

Allelopathic effects of agroforestry trees on field crops in Eastern Himalaya, India

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ABSTRACT

The allelopathic potential of top soil, rhizosphere soil, leaf mulch and aqueous extract of *Chukrasia tabularis* A. Juss., *Gmelina arborea* L., *Michelia oblonga* Wall. and *Terminalia myriocarpa* Heurck & Muell. Arg. were determined on rice (cv. Nagaland Special), maize (cv. Vijay Composite), green gram (cv. SG-I), rice bean (cv. Nagaland Local) and rapeseed (TS- 38). Inhibitory effects were more on germination, dry matter yield and pigment contents of all test crops than on root and shoot length. All test crops were found sensitive to allelopathic influences of tree species particularly, *T. myriocarpa* and *M. oblonga*. The allelopathic influences were species specific. Rapeseed and legume test crops were highly susceptible to toxicity of trees than cereal test crops.

Key words: Agro forestry, allelopathy, *Chukrasia tabularis* A. Juss, Eastern Himalaya, food crops, germination, *Gmelina arborea* L., greengram, maize, *Michelia oblonga*, pigment, rapeseed, rice, ricebean, root length, shoot length, *Terminalia myriocarpa*.

INTRODUCTION

Woody perennials release some phytochemicals into the soil which adversely effect the germination and yield of understorey crops (7). Allelopathic interactions in tree - crop associations in agroforestry greatly influence the crop production. In most cases, the allelopathic effects are selective and vary with tree species (13). Although, the toxic metabolites are present in all plant parts in different concentrations, but leaves are the most potent source of allelochemicals (2).

C. tabularis and *M. oblonga* are fast growing timber tree species in agrisilviculture agroforestry system in Eastern Himalaya (17) and provide quality firewood. *G. arborea* is promising multipurpose tree spp. (wood provides quality timber and firewood, foliage is used as fodder and fruits are edible). Hence it is major spp. in plantation forestry in eastern Himalayas and in agrisilviculture agroforestry system (17). *T. myriocarpa* is also an excellent timber and firewood species of Eastern Himalaya, hence grown extensively in agrisilviculture agroforestry systems (17).

Aqueous leaf extracts of these trees [*Chukrasia tabularis* A. Juss., *Gmelina arborea* L., *Michelia oblonga* Wall. and *Terminalia myriocarpa* Heurck & Muell. Arg] are

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allelopathic to germination, root-shoot growth and dry matter yields of test crops (rice, maize, green gram, rice bean, rapeseed) (2). In this study we have determined the effects of different growth media (containing allelochemicals released by the trees) on germination, growth attributes and Chlorophyll 'a' and 'b' of these test crops.

MATERIALS AND METHODS

The study was conducted at Medziphema, Nagaland, India, (25°45'24" N latitude, 93°15'26" E longitude and 250m asl altitude). During the study period, the mean maximum and minimum air temperature was 31.6 and 24.2°C, respectively, total rainfall: 207.6 mm, relative humidity: 86.5% and total sunshine hours were 176.4. The study consisted of 3 factors, (i). Agroforestry Trees spp.: 4 [*Chukrasia tabularis* A. Juss., *Gmelina arborea* L., *Michelia oblonga* Wall and *Terminalia myriocarpa* Heurck and Muell], (ii). Soil mediums: 5 (Top soil, rhizosphere soil, field soil [outside the wood lot]+leaf mulch, field soil+leaf extract, field soil control) and (iii). Test crops: 5 [rice (*Oryza sativa* L. cv. Ranjit), maize (*Zea mays* L. cv. Vijay Composite), rice bean (*Vigna umbellata* Thunb. cv. Naga Local), green gram (*V. radiata* L. cv. SG-1) and rapeseed (*Brassica campestris* L. cv. TS 38)]. The treatments were replicated four times in Complete Randomised Design. Experimental soils were sandy loam in texture (pH 5.1-5.5, organic carbon 1.6-2.0%, available N, P, K 233, 10.2 and 202 kg/ha). The test crops were sown in pots (0.45 x 0.30 cm, 5 kg soil) in first week of June 2008 using the following germination medium:

- (i) Top soil collected from the 15-years old native woodlots of above tree species,
- (ii) Rhizosphere soil collected from the root system of the above tree spp. from native woodlots (after digging 2-3 ft. near root zones),
- (iii) Field soil (collected from outside the woodlot) + leaf mulch (20 g per pot @ 5 ton/ha) mixed in the top layer of each pot,
- (iv) Field soil irrigated with 5% aqueous leaf extracts of above tree species,
- (v) Field soil irrigated with tap water (control).

The pots were maintained in net house and watered regularly. The 5% aqueous leaf extracts (pH 7.2) of each tree spp was obtained after Hollis *et al* (8) and stored in refrigerator at 4±1°C. 100 ml extract was added per pot before seed sowing. Seed germination was recorded 7 days after sowing (4) and shoot length, root length, dry matter production and pigment contents at 30 days after sowing. For pigments, three replicated measurements were undertaken for each test species following the Holm (9) method.

For statistical analysis, critical difference between treatment means was calculated to observe the significant variations at 5% level of probability.

