Screening indigenous tree species for suitable tree–crop combinations in the agroforestry system of Mizoram, India

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Abstract. The study was conducted in the northeastern state of Mizoram in India to find out the allelopathic effect of trees on agricultural crops. The study was conducted in a bioassay culture and a pot culture. The following results were received:

- In the bioassay culture, the germination and radicle length of all food crops decreased in leaf and bark extracts of *Aporosa octandra*, *Anthocephallus chinensis*, and *Albizzia procera* compared with the control, except the radicle length of *Glycine max* in the bark extract of *Anthocephallus chinensis*.
- In the pot culture, *Glycine max* was the most resistant crop (irrespective of trees and growth media), which showed the highest germination (75.28%) followed by *Oryza sativa* (68.33%) and *Brassica campestris* (54.44%). The length of crops (irrespective of growth media and crops) was the largest (86.39 cm) in combination with *Anthocephallus chinensis*, followed by *Albizzia procera* (83.85 cm) and *Aporosa octandra* (81.85 cm).
- Dry matter production of crops was highest in *Anthocephallus chinensis* (1.06 g/plant) followed by *Aporosa octandra* (0.83 g/plant) and *Albizzia procera* (0.81 g/plant).

Thus, we concluded that the order of tree suitability for crops was *Anthocephallus chinensis* > *Albizzia procera* > *Aporosa octandra* and that of crops to trees was *Glycine max* > *Oryza sativa* > *Brassica campestris*.

Key words: allelopathy, allelochemical, dry matter production, growth media, growth inhibition, growth stimulation.

INTRODUCTION

Allelopathy is a natural phenomenon in which plant–plant interactions play an important role in the agroforestry system. Rice (1984) defined allelopathy as a process by which plants release chemical compounds in their environment to keep themselves with a competitive advantage (Kong et al., 2004). There are hundreds of secondary metabolites in the plant kingdom and many are known to be phyto-toxic (Einhellig, 2002). Allelopathic effects of these compounds such as inhibition of seed germination and seedling growth are often observed. Many secondary metabolites recorded in plants such as phenolics, terpenoids, alkaloids, fatty acids, steroids, and polyacetylenes are known to play an important role in allelopathy, which includes positive and negative effects in the plants (Inderjit, 1996). The multiple effects resulting from allelopathic phenolics include decrease in plant growth, absorption of water, mineral nutrients, ion uptake, leaf water potential, shoot turgor pressure, osmotic potential, dry matter production, leaf area expansion, stomatal aperture size, stomata diffusive conductance, and photosynthesis (Chou & Lin, 1996). Harborne (1977) proved that higher plants (trees) release some phytotoxins into soil, which adversely affect the germination and yield of crops.

In the shifting cultivation of the agroforestry systems of Mizoram, India, a number of principal trees are left growing in the field for the basic needs of the villagers (i.e., fuel, fodder) and to help protect soil against erosion. Agriculture is the main source of subsistence in Mizoram. More than 80% of the population of the area depends on agriculture. Members of the farming community of Mizoram have observed that the trees reduce production of agricultural crops and now the community tends to pay less attention to leaving trees in agricultural fields. The basic causes why trees reduce agricultural production are creation of several barriers in agricultural activities and the fact that some might have toxic effects. The landscape of the area is a steep slope and therefore it is presumed that washing or leaching of tree chemicals should be having some allelopathic effect on understory crops. So far no such tree–crop interaction studies have been carried out by any researcher from this region. Therefore, to address the problems of this region seen by the villagers, the paper discusses the results on (a) the effect of tree extracts on the germination and radicle length of test crops and (b) the effect of growth media treated with leaf and bark powder on crop production (length and dry matter production).

MATERIALS AND METHODS

The study area was located in the Mizoram University campus between lat 92°38′ E to 92°42′ E and long 23°42′ N to 23°46′ N at an elevation of 900 m a.s.l. (Fig. 1). Mizoram is hilly in topography and the hills are steep. The annual rainfall ranges between 2000 mm and 2500 mm. The soils varying from sandy to clayey loams to clay are acidic with a low base saturation and a low productivity potential.

To identify suitable combinations of trees and crops, the trees *Aporosa octandra* (Buch.-Ham. ex D. Don) Vickery, *Anthocephallus chinensis* (Lam.) A. Rich ex Walp., and *Albizzia procera* (Roxb.) Benth. and the crops *Oryza sativa* L., *Brassica campestris* L., and *Glycine max* (L.) Merr. were selected for the experiment carried out in two phases, i.e. (a) bioassay culture and (b) pot culture.

