 1-9.
9. Lovett JV, Jackson HF. 1980. Allelopathie activity of *Camelina sativa* (L.) Crantz in relation to its phylloshere bacteria. *New Phytology* 86: 273-277.
10. Chatterji UN. 1975. Some aspects of plant-plant chemical interactions. *Indian Jr. Plant Physiology* 28: 91-96.
11. Muller CH. 1974. *Handbook of Vegetation Science* (Eds) B. R. Strain and W. D. Billings. 6: 73–85. W. Junk, Bv Publisher, The Hague.
12. Ghosh C, Sarkar S, Das AP. 2020. Study on efficacy of herbicides in the tea cultivation of Darjeeling district of West Bengal, India. *Research Journal of Agricultural Sciences* 11(4): 860-870.
13. Putnam AR, Duke WB. 1978. Allelopathy in agroecosystems. *Annu. Rev. Phytopathology* 16: 431-451.
14. Kadir AKM, Manzur. 2001. *Ecology of Subhimalayan Herblands in Darjeeling with Special Emphasis on Streptocaulon sylvestre Wight – an Endangered and Endemic plant*. *Ph. D. Thesis*, North Bengal University, India.
15. Datta SC, Ghosh KN. 1987. Allelopathy in two species of *Chenopodium*-inhibition of germination and Seedling growth is certain weeds. *Acta Societies Botanicorum Poloniae* 56(2): 257-270.
16. Saxena A, Singh DV, Joshi NL. 1995. Allelopathy of pearl millet as influenced by vegetative and reproductive stage of crop growth. *Annals of Arid Zone* 34(4): 293-296.
17. Bajpai A, Sant HR, Tripathi A. 1995. Effect of simulated drought on germination and seedling growth of *Boerhavia verticillata. Geobios* 22(1): 30-34.
18. Thind SK, Malik CP. 1988. Effect of aliphatic alcohols on water uptake, seed germination and early seedling growth responses of two wheat cultivars to different water potential treatments. *Proc. Nat. Acad. Sciences* 58(B): 611-619.