

Allelopathic effects of some promising agro forestry tree species on different annual crops

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ABSTRACT

An experiment was conducted at ICAR RCER, RC, Ranchi, India during 2012-13 to assess the potential allelopathic effect of leaf extract of eleven tree species [Mango (*Mangifera indica*), Poplar (*Populus deltoides*), Arjun (*Terminalia arjuna*), Palas (*Butea monosperma*), Bakaine (*Melia azedarach*), *Acacia mangium*, *Acacia auriculiformis*, Bael (*Aegle marmelos*), Teak (*Tectona grandis*), Jackfruit (*Artocarpus heterophyllus*), *Shisham* (*Dalbergia sissoo*)] on nine annual crops (black gram, gram, pea, sponge gourd, mustard, okra, brinjal, chilli, tomato). Data were recorded on seed germination (after 10 days of seed sowing) and growth and biochemical composition of 20 days old seedlings. Reduction in germination % of annual crops was recorded with application of leaf leachate of each tree species except *D. sissoo*, *A. heterophyllus*, *A. marmelos* and *A. mangium*. With respect to weight of whole plant, application of leaf extract of *M. indica*, *B. monosperma*, *A. mangium*, *A. auriculiformis* and *A. marmelos* resulted in significant increase in total fresh and dry weight over that of control whereas none of the treatments resulted in significant reduction in fresh weight of annual crops. Among the annual crops, reduction in total fresh weight of the plant than that of control was recorded in case of bottle gourd whereas significant increase in fresh weight due to application of leaf extract was recorded in case of black gram, gram, okra and brinjal. Application of leaf extract of *M. indica*, *A. mangium*, *A. auriculiformis* and *A. marmelos* resulted in significant decrease in total chlorophyll content over that of control. Hence, the study clearly indicated beneficial effect of leaf extract of *Mangifera indica*, *Butea monosperma*, *Acacia mangium*, *Acacia auriculiformis* and *Aegle marmelos* with respect to plant growth of annual crops.

Key words : Allelopathy, Leaf extract, Seed germination

Introduction

The uplands constitute more than 60% of the total area of the eastern plateau and hill region of India. Agroforestry systems are effective approaches for sustainable utilization of the rainfed uplands of the region. The major agroforestry species grown in the region include *Mangifera indica*, *Artocarpus heterophyllus*, *Terminalia arjuna*, *Butea monosperma* etc. Apart from this, timber species like *Populus deltoides*, *Acacia mangium* etc. have also been found suitable to be grown in this region. Among the an-

nual crops grown in the region, black gram and chick pea are important pulses, mustard is an important oilseed crop and garden pea, sponge gourd, okra, brinjal, chilli, tomato are important vegetable crops.

Perennial species remain a part of the agro-eco-system for a longer period and produce large amount of litter. Suppressing or stimulating effects of tree crops on the annual crops due to allelopathic interaction are the major considerations for selection of crop combination under agroforestry systems. The allelopathy describes the field that studies the

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contradictory relationships between different plant species, as well as those between the individuals of the same species. The chemical compounds that are involved in the interactions between plants are generally called allelopathic substances or allelochemicals and play an important part in the primary metabolic processes, essential for the survival of the plants (Rice, 1974). Root exudation, leaching by dews, rains and irrigation, and volatilization or decaying plant tissue from allelopathic plants results in release of compounds into the environment (Rice, 1984, Khan *et al.*, 2011). In many tree species, the allelopathic substances have been identified as phenolic compounds like caffeic acid, ferulic acid; coumaric acid, benzoic acid; vanilic, chlorogenic; gallic; hydroxybenzoic and cinnamic acid etc. (El-Rokiek *et al.* 2010). Effects of allelochemicals are dependent on the concentration of the extracts, target species, and the plant tissues from which the chemicals were extracted (Daniel, 1999; Kavitha *et al.*, 2012). Generally leaves are the most potent source of allelochemicals. However, the toxic metabolites are also distributed in all other plant parts in various concentrations (Siddiqui *et al.*, 2009). Apart from alteration in plant growth parameters, plants' response to allelopathic chemicals have also been recorded in form of alterations in different biochemicals like chlorophyll (Elisante *et al.* 2013), sugars (Kavitha *et al.* 2012) and phenols (Al-Hakimi, 2008).

Allelopathic effect of the above tree species on different annual crops have been reported by various workers [El-Rokiek *et al.* (2010) and Venkateshwarlu *et al.* (2001) in *Mangifera indica*; Perdomo and Magalhaes (2007) in *Artocarpus heterophyllus*; Rao *et al.* (1994) in *Terminalia arjuna*, *Dalbergia sissoo* and *Acacia auriculiformis*; Hoque *et al.* (2003) in *Acacia auriculiformis*; Francisco *et al.* (2010) and Joyakumar *et al.* (1978) in *Tectona grandis*; Roy *et al.* (2011) in *Butea monosperma*; Thapaliyal *et al.* (2008) in *Aegle marmelos*; Farrukh *et al.* (1985) and Hussain *et al.* (1984) in *Melia azedarach*, Otsamo (2002) in *Acacia mangium*; Singh *et al.* (2001) in *Populus eltoids*]. In eastern plateau and hill region of India a number of households have *Mangifera indica*, *Aegle marmelos* and *Artocarpus heterophyllus* trees. Petmark and Williams (1991) recommended *Acacia auriculiformis* as agroforestry species. However, information on interaction between the above mentioned tree species and annual crops are meager. Keeping in view the present investigation was undertaken to identify

different promising synergistic crop combinations to be grown under agroforestry systems.