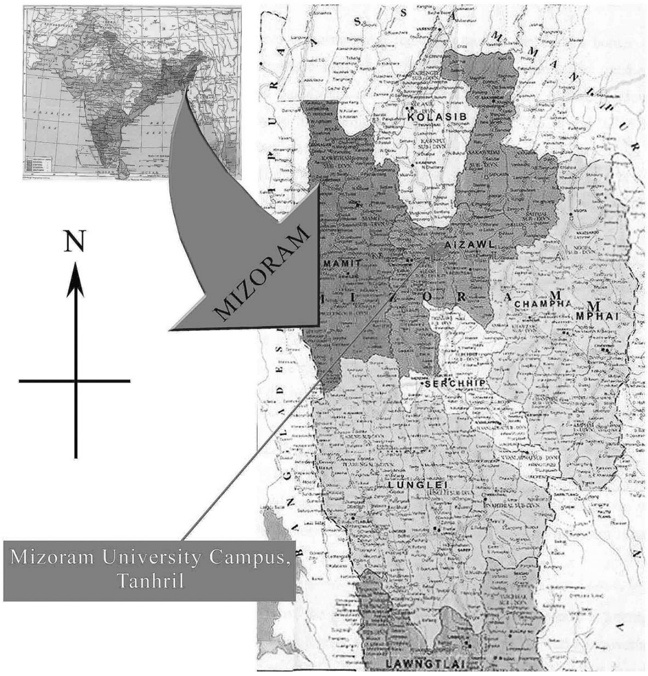


Fig. 1. Location of the study site.

(a) **Bioassay culture**. In the bioassay culture mature leaf and dry natural flaked off bark of middle-aged trees were collected from naturally growing trees. The leaf and bark were sun-dried and ground separately in a mechanical grinder. A powder sample of 2 g of each component (leaf and bark) was weighed and added to 100 mL of double distilled water and kept at room temperature (25–30 °C) for 24 h. The solutions were filtered through Whatman No. 1 filter paper and stored in dark. The effect of the aqueous extracts on germination and radicle length was tested by placing 25 seeds in Petri dishes (15 cm in diameter) with four replicates of each test crop. The filter paper was kept saturated with the aqueous extracts. A separate series of control was set up using distilled water. The germinated seeds were counted every day for 7 days.

(b) **Pot culture.** There were three factors, viz., three tree crops, three test crops, and four growth media. The seeds (5 plants of test crops in each pot) were sown in shallow pots (size 9 cm × 9 cm) containing 1 kg of soil using the following germination media:

1. Topsoil (collected from a 0–5 cm deep layer within 50 cm radius around tree boles).
2. Garden soil (from an experimental garden) + sun-dried powdered leaf (2 g/pot).
3. Garden soil (from an experimental garden) + sun-dried powdered bark (2 g/pot).
4. Garden soil alone serving as control.

In pots, leachates of leaf and bark powder of trees were mixed in the upper layer of the soil. Each crop was planted in soil under four treatments of each tree and replicated four times, and each pot contained five plants. The pots were watered regularly and seed germination was recorded after 7 days of sowing. The growth characteristics such as length (roots + shoots) and dry matter production (roots + shoots) for each crop were measured 90 days after sowing.

All the data collected for germination and growth characteristics (length and dry matter production) were statistically analysed using least significant difference at $P < 0.05$ (Sharma, 1998).

RESULTS

Effect of leaf and bark aqueous extracts on the germination and radicle length of test crops in the bioassay culture

The germination of all test crops (*O. sativa*, *B. campestris*, and *G. max*) was suppressed in the aqueous extracts (leaf and bark) of all trees as compared with control (Fig. 2). The germination of *O. sativa* was most strongly suppressed (13.58%) in *A. procera* followed by *A. chinensis* and *A. octandra*. The germination of *B. campestirs* was highly inhibited in *A. octandra* (88.37%) followed by *A. procera* (15.70%) and *A. chinensis* (4.07%). The maximum germination of *G. max* was observed in *A. chinensis* and the minimum in *A. procera* (Fig. 2). The germination of test crops was significantly ($P < 0.05$) inhibited by leaf and bark extracts.

The radicle length of all test crops was similar to their germination: the length of all test crops was suppressed in all extracts. It is interesting to note that the radicle length of *G. max* was stimulated (30.03%) in *A. chinensis* bark when tested

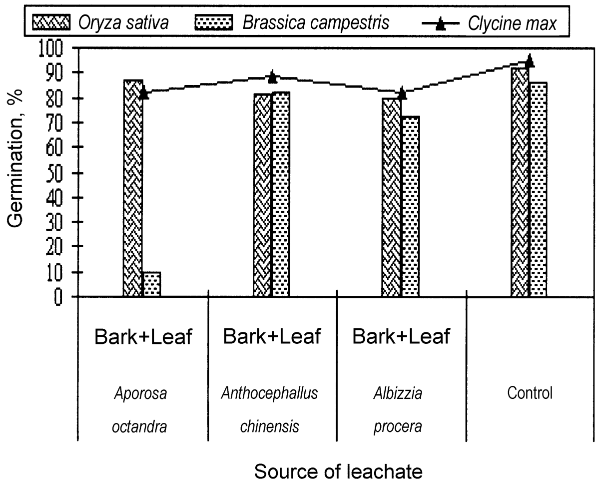


Fig. 2. Effect of leachates on the germination of food crops in the bioassay culture.