RESULTS AND DISCUSSION

Oryza sativa (Rice)

The growth media of *M. oblonga* (except leaf mulch) and *T. myriocarpa* significantly reduced its germination compared to control (Table 1). Top soil and leaf

mulch of *C. tabularis* and aqueous leaf extract of *G. arborea* also significantly reduced the germination. The rhizosphere soil of *G. arborea*, *M. oblonga* and *T. myriocarpa* and aqueous leaf extract of *M. oblonga* suppressed its shoot length. The aqueous leaf extract of *C. tabularis*; aqueous extracts and rhizosphere soil of *G. arborea*; rhizosphere soil and leaf mulch of *T. myriocarpa* and all growth media of *M. oblonga* (except leaf mulch) reduced the dry matter in rice. The growth media of tree spp. more severely suppressed the pigment contents than germination, growth attributes and dry matter yield. Top and rhizosphere soil of all tree crops (except *T. myriocarpa*); leaf mulch of *C. tabularis*, *M. oblonga* and *T. myriocarpa*; rhizosphere soil of *C. tabularis* and *M. oblonga*; and aqueous extract of *T. myriocarpa* significantly decreased the chlorophyll 'a'. All growth media of *C. tabularis* and *T. myriocarpa*; top and rhizosphere soil of *G. arborea* and *M. oblonga* and leaf mulch of *M. oblonga* inhibited the chlorophyll 'b' content (Table 1).

On the contrary, the Top soil, leaf mulch and aqueous leaf extract increased the root-shoot length of rice by 3.2, 10.4, and 3.7 % respectively (Fig. 2). However, the growth media inhibited the germination, dry matter yield and pigment contents.

***Zea mays* (Maize)**

Growth media significantly inhibited its germination, dry matter yield and pigment contents. The leaf mulch and aqueous extracts drastically inhibited the germination. The inhibitory effects of aqueous extracts on germination of maize are known (16). Similarly top soil and rhizosphere soils inhibited the germination of maize (6). However, the aqueous extract stimulated the root growth of maize (5) (Fig. 2) and rhizosphere soil increased the root-shoot length over the control.

All growth media except aqueous leaf extract of *C. tabularis*; top soil of *G. arborea*, and rhizosphere soil of *M. oblonga* reduced its germination than control (Table 2). All growth media of *M. oblonga* and *T. myriocarpa* (except leaf mulch of both tree spp.); top soil of *C. tabularis*, and rhizosphere soil of *G. arborea* significantly suppressed the dry matter yield. Similarly, leaf mulch of all tree crops; rhizosphere soil of *G. arborea*, *M. oblonga*, and *T. myriocarpa* and aqueous extract of *C. tabularis* and *T. myriocarpa* significantly suppressed the chlorophyll 'a'. Likewise, all growth media of *M. oblonga*; rhizosphere soil and leaf mulch of *C. tabularis* and *T. myriocarpa*; aqueous extract of *G. arborea*; top soil of *T. myriocarpa* and aqueous extract of *G. arborea* suppressed the chlorophyll 'b'.

***Vigna umbellata* (Rice bean)**

Soil mulched with tree leaves caused maximum inhibition in germination (12.5%) over the control but stimulated the shoot length (13.4%). However, the aqueous extract increased the germination (3.4%) compared to control.

All growth media of *M. oblonga* significantly suppressed its germination. Top and rhizosphere soil of *M. oblonga* and *T. myriocarpa* and rhizosphere soil of *G. arborea* decreased the shoot length (Table 3). Top and rhizosphere soil of *M. oblonga* and *T. myriocarpa* and aqueous leaf extract of *C. tabularis* and *G. arborea* inhibited its root length. Top soil and rhizosphere soil of *M. oblonga* and *T. myriocarpa* and rhizosphere soil of *C. tabularis* and *G. arborea* significantly decreased the dry matter production. All

Table 1. The effects of different growth media germination, growth, dry matter yield and chlorophyll content of rice

Growth media	Germination (%)	Shoot length (cm)	Root length (cm)	Dry matter yield (g/plant)	Chlorophyll 'a' (mg/g)	Chlorophyll 'b' (mg/g)
<i>Chakrasia tabularis</i>						
Control	100.0	56.3	56.3	0.88	1.60	0.60
Top soil	95.0	54.3	27.2	1.14	1.29	0.49
Rhizosphere soil	100.0	52.5	30.8	0.62	1.12	0.39
Leaf mulch	92.5	68.4	29.3	0.82	1.08	0.46
Aqueous extract	97.5	63.4	23.2	0.54	1.66	0.37
Mean	97.0	60.0	27.3	0.77	1.35	0.46
CD _{0.05}	4.1	8.3	3.6	0.29	0.33	0.11
<i>Goniatia arborea</i>						
Control	100.0	56.3	26.3	0.88	1.60	0.6
Top soil	97.5	63.1	29.0	0.98	1.08	0.27
Rhizosphere soil	97.5	45.5	26.6	0.27	1.4	0.38
Leaf mulch	97.5	65.1	30.8	0.71	1.38	0.46
Aqueous extract	92.5	55.5	24.9	0.49	1.47	0.66
Mean	97.0	57.0	27.5	0.67	1.39	0.47
CD _{0.05}	3.4	9.8	2.9	0.36	0.24	0.20
<i>Michelia oblonga</i>						
Control	100.0	56.3	26.3	0.88	1.60	0.60
Top soil	95.0	55.4	30.6	0.44	1.08	0.27
Rhizosphere soil	92.5	47.5	25.5	0.30	0.84	0.28
Leaf mulch	97.5	59.8	26.3	0.71	1.09	0.37
Aqueous extract	95.0	56.3	22.8	0.34	1.6	0.5
Mean	96.0	55.0	26.3	0.54	1.24	0.40
CD _{0.05}	3.5	5.6	3.5	0.30	0.42	0.18
<i>Terminalia neriocarpa</i>						
Control	100.0	54.8	27.0	0.88	1.60	0.60
Top soil	97.5	59.4	31.6	0.64	1.56	0.38
Rhizosphere soil	97.5	43.7	26.6	0.24	1.34	0.43
Leaf mulch	97.5	56.3	26.3	0.59	1.19	0.40
Aqueous extract	95.0	58.2	24.2	0.70	1.08	0.47
Mean	97.5	56.3	26.3	0.61	1.34	0.46
CD _{0.05}	2.2	7.9	3.4	0.29	0.3	0.11