Materials and Methods

The investigations were undertaken at ICAR Research Complex for Eastern Region, Research Centre, Ranchi, during 2012-13. The treatments consisted of 11 tree species [*Mango (Mangifera indica)*, *Poplar (Populus eltoids)*, *Arjun (Terminalia arjuna)*, *Palas (Butea monosperma)*, *Bakaine (Melia azedarach)*, *Acacia mangium*, *Acacia auriculiformis*, *Bael (Aegle marmelos)*, *Teak (Tectona grandis)*, *Jackfruit (Artocarpus heterophyllus)*, *Shisham (Dalbergia sissoo)*] and nine annual crops (black gram, gram, pea, sponge gourd, mustard, okra, brinjal, chilli, tomato) in 99 combinations. Seeds (108 numbers per replication) of the annual crops were sown in pro-trays of 4.0 inches size filled with growing media composed of cocopeat and vermicompost at 1:1 ratio. For preparation of leaf extract of tree species, one kg of fully mature leaves were grinded, stirred with 3.5 litres of distilled water and the leaf water extract was filtered out. 25 ml of leaf water extract from the selected tree species was applied in the media of each cup. In case of control, only water was applied. Before application in the media, fresh leaves of each tree species were analyzed for content of total phenol. All the samples were irrigated daily with distilled water. The experiment was laid out in Factorial RBD with three replications. Data on seed germination (%) was recorded after 10 days of seed sowing. The seedlings were removed from the media after 20 days of sowing and data were recorded on length of shoot, fresh weight and dry weight of root, shoot and whole plant, content of chlorophyll, total phenol and total soluble sugars in the shoot. Chlorophyll content was estimated spectrophotometrically after extraction in chilled acetone (Thimaiah, 2000). Content of total phenol was estimated spectrophotometrically using Folin-Ciocateau reagent while the content of total soluble sugars was estimated spectrophotometrically using Anthrone reagent (Thimaiah, 2000). The data were subjected to analysis of variance.

Result and Discussion

Seed germination

Significant effects of the treatment on germination %

were recorded with respect to tree species, annual crops as well as interaction between tree species and annual crops (Table 1). Reduction in germination % of annual crops was recorded with application of leaf leachate of each tree species except *D. sissoo*, *A. heterophyllum*, *A. marmelos* and *A. mangium*. Stimulatory effect of *D. sissoo* on seed germination of annual crops have been attributed to presence of phenols, carbohydrates, terpenoids and flavonoids in extracts (Tripathy *et al.*, 2000). In the present investigation, leaf leachate of *M. azedarach* resulted in minimum seed germination of annual crops. Inhibitory effects of *M. azedarach* on seed germination of different annual species have been reported by a number of workers (Farrukh *et al.*, 1985; Liliana *et al.*, 2011; Wirat *et al.*, 2012). Inhibition of seed germination was recorded in all the annual crops except garden peas. Application of leaf extract of *A. mangium* resulted in significant increase in the germination % of garden peas indicating synergistic interaction. The maximum inhibition of seed germination was recorded in case of okra (33.48%). Venkateshwarlu (2001) has recorded 90% inhibition in seed germination of okra when treated with leaf extract of *M. indica*. Both stimulatory and inhibitory effect on seed germination of annual crops, were recorded by Sahoo *et al.*, (2010), with the aqueous leaf leachate of *M. indica*. Inhibition of seed germination by allochemicals has been attributed to suppression of mitotic activities of young cells (Rice, 1984).

Shoot length

With respect to shoot length, treatmental effects were significant with respect to tree species, annual crops and interaction between tree species and annual crop (Table 2). Application of water extract of all the tree species except *B. monosperma*, *A. mangium* and *D. sissoo* resulted in significant decrease in shoot length of annual crops over that of water application. Among the annual crops, the maximum reduction in shoot length was recorded in case of garden pea (33.07%) whereas the maximum increase was recorded in case of okra (19.86%). Venkateshwarlu (2001) has reported reduced root and shoot length in okra when treated with leaf extract of *M. indica* at 1000 ppm. Hoque *et al.* (2003) has reported significant inhibitory effect on shoot elongation (-41.56%) in mustard with 100% leaf water extracts of *A. auriculiformis* whereas, in present study it was found at par with control.

Table 1. Effect of soil application of leaf water extracts on seed germination (%) of annual crops