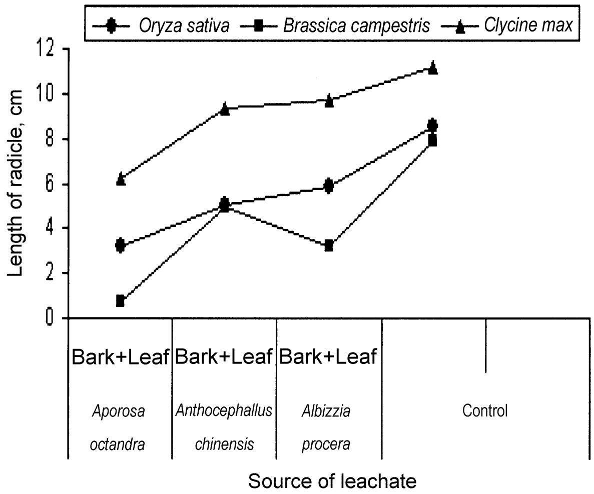


Fig. 3. Effect of leachates on the radicle length of food crops in the bioassay culture.

separately (Fig. 3). The radicle length was significantly ($P < 0.05$) inhibited in leaf and bark extracts of trees.

Effect of growth media on the germination of test crops in the pot culture

The germination of crops in different growth media of trees was pooled and is shown in Fig. 4. The germination of *O. sativa* was inhibited in each growth medium of trees compared with control. Of the trees *A. procera* had the least

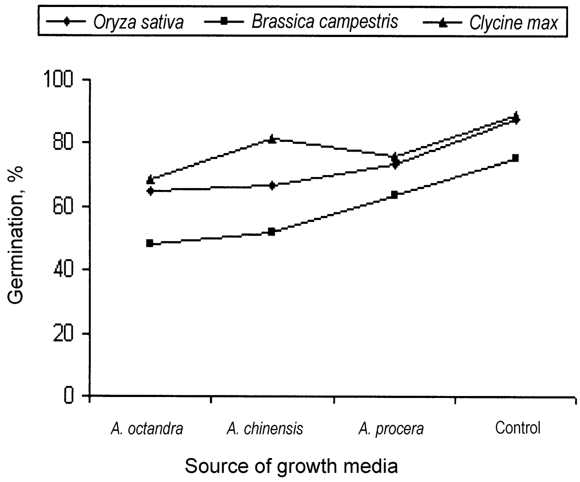


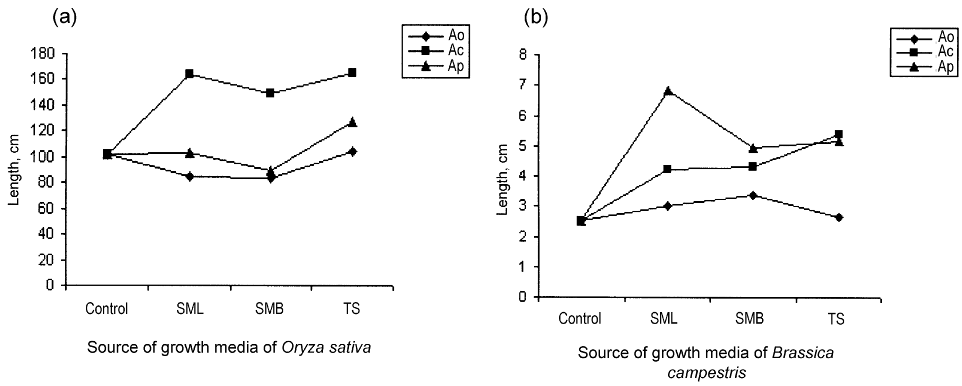
Fig. 4. Effect of growth media on the germination of food crops in the pot culture.

toxic effect on *O. sativa* followed by *A. chinensis* and *A. octandra*. The germination of *B. campestris* and *G. max* was also depressed in all growth media of all trees (Fig. 4).