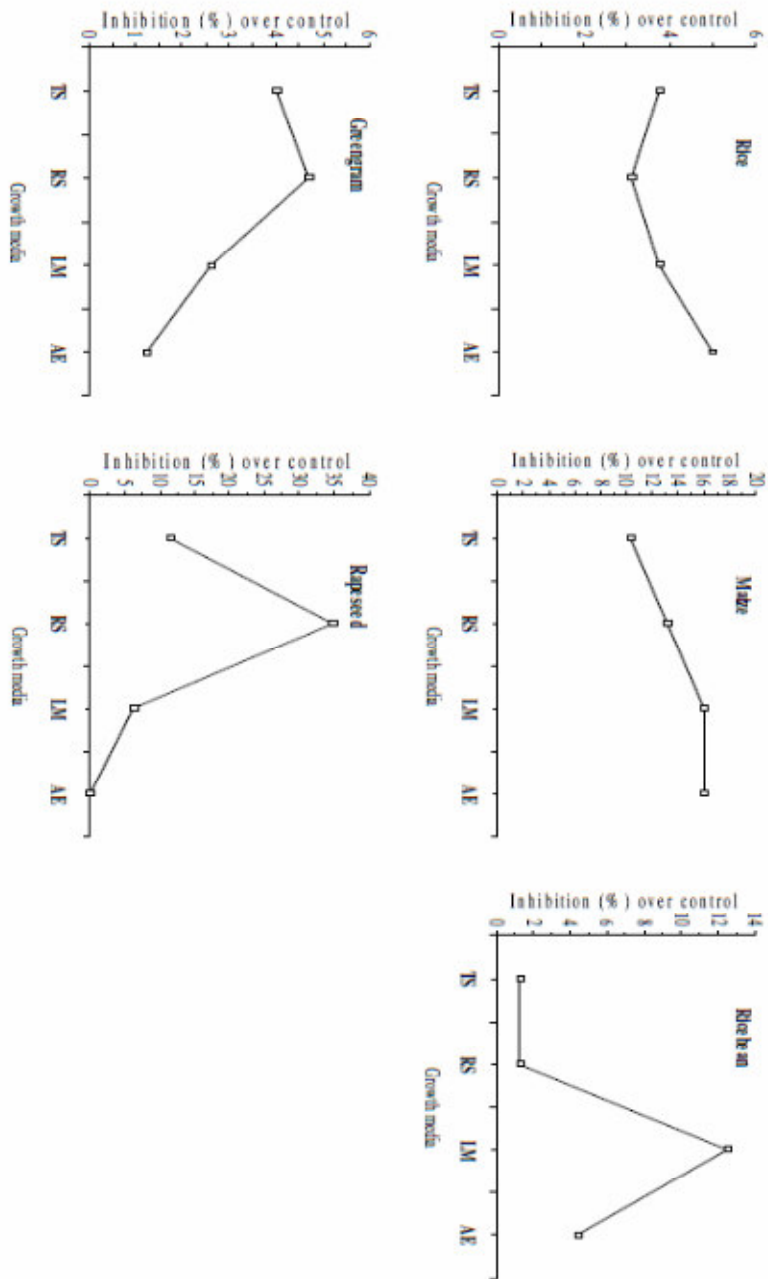


Figure 1. Effects of growing media on germination of test crops (TS: Top Soil, RS: Rhizosphere Soil, LM: Leaf Mulch, AE: Aqueous Extract)

Table 2. The effects of different growth media germination, growth, dry matter yield and chlorophyll content of maize

Growth media	Germination (%)	Shoot length (cm)	Root length (cm)	Dry matter yield (g/plant)	Chlorophyll 'a' (mg/g)	Chlorophyll 'b' (mg/g)
<i>Chukrasia tabularis</i>						
Control	97.5	73.8	61.6	4.07	1.48	0.48
Top soil	87.5	76.7	71.8	2.38	1.16	0.39
Rhizosphere soil	85.0	51.8	62.3	2.75	1.51	0.2
Leaf mulch	87.5	111.2	85.6	4.43	0.94	0.31
Aqueous extract	92.5	105.3	58.1	4.25	0.91	0.54
Mean	90.0	84.0	67.9	3.58	1.20	0.38
CD _{0.05}	5.7	23.3	13.8	1.67	0.35	0.17
<i>Gnetina arborea</i>						
Control	97.5	73.8	61.6	4.07	1.48	0.48
Top soil	92.5	101.1	62.2	4.3	1.42	0.47
Rhizosphere soil	82.5	66.6	68.1	1.34	1.2	0.41
Leaf mulch	72.5	112.3	70.3	2.59	0.91	0.2
Aqueous extract	87.5	83.5	66.8	3.19	1.23	0.34
Mean	86.5	87.5	65.8	3.1	1.25	0.38
CD _{0.05}	7.4	13.6	4.7	1.49	0.28	0.14
<i>Micelia oblonga</i>						
Control	97.5	73.8	61.6	4.07	1.48	0.48
Top soil	85.0	62.4	76.2	2.35	1.26	0.39
Rhizosphere soil	90.0	43.0	51.3	1.65	0.91	0.34
Leaf mulch	80.0	83.5	61.6	3.94	1.03	0.36
Aqueous extract	70.0	73.8	64.0	2.59	1.45	0.29
Mean	84.5	67.3	62.9	2.92	1.23	0.37
CD _{0.05}	9.1	19.3	11.0	1.3	0.31	0.09
<i>Terminalia myriocarpa</i>						
Control	97.5	64.6	56.5	4.07	1.48	0.48
Top soil	85.0	57.9	60.7	2.37	1.05	0.2
Rhizosphere soil	90.0	35.1	39.1	1.35	0.47	0.18
Leaf mulch	87.5	73.8	59.7	3.86	0.97	0.31
Aqueous extract	77.5	82.2	61.6	2.59	0.91	0.37
Mean	87.5	73.8	61.6	2.85	0.98	0.31
CD _{0.05}	5.9	23.2	12.1	1.40	0.45	0.15