Trees/ Annual Crop	<i>Mangifera indica</i> L.	<i>Populus deltoides</i>	<i>Terminalia arjuna</i>	<i>Butea monosperma</i>	<i>Melia azadirach</i>	<i>Acacia mangium</i>	<i>Acacia auriculif- formis</i>	<i>Aegle marmelos</i>	<i>Tectona grandis</i>	<i>Artocarpus heterophyllum</i>	<i>Dalbergia sissoo</i>	Water	Mean	SEm±	C.D. at 5%
Black gram	80.86	77.16	82.72	69.75	34.57	73.46	84.57	77.78	71.60	62.96	90.12	90.12	74.64	Extract: 2.21, Seed: 1.92,	Extract: 6.13, Seed: 5.31,
Gram	79.01	83.33	74.07	85.19	56.17	82.10	81.48	94.44	87.04	85.80	98.15	89.51	83.02	2.21, Seed: 1.92,	6.13, 5.31,
Pea	69.75	64.81	69.75	72.84	62.35	82.72	66.67	48.15	70.99	62.96	68.52	54.94	66.20	Seed: 1.92,	5.31,
Sponge gourd	40.12	40.74	46.30	45.68	57.41	62.96	71.60	41.36	38.27	64.20	50.62	57.41	51.39	1.92,	5.31,
Mustard	88.27	74.07	75.93	80.25	81.48	73.46	83.95	89.51	67.28	82.10	93.83	87.04	81.43	Extract x Extract	
Okra	72.84	53.09	57.41	67.90	69.14	45.06	24.69	63.58	32.10	57.41	67.90	74.69	57.15	Seed: x	
Brinjal	56.17	74.07	72.84	75.93	80.86	78.40	68.52	82.10	72.22	95.06	71.60	78.40	75.51	6.64	Seed: 18.39
Chilli	65.43	68.52	73.46	84.57	86.42	87.65	82.72	87.04	95.06	99.38	98.15	90.74	84.93		
Tomato	64.20	77.78	83.95	92.59	70.37	83.33	65.43	78.40	85.19	84.57	79.01	83.33	79.01		
Mean	68.52	68.18	70.71	74.97	66.53	74.35	69.96	73.59	68.86	77.16	79.77	78.46			

Table 2. Effect of soil application of leaf water extracts on shoot length (cm) of annual crops

Trees/ Annual crop	<i>Mangifera indica</i> L.	<i>Populus deltooides</i>	<i>Terminalia arjuna</i>	<i>Butea monosperma</i>	<i>Melia azadirach</i>	<i>Acacia mangium</i>	<i>Acacia auriculiformis</i>	<i>Aegle marmelos</i>	<i>Tectona grandis</i>	<i>Artocarpus heterophyllus</i>	<i>Dalbergia sissoo</i>	Water	Mean	SEm±	C.D. at 5%
Black gram	12.64	11.98	14.38	13.74	10.83	13.52	13.51	12.18	12.08	12.47	14.68	14.04	13.00	Extract: 0.194, Seed: 0.539,	
Gram	13.70	13.97	15.23	15.91	12.71	13.97	14.73	13.83	14.02	14.25	14.38	15.42	14.34	Seed: 0.168, Extract x Extract	
Pea	4.82	4.59	4.66	5.08	4.87	5.74	5.79	5.82	6.43	5.37	7.73	8.27	5.77	Seed: 0.467,	
Sponge gourd	8.20	7.60	8.44	9.30	7.60	6.86	4.70	7.24	5.45	7.31	10.35	10.03	7.76	Seed: 0.583	
Mustard	5.92	5.86	6.18	6.25	5.40	5.79	5.32	5.18	5.54	5.98	6.73	5.41	5.80	Seed: 1.616	
Okra	5.63	5.16	5.20	4.79	5.93	6.23	6.73	3.27	4.09	6.33	5.26	4.45	5.26		
Brinjal	3.72	3.52	1.09	3.87	3.89	4.28	3.49	3.34	3.96	4.16	3.79	3.63	3.56		
Chilli	6.12	6.43	5.63	6.65	5.77	6.01	6.18	6.42	7.07	6.66	6.44	6.02	6.28		
Tomato	6.63	7.68	4.39	5.03	8.45	7.98	6.58	7.31	6.29	6.64	6.39	7.24	6.72		
Mean	7.49	7.42	7.25	7.85	7.27	7.82	7.45	7.18	7.22	7.69	8.42	8.28			

Plant weight

a. Root: The treatments different significantly with respect to fresh as well as dry weight of root of annual crops (Table 3 & 4). Among the tree species, application of water extract of *M. indica*, *P. deltooides*, *T. arjuna* and *B. monosperma* resulted in significant increase in fresh weight of root over that of water application, the maximum being in case of *M. indica*. However, with respect to dry weight of root, significant increase over control was recorded in case of *M. indica*, *P. deltooides*, *A. auriculiformis*, *A. marmelos* and *T. grandis*, the maximum being in case of *A. marmelos*. Among the annual crops, significant increase in root fresh weight over that of control was recorded in case of black gram (151.56% increase) and gram (30.18% increase) whereas in case of dry weight of root, significant increases were recorded in case of brinjal (105.93% increase), sponge gourd (40.41% increase) and gram (25.74% increase).

b. Shoot : With respect to shoot fresh as well as dry weight, significant effects of the treatments could be recorded (Table 5 & 6). Among the tree species, application of leaf extract of *M. indica*, *A. mangium*, *A. auriculiformis*, *A. marmelos* resulted in significantly higher shoot fresh weight than that of control whereas significantly higher shoot dry weight was recorded in case of *M. indica*, *P. deltooides*, *B. monosperma*, *A. auriculiformis*, *A. mangium* and *A. marmelos*. Among the annual crops, significant decrease in shoot fresh weight was recorded in case of sponge gourd, whereas significant increases were recorded in case of mustard, okra, brinjal, chilli and black gram. In case of shoot dry weight, significant decrease was recorded in garden pea whereas significant increases were recorded in gram, okra, brinjal, tomato.

c. Whole plant : With respect to total fresh weight and dry weight of the plant, significant effects of the treatments could be recorded (Table 7 & 8). Application of leaf extract of *M. indica*, *B. monosperma*, *A. mangium*, *A. auriculiformis* and *A. marmelos* resulted in significant increase in total fresh and dry weight over that of control whereas none of the treatments resulted in significant reduction in fresh weight of annual crops. Stimulatory effect of bael-leaf-water-extract at lower concentration has also been reported by Thapaliyal *et al.* (2008). Hoque *et al.*, (2003) has reported stimulatory effect of *A. auriculiformis* on growth of annual crops at lower

Table 3. Effect of soil application of leaf water extracts on root fresh weight (g) of annual crops

Trees/ annual	<i>Mangifera indica</i> L	<i>Populus deltoides</i>	<i>Terminalia arjuna</i>	<i>Butea monosperma</i>	<i>Melia azadirach</i>	<i>Acacia mangium</i>	<i>Acacia auriculi-</i> <i>formis</i>	<i>Aegle marmelos</i>	<i>Tectona grandis</i>	<i>Artocarpus heterophyllus</i>	<i>Dalbergia sissoo</i>	Water	Mean	S \bar{E} m \pm	C.D. at 5%
Black gram	0.79	0.73	0.48	0.83	0.40	0.54	0.30	0.31	0.58	0.52	0.13	0.20	0.49	Extract: 0.051,	Extract: 0.142,
Gram	3.26	3.10	3.87	3.45	2.13	2.73	2.98	2.23	2.01	1.77	1.53	2.03	2.59	0.051,	0.142,
Pea	2.04	1.84	1.51	1.88	1.90	2.47	2.23	2.29	2.29	1.42	1.52	1.94	1.94	Seed: 0.044,	Seed: 0.123,
Sponge gourd	0.49	0.51	0.46	0.53	0.93	0.57	0.28	0.64	0.59	0.60	0.85	0.66	0.59	0.044,	0.123,
Mustard	0.07	0.03	0.03	0.06	0.02	0.04	0.04	0.07	0.05	0.03	0.02	0.03	0.04	Extract \times 0.154	Extract \times 0.426
Okra	1.16	0.91	1.00	0.72	0.41	0.35	0.55	0.63	0.95	0.58	0.49	0.77	0.71	Seed: 0.154	Seed: 0.426
Brinjal	0.03	0.03	0.04	0.05	0.03	0.03	0.04	0.05	0.06	0.04	0.02	0.03	0.04	0.154	0.426
Chilli	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.06	0.04	0.04	0.03	0.03	0.04		
Tomato	0.06	0.09	0.04	0.06	0.13	0.11	0.14	0.29	0.41	0.25	0.21	0.23	0.17		
Mean	0.88	0.81	0.83	0.85	0.67	0.76	0.73	0.73	0.78	0.59	0.53	0.66			

Table 4. Effect of soil application of leaf water extracts on root dry weight (g) of annual crops

Trees/ annual crop	<i>Mangifera indica</i> L	<i>Populus deltoides</i>	<i>Terminalia arjuna</i>	<i>Butea monosperma</i>	<i>Melia azadirach</i>	<i>Acacia mangium</i>	<i>Acacia auriculi-</i> <i>lijformis</i>	<i>Aegle marmelos</i>	<i>Tectona grandis</i>	<i>Artocarpus heterophyllus</i>	<i>Dalbergia sissoo</i>	Water	Mean	S \bar{E} m \pm	C.D. at 5%
Black gram	0.035	0.038	0.033	0.037	0.027	0.027	0.060	0.035	0.033	0.030	0.040	0.054	0.038	Extract: 0.003,	Extract: 0.008,
Gram	0.212	0.194	0.229	0.179	0.189	0.206	0.208	0.197	0.152	0.129	0.129	0.146	0.181	0.003,	0.008,
Pea	0.163	0.180	0.109	0.134	0.140	0.161	0.173	0.228	0.219	0.189	0.159	0.174	0.169	Seed: 0.003,	Seed: 0.007,
Sponge gourd	0.042	0.055	0.039	0.037	0.046	0.050	0.029	0.039	0.053	0.046	0.037	0.031	0.042	0.003,	0.007,
Mustard	0.006	0.003	0.003	0.006	0.006	0.009	0.006	0.008	0.005	0.004	0.003	0.004	0.005	Extract \times 0.009	Extract \times 0.024
Okra	0.068	0.070	0.072	0.065	0.042	0.047	0.057	0.058	0.069	0.056	0.041	0.056	0.058	Seed: 0.009	Seed: 0.024
Brinjal	0.015	0.009	0.009	0.019	0.008	0.010	0.026	0.035	0.025	0.011	0.005	0.008	0.015	0.009	
Chilli	0.011	0.011	0.010	0.014	0.009	0.014	0.015	0.020	0.015	0.012	0.010	0.010	0.013		
Tomato	0.013	0.020	0.012	0.016	0.015	0.017	0.017	0.031	0.024	0.016	0.010	0.010	0.017		
Mean	0.063	0.065	0.057	0.056	0.054	0.060	0.065	0.073	0.066	0.055	0.048	0.055			

Table 5. Effect of soil application of leaf water extracts on shoot fresh weight (g) of annual crops