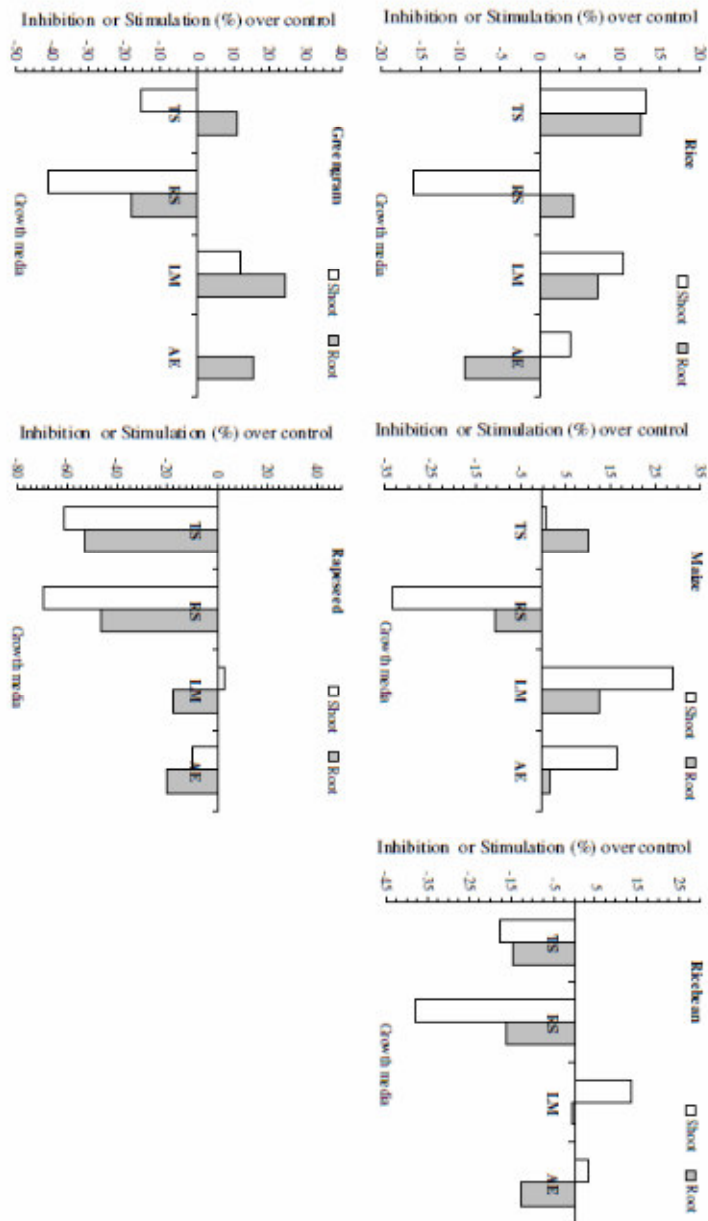


Figure 2. Effects of growing media on shoot and root length of test crops (TS: Top Soil, RS: Rhizosphere Soil, LM: Leaf Mulch, AE: Aqueous Extract)

Table 3. The effects of different growth media germination, growth, dry matter yield and chlorophyll content of ricebean

Growth media	Germination (%)	Shoot length (cm)	Root length (cm)	Dry matter yield (g/plant)	Chlorophyll 'a' (mg/g)	Chlorophyll 'b' (mg/g)
<i>Chitrastra tabularis</i>						
Control	100.0	39.5	32.3	0.76	1.87	0.67
Top soil	97.5	35.9	32.9	0.53	1.6	0.51
Rhizosphere soil	100.0	27.8	32.8	0.29	1.49	0.53
Leaf mulch	97.5	59.2	32.3	0.76	1.41	0.51
Aqueous extract	97.5	49.7	25.7	0.77	1.47	0.46
Mean	98.5	42.4	31.2	0.62	1.57	0.54
CD _{0.05}	1.7	15.2	3.9	0.26	0.23	0.1
<i>Ganetina arborea</i>						
Control	100.0	39.5	32.3	0.76	1.87	0.67
Top soil	100.0	46.2	37.2	0.73	1.9	0.51
Rhizosphere soil	97.5	26.0	32.6	0.41	1.59	0.46
Leaf mulch	62.5	46.1	34.0	0.76	1.68	0.72
Aqueous extract	90.0	37.2	27.6	0.66	1.27	0.41
Mean	90.0	39.0	32.7	0.66	1.66	0.55
CD _{0.05}	11.1	10.3	4.3	0.18	0.32	0.17
<i>Michelia oblonga</i>						
Control	100.0	39.5	32.3	0.76	1.87	0.67
Top soil	97.5	26.3	24.6	0.36	1.68	0.51
Rhizosphere soil	97.5	27.1	24.8	0.33	1.72	0.58
Leaf mulch	97.5	34.5	30.3	0.74	1.7	0.62
Aqueous extract	97.5	36.9	29.2	0.62	1.8	0.58
Mean	98.0	32.9	28.2	0.56	1.75	0.59
CD _{0.05}	1.4	7.4	4.3	0.26	0.1	0.07
<i>Terminalia myriocarpa</i>						
Control	100.0	31.3	25.8	0.76	1.87	0.67
Top soil	100.0	21.5	15.9	0.17	1.8	0.65
Rhizosphere soil	100.0	16.7	18.2	0.12	1.23	0.48
Leaf mulch	92.5	39.5	32.3	0.66	1.68	0.51
Aqueous extract	97.5	39.5	30.2	0.75	1.35	0.43
Mean	98.0	39.5	32.3	0.49	1.59	0.55
CD _{0.05}	3.1	14.0	10.0	0.4	0.35	0.13