Trees/ annual crop	<i>Mangifera indica</i> L.	<i>Populus deltoides</i>	<i>Terminalia arjuna</i>	<i>Butea monosperma</i>	<i>Melia azadirach</i>	<i>Acacia mangium</i>	<i>Acacia auriculiformis</i>	<i>Aegle marmelos</i>	<i>Tectona grandis</i>	<i>Artocarpus heterophyllus</i>	<i>Dalbergia sissoo</i>	Water	Mean	SEm±	C.D. at 5%
Black gram	2.85	2.82	3.07	3.41	2.39	3.14	2.90	2.89	2.70	2.80	2.52	2.53	2.84	Extract: 0.11,	0.30,
Gram	4.93	4.19	5.79	5.84	4.35	4.86	4.53	4.21	4.08	3.97	4.42	4.70	4.66	Seed: 0.09,	0.26,
Pea	3.85	3.43	3.11	3.75	3.80	5.20	4.68	3.93	3.96	3.11	4.29	4.10	3.93	Seed: 0.07,	0.08,
Sponge gourd	5.60	4.18	5.71	6.26	5.67	4.73	3.82	5.44	3.97	4.61	6.30	5.93	5.19	Extract × Extract ×	0.26,
Mustard	1.38	1.33	1.57	1.77	1.21	1.50	1.60	1.57	1.29	1.35	1.33	1.14	1.42	Seed: 0.32	0.90
Okra	11.28	8.71	9.22	8.78	10.32	10.19	11.93	9.21	8.31	10.89	10.94	8.66	9.87	Seed: 0.32	0.90
Brinjal	1.96	1.80	1.51	1.07	1.43	1.44	1.21	1.91	1.76	1.67	0.75	0.92	1.45	Seed: 0.32	0.90
Chilli	1.57	1.58	1.02	1.40	1.31	1.30	1.53	1.76	1.77	1.47	1.22	1.18	1.43	Seed: 0.32	0.90
Tomato	2.25	2.85	1.60	1.92	3.47	2.84	3.32	4.27	3.99	3.08	2.30	2.69	2.88	Seed: 0.32	0.90
Mean	3.96	3.43	3.62	3.80	3.77	3.91	3.95	3.91	3.54	3.66	3.79	3.54			

Table 6. Effect of soil application of leaf water extracts on shoot dry weight (g) of annual crops

Trees/ annual crop	<i>Mangifera indica</i> L.	<i>Populus deltoides</i>	<i>Terminalia arjuna</i>	<i>Butea monosperma</i>	<i>Melia azadirach</i>	<i>Acacia mangium</i>	<i>Acacia auriculiformis</i>	<i>Aegle marmelos</i>	<i>Tectona grandis</i>	<i>Artocarpus heterophyllus</i>	<i>Dalbergia sissoo</i>	Water	Mean	SEm±	C.D. at 5%
Black gram	0.219	0.260	0.270	0.279	0.216	0.257	0.278	0.273	0.234	0.212	0.258	0.240	0.250	Extract: 0.008,	0.023,
Gram	0.585	0.564	0.642	0.647	0.526	0.575	0.550	0.495	0.507	0.464	0.512	0.508	0.548	Seed: 0.007,	0.019,
Pea	0.409	0.402	0.367	0.407	0.364	0.486	0.411	0.462	0.495	0.430	0.503	0.516	0.438	Seed: 0.007,	0.019,
Sponge gourd	0.415	0.375	0.387	0.447	0.389	0.360	0.289	0.412	0.315	0.332	0.391	0.382	0.375	Extract × Extract ×	0.068
Mustard	0.072	0.064	0.075	0.088	0.072	0.094	0.081	0.087	0.066	0.074	0.066	0.066	0.075	Seed: 0.024	0.068
Okra	0.735	0.707	0.653	0.600	0.695	0.704	0.804	0.633	0.612	0.723	0.548	0.565	0.665	Seed: 0.024	0.068
Brinjal	0.171	0.153	0.084	0.111	0.119	0.131	0.162	0.222	0.175	0.163	0.082	0.097	0.139	Seed: 0.024	0.068
Chilli	0.134	0.145	0.102	0.132	0.110	0.120	0.148	0.193	0.160	0.131	0.134	0.102	0.134	Seed: 0.024	0.068
Tomato	0.146	0.189	0.110	0.129	0.183	0.146	0.167	0.230	0.188	0.155	0.112	0.132	0.157	Seed: 0.024	0.068
Mean	0.321	0.318	0.299	0.316	0.297	0.319	0.321	0.334	0.306	0.298	0.290	0.290			

Table 7. Effect of soil application of leaf water extracts on total plant fresh weight (g) of annual crops

Trees/ annual crop	<i>Mangifera indica</i> L.	<i>Populus deltoides</i>	<i>Terminalia arjuna</i>	<i>Butea monosperma</i>	<i>Melia azadirach</i>	<i>Acacia mangium</i>	<i>Acacia auriculiformis</i>	<i>Aegle marmelos</i>	<i>Tectona grandis</i>	<i>Artocarpus heterophyllus</i>	<i>Dalbergia sissoo</i>	Water	Mean	SEm±	C.D. at 5%
Black gram	3.64	3.56	3.55	4.24	2.80	3.68	3.21	3.20	3.28	3.32	2.66	2.73	3.32	Extract: 0.13, 0.38,	Extract: 0.38,
Gram	8.19	7.30	9.66	9.28	6.48	7.59	7.51	6.45	6.09	5.74	5.95	6.73	7.25	Seed: 0.11, 0.33,	Seed: 0.33,
Pea	5.89	5.27	4.62	5.63	5.70	7.67	6.90	6.22	6.26	4.53	5.81	6.04	5.88	Extract × Seed: 0.41, 1.14	Extract × Seed: 1.14
Sponge gourd	6.09	4.69	6.17	6.79	6.61	5.29	4.10	6.09	4.56	5.22	7.15	6.60	5.78		
Mustard	1.44	1.35	1.61	1.83	1.23	1.54	1.64	1.64	1.34	1.37	1.35	1.17	1.46		
Okra	12.44	9.63	10.22	9.50	10.73	10.54	12.49	9.84	9.26	11.47	11.43	9.43	10.58		
Brinjal	1.99	1.83	1.55	1.13	1.46	1.46	1.25	1.96	1.82	1.71	0.78	0.95	1.49		
Chilli	1.61	1.60	1.06	1.44	1.35	1.35	1.57	1.82	1.81	1.52	1.25	1.21	1.46		
Tomato	2.31	2.94	1.64	1.98	3.60	2.94	3.47	4.56	4.40	3.33	2.51	2.91	3.05		
Mean	4.85	4.24	4.45	4.65	4.44	4.67	4.68	4.64	4.31	4.25	4.32	4.20			

Table 8. Effect of soil application of leaf water extracts on total plant dry weight (g) of annual crops

Trees/ annual crop	<i>Mangifera indica</i> L.	<i>Populus deltoides</i>	<i>Terminalia arjuna</i>	<i>Butea monosperma</i>	<i>Melia azadirach</i>	<i>Acacia mangium</i>	<i>Acacia auriculiformis</i>	<i>Aegle marmelos</i>	<i>Tectona grandis</i>	<i>Artocarpus heterophyllus</i>	<i>Dalbergia sissoo</i>	Water	Mean	SEm±	C.D. at 5%
Black gram	0.219	0.260	0.270	0.279	0.216	0.257	0.278	0.273	0.234	0.212	0.258	0.240	0.250	Extract: 0.008, 0.023,	Extract: 0.023,
Gram	0.585	0.564	0.642	0.647	0.526	0.575	0.550	0.495	0.507	0.464	0.512	0.508	0.548	Seed: 0.0071, 0.019,	Seed: 0.019,
Pea	0.409	0.402	0.367	0.407	0.364	0.486	0.411	0.462	0.495	0.430	0.503	0.516	0.438	Extract × Seed: 0.071, 0.019,	Extract × Seed: 0.019,
Sponge gourd	0.415	0.375	0.387	0.447	0.389	0.360	0.289	0.412	0.315	0.332	0.391	0.382	0.375		
Mustard	0.072	0.064	0.075	0.088	0.072	0.094	0.081	0.087	0.066	0.074	0.066	0.066	0.075		
Okra	0.735	0.707	0.653	0.600	0.695	0.704	0.804	0.633	0.612	0.723	0.548	0.565	0.665		
Brinjal	0.171	0.153	0.084	0.111	0.119	0.131	0.162	0.222	0.175	0.163	0.082	0.097	0.139		
Chilli	0.134	0.145	0.102	0.132	0.110	0.120	0.148	0.193	0.160	0.131	0.134	0.102	0.134		
Tomato	0.146	0.189	0.110	0.129	0.183	0.146	0.167	0.230	0.188	0.155	0.112	0.132	0.157		
Mean	0.321	0.318	0.299	0.316	0.297	0.319	0.321	0.334	0.306	0.298	0.290	0.290			

concentrations. Similarly stimulatory effect of *B. monosperma* on growth of annual crops has been reported by Roy *et al.* (2011). However, inhibitory effects of *M. indica* on growth of different medicinal plants have been reported by Krishna *et al.* (2005). Among the annual crops, reduction in total fresh weight of the plant than that of control was recorded in case of bottle gourd whereas significant increase in fresh weight due to application of leaf extract was recorded in case of black gram, gram, okra and brinjal. The maximum increase in total fresh weight recorded in case of brinjal (61.57%). Data on interaction between tree species x annual crops indicated inhibitory effect of *A. heterophyllum* on garden peas; *P. deltooides*, *T. grandis* and *A. heterophyllum* on sponge gourd; *T. arjuna* on tomato.

Phenolic content in leaf-water-extract of tree species

Analysis of leaf-water extract of different tree species indicated significant difference with respect to content of total phenol (Table 9). The maximum phenol content was recorded in case of *T. grandis* which was at par with *A. heterophyllum* and *D. sissoo*. Phenolic content of all other tree species were significantly lower and were at par with each other. Lower total fresh weight of whole plant treated with the above three tree species can be partly attributed to significantly higher phenolic content in the water extracts.

Biochemical composition of annual crops

a. Total chlorophyll- Significant effects of the treatments on total chlorophyll content was recorded with respect to tree species, annual crops as well as interaction between tree species and annual crops (Table 10). Application of leaf extract of *M. indica*, *A. mangium*, *A. auriculiformis* and *A. marmelos* resulted

in significant decrease in total chlorophyll content over that of control. Among the annual crops, significant increase was recorded in Pea while, decrease was recorded in black gram, sponge gourd, chilli and tomato. Among the annual crops, pea (1229.87 µg/g), when treated with extract of *T. grandis*, showed a maximum decrease of total chlorophyll, whereas, sponge gourd (2607.62 µg/g), when treated with extract of *M. indica* showed a reverse trend in all the extracts assayed. Results were found similar with the findings of Venkateshwarlu (2001), who has reported inhibition in chlorophyll a and chl. b content (41.66% and 11.36% respectively) in radish when treated with leaf extract of *M. indica* (200 ppm). The reduction in chlorophyll contents observed in the few combinations might be due to degradation of chlorophyll pigments or reduction in their synthesis and the action of flavanoids, terpenoids or other phytochemicals present in leaf extracts (Tripathi *et al.*, 1999). Reduction in chlorophylls may decrease the photosynthesis and thereby substantially decrease all the metabolites viz., total sugars, proteins and soluble amino acids (Singh and Ranjana, 2003). During present study significant inhibitory effect of leaf extracts in chlorophyll content has been recorded in pea, but no significant changes could be found on total phenol and total soluble sugar content of this crop.