growth media of *C. tabularis*; aqueous extract of *G. arborea* and *T. myriocarpa*; top soil, rhizosphere soil and leaf mulch of *M. oblonga* and rhizosphere soil of *T. myriocarpa* decreased the Chlorophyll 'a' content. All growth media of *C. tabularis*, *M. oblonga* (except leaf mulch) and *T. myriocarpa* (except top soil) and rhizosphere soil and aqueous extract of *G. arborea* reduced the chlorophyll 'b'.

***Vigna radiata* (Green gram)**

The rhizosphere soil inhibited its germination, growth attributes and dry matter yield. Likewise, top soil growth media also inhibited the pigment contents. However, leaf mulch increased the shoot length (11.94%) than control (Fig. 2).

All growth media of *T. myriocarpa* (except top soil); top soil of *C. tabularis* and *G. arborea* and rhizosphere soil of *M. oblonga* inhibited its germination compared to control. Rhizosphere soil of *C. tabularis* and *T. myriocarpa* and top and rhizosphere soil of *M. oblonga* suppressed its shoot length. The rhizosphere soil of *M. oblonga* and *T. myriocarpa* inhibited the root length. All growth media of *T. myriocarpa*; top and rhizosphere soil of *M. oblonga*, and rhizosphere soil of *C. tabularis* and *G. arborea* inhibited the yield. All growth media of *M. oblonga*; aqueous extracts of remaining tree crops; top soil of *C. tabularis* and *G. arborea*; leaf mulch of *C. tabularis* and rhizosphere soil of *T. myriocarpa* inhibited its chlorophyll 'a'. Chlorophyll 'b' was also significantly ($P < 0.05$) suppressed by all tree spp. except rhizosphere soil of *T. myriocarpa* (Table 4).

***Brassica campestris* (Rapeseed)**

Rhizosphere soil inhibited its germination by 34.7 % (Fig 1). The top soil and rhizosphere soil were most inhibitory to shoot length as compared to root length (Fig. 2).

All growth media of *M. oblonga* (except aqueous leaf extract); rhizosphere soil of *C. tabularis* and *T. myriocarpa*, and top soil of *G. arborea* significantly inhibited its germination over the control (Table 5). All growth media of *M. oblonga*; top soil of *C. tabularis*; top soil and rhizosphere soil of *T. myriocarpa*, and rhizosphere soil and aqueous leaf extract of *G. arborea* decreased the shoot length compared to control. All growth media of *G. arborea*, *M. oblonga* and *T. myriocarpa* (except aqueous leaf extract) and top soil of *C. tabularis* also significantly inhibited the root length. Further, all growth media except aqueous extract of *T. myriocarpa* decreased the dry matter content. All growth media of tree spp. (except top soil of *C. tabularis* and leaf mulch of *T. myriocarpa*) reduced the chlorophyll 'a' content. Significant reduction in chlorophyll 'b' in rapeseed was recorded due to the various growth media of *C. tabularis*, *M. oblonga* and *T. myriocarpa* besides top, rhizosphere soil and aqueous extract of *G. arborea* decreased the chlorophyll 'b' over the control.

These results showed that *T. myriocarpa* followed by *M. oblonga* were inhibitory to test crops. *G. arborea* ranked third in order of toxicity, whereas, *C. tabularis* promoted the growth of some test crops. Tree species were more harmful to dry matter yield and pigment contents than germination and growth. The aqueous leaf extracts of *C. tabularis* are least toxic, whereas, other tree spp. are most active allelopathically (2), which supports our findings.

Some growth media, enhanced the germination and growth in some test crops. Similarly, leaf mulch and aqueous extract of same tree crop increased the germination in

Table 4. The effects of different growth media germination, growth, dry matter yield and chlorophyll content of green gram