b. Phenol- With respect to total phenol content of the annual plants, significant effect of the treatments could be recorded (Table 11). All the tree species except *P. deltooides*, *M. azadirach* and *D. sissoo* resulted in significant decrease in the phenolic content in annual crops. Among annual crops significantly higher values could be found in gram, pea, sponge gourd, okra, brinjal and tomata, while it was recorded significantly lower in Chilli. With respect to

Table 9. Total phenol content of leaf extract of different tree species

Sl. No.	Tree species	Total phenol content of leaf extract (mg/100g)	Sl. No.	Tree species	Total phenol content of leaf extract (mg/100g)
1.	<i>Mangifera indica</i> L	1.89	7	<i>Acacia auriculiformi</i>	0.55
2.	<i>Populus deltooides</i>	0.10	8	<i>Aegle marmelos</i>	1.61
3.	<i>Terminalia arjuna</i>	0.67	9	<i>Tectona grandis</i>	4.09
4.	<i>Butea monosperma</i>	0.86	10	<i>Artocarpus heterophyllum</i>	2.38
5.	<i>Melia azedarach</i> L	1.04	11	<i>Dalbergia sissoo</i>	3.13
6.	<i>Acacia mangium</i>	1.32			

SEM± : 0.68, C.D. at 5% : 2.11

Table 10. Effect of soil application of leaf water extracts on chlorophyll content ($\mu\text{g/g}$) of annual crops

Trees/ annual crop	<i>Mangifera indica</i> L.	<i>Populus deltoides</i>	<i>Terminalia arjuna</i>	<i>Butea monosperma</i>	<i>Melia azadirach</i>	<i>Acacia mangium</i>	<i>Acacia auricu- liformis</i>	<i>Aegle marmelos</i>	<i>Tectona grandis</i>	<i>Artocarpus heterophyllus</i>	<i>Dalbergia sissoo</i>	Water	Mean	SEm \pm	C.D. at 5%
Black gram	1484.01	1368.20	1363.24	1548.21	1360.32	1535.96	1666.68	1482.76	1372.82	1407.82	1443.76	1338.24	1438.36	Extract:	Extract:
Gram	1517.92	1188.17	1363.26	1537.00	1260.20	1434.91	1472.88	1371.38	1315.64	1244.12	1344.44	1289.28	1385.79	41.69,	128.37,
Pea	1399.24	1548.22	1647.21	1376.89	1360.47	1515.75	1647.30	1677.86	1229.87	1489.67	1521.34	1762.56	1514.59	Seed:	Seed:
Sponge gourd	2607.62	2214.32	2341.42	1969.28	1865.18	2485.83	2383.74	2399.73	2063.44	2013.51	1998.97	2039.41	2198.43	34.28,	114.37,
Mustard	1844.43	1566.23	1405.87	1392.90	1460.23	1758.27	1686.06	1697.37	1244.11	1424.19	1539.03	1419.84	1536.46	Extract	Extract
Okra	1823.27	1548.22	1647.22	1889.23	1360.63	1940.16	2054.28	2068.06	1658.83	1898.92	1698.24	1893.12	1787.20	x	x
Brinjal	1717.21	1638.24	1590.43	1857.21	1361.23	1637.01	1763.58	1775.41	1630.27	1489.67	1609.79	1648.32	1649.67	Seed:	Seed:
Chilli	1632.44	1566.23	1562.06	1697.10	1440.67	1556.17	1686.06	1677.86	1515.81	1424.19	1539.03	1419.84	1572.98	79.46	243.39
Tomato	1348.32	1332.19	1363.22	1338.47	1360.13	1487.46	1426.37	1435.94	1372.83	1204.83	1301.98	1201.15	1347.67		
Mean	1708.25	1552.22	1587.07	1622.92	1434.11	1705.72	1754.11	1714.19	1489.26	1510.77	1569.14	1556.86			

Table 11. Effect of soil application of leaf water extracts on phenol content ($\text{mg}/100\text{g}$) of annual crops

Trees/ annual crop	<i>Mangifera indica</i> L.	<i>Populus deltoides</i>	<i>Terminalia arjuna</i>	<i>Butea monosperma</i>	<i>Melia azadirach</i>	<i>Acacia mangium</i>	<i>Acacia auricu- liformis</i>	<i>Aegle marmelos</i>	<i>Tectona grandis</i>	<i>Artocarpus heterophyllus</i>	<i>Dalbergia sissoo</i>	Water	Mean	SEm \pm	C.D. at 5%
Black gram	0.082	0.148	0.147	0.136	0.396	0.473	0.333	0.280	0.204	0.418	0.297	0.339	0.271	Extract:	Extract:
Gram	0.559	1.984	0.342	1.013	0.943	0.052	0.149	0.165	0.282	0.405	0.548	0.765	0.601	0.035,	0.098,
Pea	0.289	0.177	0.145	0.218	0.161	0.131	0.193	0.184	0.142	0.073	0.115	0.358	0.182	Seed:	Seed:
Sponge gourd	0.028	0.022	0.138	0.052	0.010	0.117	0.171	0.238	0.518	0.379	0.672	0.578	0.244	0.031,	0.085,
Mustard	0.327	0.183	0.215	0.338	0.174	0.129	0.158	0.188	0.004	0.008	0.107	0.113	0.162	Extract x	Extract
Okra	0.088	0.341	0.078	0.084	0.070	0.084	0.087	0.028	0.027	0.027	0.136	0.253	0.109	Seed:	x Seed:
Brinjal	0.223	0.115	0.107	0.205	0.145	0.093	0.233	0.216	0.032	0.113	0.202	0.277	0.163	0.106	0.293
Chilli	0.148	0.236	0.298	0.272	0.289	0.039	0.192	0.284	0.191	0.312	0.268	0.039	0.214		
Tomato	0.487	0.188	0.174	0.053	0.561	0.053	0.292	0.180	0.260	0.033	0.343	0.558	0.265		
Mean	0.248	0.377	0.183	0.263	0.305	0.130	0.201	0.196	0.184	0.196	0.299	0.364			

Table 12. Effect of soil application of leaf water extracts on total soluble sugar content (%) of annual crops

Trees/ annual crop	<i>Mangifera indica</i> L.	<i>Populus deltooides</i>	<i>Terminalia arjuna</i>	<i>Butea monosperma</i>	<i>Melia azadirach</i>	<i>Acacia mangium</i>	<i>Acacia auriculiformis</i>	<i>Aegle marmelos</i>	<i>Tectona grandis</i>	<i>Artocarpus heterophyllus</i>	<i>Dalbergia sissoo</i>	Water	Mean	S _{Em} ±	C.D. at 5%
Black gram	2.17	2.40	1.12	0.99	1.35	1.73	1.47	1.59	2.11	2.39	2.41	1.57	1.78	Extract: 0.28,	Extract: ns,
Gram	0.65	0.40	1.30	0.56	0.53	0.52	0.52	0.66	1.37	0.91	0.72	0.97	0.76	Seed: 0.24,	Seed: 0.70,
Pea	0.15	0.52	0.66	0.74	0.76	0.57	0.63	0.78	0.87	0.87	0.96	1.10	0.72	Extract x Seed:	Extract x Seed:
Sponge gourd	1.41	1.52	1.52	2.00	1.92	1.73	2.23	2.80	1.96	1.68	1.93	2.26	1.91	Extract x	Extract x
Mustard	0.61	2.13	1.33	0.94	1.01	2.90	1.24	1.41	2.10	2.64	0.94	1.33	1.55	×	Seed:
Okra	2.49	2.07	1.99	1.84	1.78	1.54	1.85	2.05	1.94	1.98	1.95	2.07	1.96	Seed: 1.48	Seed: 1.48
Brinjal	0.45	0.55	1.77	0.98	0.76	1.09	1.43	1.54	1.40	1.20	1.35	1.32	1.15	0.56	0.56
Chilli	1.55	1.71	1.62	1.15	1.70	1.74	1.21	1.36	1.71	1.74	1.77	1.44	1.56		
Tomato	3.14	7.33	0.80	0.73	0.78	0.66	0.30	0.36	0.30	0.52	0.24	0.34	1.29		
Mean	1.40	2.07	1.35	1.10	1.18	1.38	1.21	1.39	1.53	1.55	1.36	1.38			

interaction between tree species and annual crops significant difference were recorded only in the case of gram, sponge gourd and tomato. Maximum stimulatory effect was found in gram (1.984 mg/100g) when treated with *P. deltooides* while maximum inhibitory effect was also recorded in the same crop (0.052 mg/100g) when treated with *A. mangium*. This phenolic compound might have interference with phosphorylation pathway or inhibiting the activation of Mg and ATPase activity or might be due to decrease synthesis of total carbohydrate, protein, and nucleic acid (DNA and RNA) or interference in cell division, mineral uptake and biosynthetic processes Pawar and Chavan, (2004).

c. Total Soluble sugar- Significant effects of the treatment on total soluble sugar content of the annual plant, were recorded with respect to annual crops and interaction between tree species and annual crops, while with respect to tree species it was found non-significant (Table 12). Among the annual crops, reduction in the content of total soluble sugar was recorded in case of Tomato, probably due to interference of photochemical in total sugar biosynthetic processes; which was also confirmed by Singh and Rao (2003) in rice. In the interaction between tree species and annual crops significant effects of the treatments could be recorded only in the case of tomato when treated with leaf extract of *M. indica* and *P. deltooides* and mustard when treated with *A. mangium*. The maximum stimulatory effect was recorded in tomato (7.33%) when treated with extract of *P. deltooides*. Rest all the treatments were found at par with each other.

Conclusion

Hence, the study clearly indicated beneficial effect of leaf extract of *Mangifera indica*, *Butea monosperma*, *Acacia mangium*, *Acacia auriculiformis* and *Aegle marmelos* with respect to plant growth of annual crops. None of the MPTs suppressed the growth of annual crops which indicate their suitability to be grown under different agroforestry systems.

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