Growth media	Germination (%)	Shoot length (cm)	Root length (cm)	Dry matter yield (g/plant)	Chlorophyll 'a' (mg/g)	Chlorophyll 'b' (mg/g)
<i>Chakrasia tabularis</i>						
Control	90.5	46.9	26.0	1.55	1.90	0.84
Top soil	87.5	41.8	32.5	0.73	0.81	0.3
Rhizosphere soil	92.5	33.0	28.8	0.47	1.59	0.45
Leaf mulch	92.5	63.2	42.3	2.63	1.36	0.46
Aqueous extract	90.0	50.2	32.4	1.26	1.25	0.41
Mean	90.5	46.4	32.4	1.33	1.38	0.49
CD _{5%}	2.6	13.9	7.6	1.05	0.50	0.25
<i>Gandina arborea</i>						
Control	90.5	46.9	26.0	1.55	1.90	0.84
Top soil	80.0	50.8	30.5	1.33	1.19	0.34
Rhizosphere soil	90.0	36.2	28.1	0.49	1.69	0.57
Leaf mulch	90.0	60.0	32.5	1.17	1.59	0.45
Aqueous extract	92.5	42.8	31.9	1.09	1.25	0.37
Mean	88.5	47.3	29.8	1.13	1.52	0.51
CD _{5%}	6.1	11.1	3.4	0.49	0.37	0.25
<i>Mitchelia okongu</i>						
Control	90.5	46.9	26.0	1.55	1.90	0.84
Top soil	90.0	30.4	28.2	0.65	1.31	0.41
Rhizosphere soil	82.5	28.7	14.5	0.05	0.96	0.42
Leaf mulch	87.5	40.0	28.8	1.17	1.28	0.44
Aqueous extract	92.5	46.9	26.0	1.39	1.37	0.45
Mean	89.5	38.6	24.7	0.96	1.36	0.51
CD _{5%}	4.8	10.9	7.2	0.76	0.42	0.23
<i>Terminalia myriocarpa</i>						
Control	90.5	38.0	24.0	1.55	1.90	0.84
Top soil	90.0	36.0	24.2	0.89	1.8	0.45
Rhizosphere soil	80.0	12.8	13.9	0.63	1.59	0.67
Leaf mulch	82.5	46.9	26.0	0.91	1.89	0.58
Aqueous extract	82.5	47.5	30.1	0.85	1.48	0.52
Mean	85.0	46.9	26.0	0.97	1.73	0.61
CD _{5%}	6.0	18.5	7.5	0.43	0.23	0.19

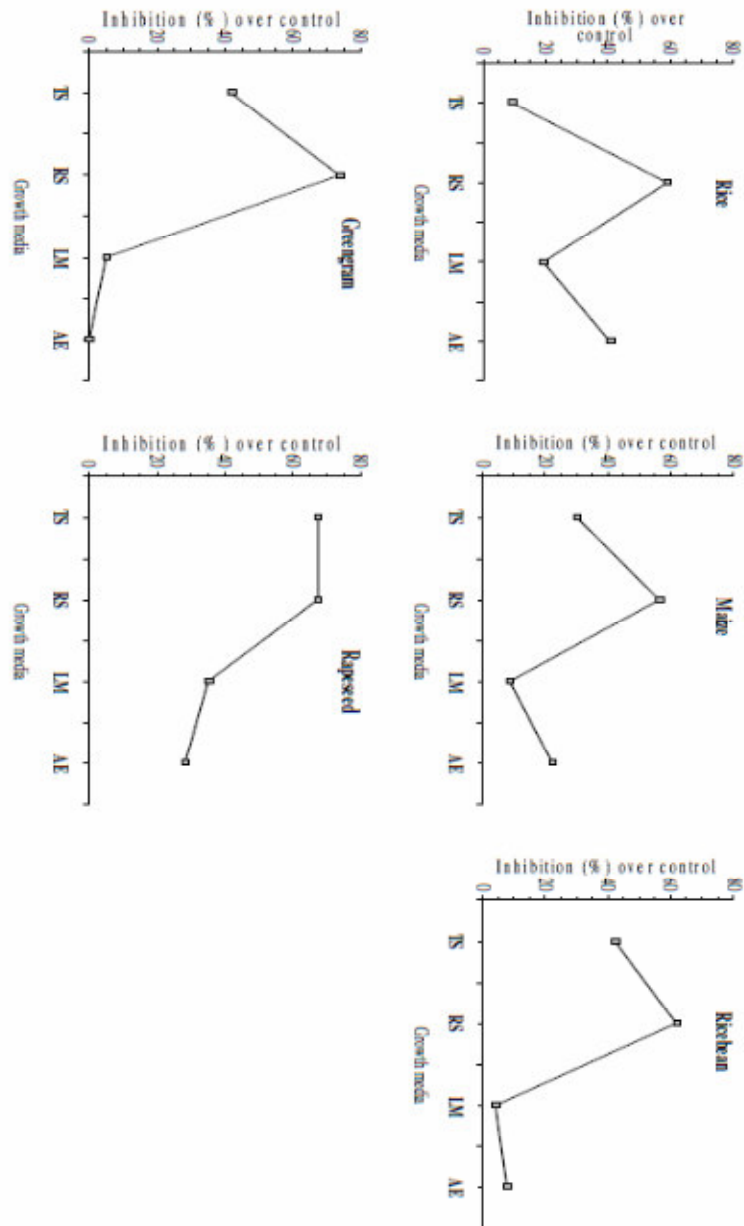


Figure 3. Effects of growing media on the dry matter of test crops (TS: Top Soil, RS: Rhizosphere Soil, LM: Leaf Mulch, AE: Aqueous Extract)

Table 5. The effects of different growth media germination, growth, dry matter yield and chlorophyll content of rapeseed

Growth media	Germination (%)	Shoot length (cm)	Root length (cm)	Dry matter yield (g/plant)	Chlorophyll 'a' (mg/g)	Chlorophyll 'b' (mg/g)
<i>Chukrasia tabularis</i>						
Control	88.0	29.7	16.6	0.46	1.43	0.50
Top soil	92.0	3.9	5.5	0.23	1.19	0.25
Rhizosphere soil	80.0	8.5	10.3	0.21	0.80	0.23
Leaf mulch	90.0	48.5	20.9	0.58	0.83	0.2
Aqueous extract	90.0	36.3	17.8	0.57	0.96	0.31
Mean	88.0	25.4	14.2	0.41	1.04	0.30
CD _{5%}	5.7	23.4	7.7	0.23	0.33	0.15
<i>Canthium arborea</i>						
Control	88.0	29.7	16.6	0.46	1.43	0.50
Top soil	70.0	22.2	11.4	0.12	0.93	0.30
Rhizosphere soil	85.0	10.9	7.3	0.15	0.95	0.36
Leaf mulch	85.0	21.7	11.3	0.17	0.99	0.42
Aqueous extract	85.0	20.3	11.8	0.23	0.93	0.34
Mean	82.6	20.9	11.7	0.23	1.05	0.36
CD _{5%}	8.0	8.3	4.1	0.17	0.27	0.14
<i>Mitchella oblonga</i>						
Control	88.0	29.7	16.6	0.46	1.43	0.50
Top soil	72.5	16.2	6.5	0.14	0.83	0.30
Rhizosphere soil	35.0	13.9	8.3	0.09	0.77	0.23
Leaf mulch	70.0	21.9	11.6	0.23	0.78	0.24
Aqueous extract	92.5	20.8	10.3	0.21	0.73	0.23
Mean	71.0	20.5	10.6	0.23	0.91	0.28
CD _{5%}	11.4	7.6	4.8	0.18	0.36	0.15
<i>Terminalia myricarpa</i>						
Control	88.0	19.1	11.6	0.46	1.43	0.50
Top soil	77.5	3.0	7.8	0.1	0.83	0.29
Rhizosphere soil	30.0	2.8	9.7	0.13	0.76	0.27
Leaf mulch	85.0	30.1	11.1	0.22	1.26	0.31
Aqueous extract	85.0	29.7	12.8	0.31	0.82	0.23
Mean	73.1	29.7	16.6	0.24	1.02	0.30
CD _{5%}	12.3	18.3	4.1	0.18	0.38	0.14

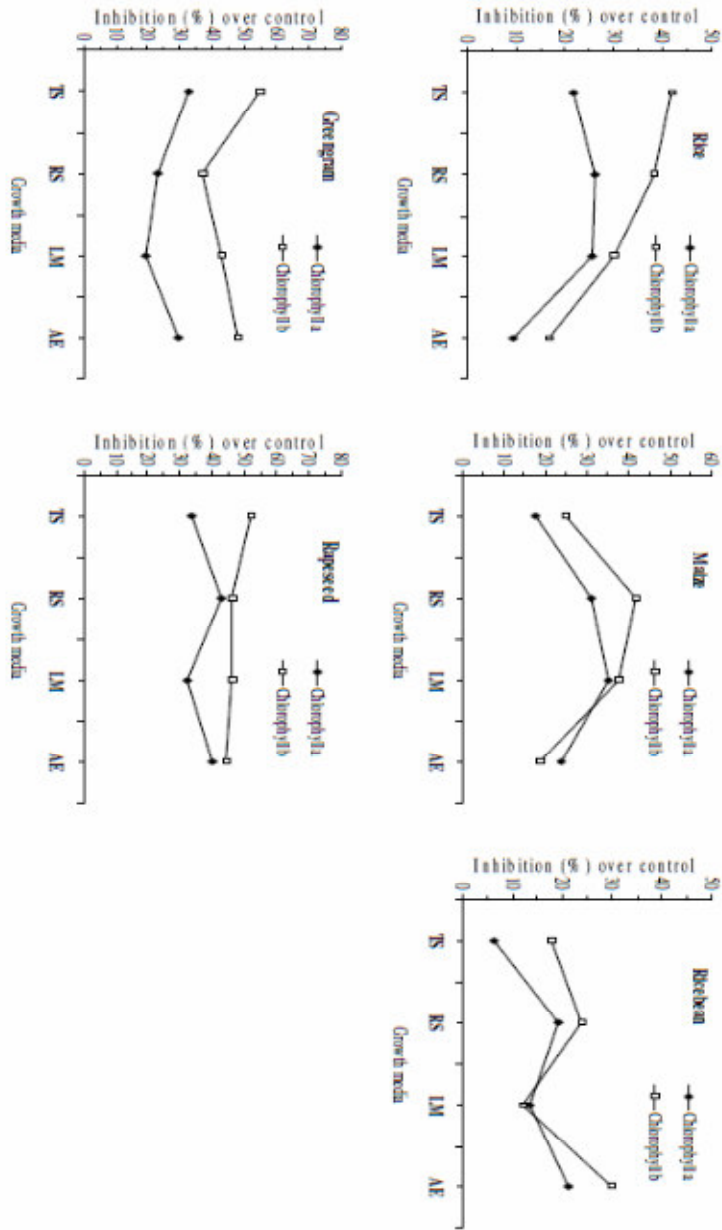


Figure 4. Influence of growing media on chlorophyll a and chlorophyll b content of test crops (TS: Top Soil, RS: Rhizosphere Soil, LM: Leaf Mutch, AE: Aqueous Extract)

rapeseed. Aqueous extract of *M. oblonga* stimulated the germination in green gram and rape seed than control. Top soil of *M. oblonga* enhanced the root length in rice, maize and green gram over the control. Shoot length of all test crops was higher with leaf mulch and aqueous extract of *C. tabularis*. Top soil, rhizosphere soil and leaf mulch of *C. tabularis* stimulated the root length of rice, maize and green gram. Top soil and leaf mulch of *G. arborea* improved the root length in all test crops, except rape seed. Top soil of *C. tabularis* and *G. arborea* increased the dry matter yield of rice. Perhaps it might be due to release of secondary metabolites from plant parts, which might have helped in germination and growth attributes of test species.

The rhizosphere soil, followed by top soil drastically decreased the growth and yield of various test crops. Soil irrigated with aqueous leaf extracts ranked third in order of toxicity. Among the test crops, growth and yield of rapeseed and green gram were more severely suppressed by tree species i.e. these crops were most sensitive.

The different tree components not only affected the germination and growth of test crops but also the physiological functioning. Kohli *et al* (10) and Bhatt and Todaria (3) also reported suppression of pigments, growth and biomass yield in test crops by tree species. Strong allelopathic influences of rhizosphere soil and soil irrigated with pulp extract of *Terminalia* spp. to test crops like *Brassica campestris*, *Eleusine coracana*, *Glycine max* and *Hordeum vulgare* have been reported (1), which supports our findings. The rhizosphere soil, soil mulched with dry leaves and soil irrigated with aqueous leaf extracts of *Eucalyptus tereticornis*, *Casuarina equisetifolia* and *Leucaena leucocephala* adversely affected the germination and dry matter production of sorghum, cowpea and sunflower (15,16). Thus the present findings are in conformity with earlier findings.

Allelopathic effects of *C. tabularis* might be due to the presence of triterpene and cedrelone in roots and 5,7-dihydroxy 2'4'5' 6-tetramethoxyflavone, quercetin 3-galactoside and tannic acid in the foliage. *T. myriocarpa* contains tannin, ellagic, gallic, chebulinic and chebulagic acid which might have reduced the growth and biomass of test crops. Likewise, phytotoxicity of *M. oblonga* might be due to presence of alkaloids and tannins, besides presence of magnoline and magnolamine in the foliage. Allelopathic influence of *G. arborea* may be attributed to presence of alkaloids, tannins, phenolic, benzoic acid and tartaric acid present in various plant parts (11). Since farmers of Eastern Himalaya are voicing concern for allelopathic influences of various tree species, detailed research is needed to verify the magnitude of toxicity of agroforestry tree spp. on test crops in field conditions, to find suitable tree-crop combinations for rainfed agroecosystems of Eastern Himalaya, India.

REFERENCES

1. Bhatt, B.P., Kumar, M. and Todaria, N.P. (1997). Studies on allelopathic effects of *Terminalia* spp. of Garhwal Himalaya. *Journal of Sustainable Agriculture* **11**: 71-84.
2. Bhatt, B.P. and Singh, J.K. (2009). Allelopathic effect of tree species on crops in Eastern Himalaya, India. *Allelopathy Journal* **23**: 333-344
3. Bhatt, B.P and Todaria, N.P. (1990). Studies on the allelopathic effects of some agroforestry tree crops of Garhwal Himalaya. *Agroforestry Systems* **12**: 251-255.
4. Bhatt, B.P., Tomar, J.M.S and Misra, L.K. (2001). Allelopathic effects of weeds on germination and growth of legumes and cereal crops of North Eastern Himalayas. *Allelopathy Journal* **8**: 225-232.

5. Carmona, M.D.C., Ortega, R.C and Anaya, A.L (2008). Allelopathic potential of some tropical trees of Ecological Reserve El Eden, Quintana Roo, Mexico. *Allelopathy Journal* **21**:57-72.
6. Espinosa, F.J., Hernandez, E.M and Flores, A.Q. (2008). Allelopathic potential of *Eucalyptus* spp plantations on germination and early growth of annual crops. *Allelopathy Journal* **21**: 25-38
7. Harborne, J.B. (1977). *Introduction to Ecological Biochemistry*. Academic Press, New York.
8. Hollis, C.A., Smith, J.E. and Fisher, R.F. (1982). Allelopathic effects of common under storey species on germination and growth of southern pines. *Forest. Science* **28**: 509-515.
9. Holm, G. (1954). Chlorophyll mutations in barley. *Acta Agriculture Scandinavia* **4**: 457-471.
10. Kohli, R.K., Kaur, K., Chaudhary, P., Kumari, A. and Saxena, D.B. (1987). Negative aspects of *Eucalyptus* farming. In: *Agroforestry for Rural Needs*. Pp. 225-233, Indian Soc. of Tree Scientists, Solan, Himachal Pradesh, India.
11. Shankar, S.R.M., Girish, R., Karthik, N., Rajendran, R. and Mahendran, V.S. (2009). Allelopathic effects of phenolics and terpenoids extracted from *Gmelina arborea* on germination of Black gram (*Vigna mungo*) and Green gram (*Vigna radiata*). *Allelopathy Journal* **23**: 323-332.
12. Singh, B., Uniyal, A.K., Bhatt, B.P and Prasad, S. (2006). Effects of agroforestry tree spp on crops. *Allelopathy Journal* **18**: 355-362
13. Stowe, L.G. (1979). Allelopathy and its influence on the distribution of plants in an Illinois old field. *Journal of Ecology* **67**: 1065-1085.
14. Suresh, K.K. and Rai, R.S.V. (1987). Studies on allelopathic effects of some agroforestry tree crops. *International Tree Crops Journal* **4**: 109-115.
15. Suresh, K.K. and Rai, R.S.V. (1988). Allelopathic exclusion of understorey by a few multipurpose trees. *The International Tree Crops Journal* **5**: 143-151.
16. Turker, M., Battal, P., Agar, G., Gulluce, M., Sahin, F., Erez, M.E. and Yildirim, N. (2008). Allelopathic effects of plant extracts on physiological and cytological processes during maize seed germination. *Allelopathy Journal* **21**: 273-286.
17. Uma Shankar (2006). Agroforestry tree spp. For conservation and rural livelihoods. In: *Agroforestry in North East India: Opportunities and Challenges*, (Eds., B. P. Bhatt and K. M. Bujarbaruah). Pp. 145-170, ICAR Research Complex for NEH Region, Umiam, Meghalaya.