Effect of growth media on the length of test crops in the pot culture

The length (roots + shoots, cm) of each crop was measured in different growth media of trees and compared with control. The length of *O. sativa* was slightly stimulated in topsoil and depressed in soil mulched with leaf and bark of *A. octandra* as compared to control. The length of *O. sativa* was also stimulated in all growth media with *A. procera* except in soil mulched with its bark. However, in all growth media with *A. chinensis* the length of *O. sativa* was stimulated (Fig. 5a). The stimulation of *O. sativa* in topsoil might be due to the availability of organic matter in the forest floor, which enriches the soil with nutrients and has therefore the least toxicity to crops. However, stimulation in soil mulched with leaf and bark might also be due to stimulatory compounds in the leaf and bark.

The length of *B. campestris* was stimulated in all growth media compared to control. Among the trees and growth media, the maximum length of *B. campestris* (6.82 cm) was observed in soil mulched with leaf of *A. procera* and minimum



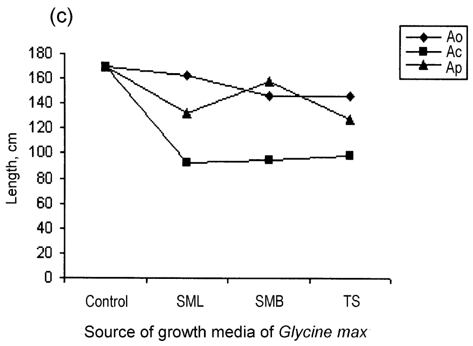


Fig. 5. Effect of growth media on the length (roots + shoots) of test crops. Growth media: topsoil (TS), soil mulched with leaf (SML), and soil mulched with bark (SMB); trees: *Aporosa octandra* (Ao), *Anthocephallus chinensis* (Ac), and *Albizzia procera* (Ap).

(2.64 cm) in topsoil of *A. octandra* (Fig. 5b). The reduction in length could be due to leaching of toxic allelochemicals to soil.

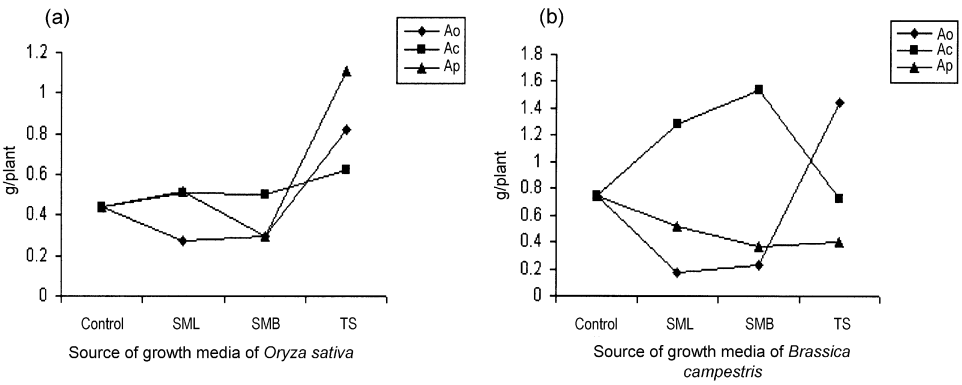
The length of *G. max* was suppressed by all trees and in all growth media over control (Fig. 5c). The length of *G. max* was suppressed most strongly in each growth medium with *A. chinensis*.

The length of test crops was significantly ($P < 0.05$) influenced by different growth media.

Effect of growth media on dry matter production of test crops in the pot culture

The dry matter production (g/plant) of test crops was also assessed in different growth media and trees. The dry matter production of *O. sativa* was stimulated in the topsoil of all trees over control. Among the trees *A. octandra* (soil mulched with leaf and bark) and *A. procera* (soil mulched with bark) suppressed dry matter production of *O. sativa*, while *A. chinensis* was the least toxic tree and stimulated the dry matter production of *O. sativa* in all growth media compared with control (Fig. 6a).

The dry matter production of *B. campestri*s was inhibited in the topsoil of *A. chinensis* and *A. procera* over control, but not of *A. octandra*, which stimulated



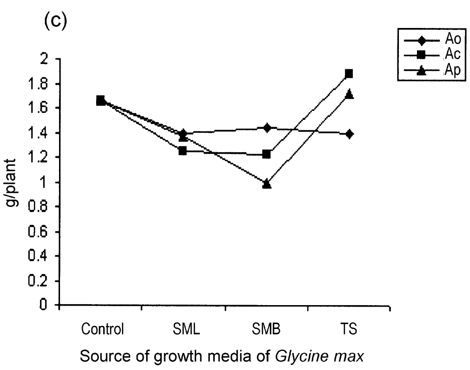


Fig. 6. Effect of growth media on the dry matter production of test crops. For media and trees see Fig. 5.

its dry matter production. The leaf and bark extracts of *A. octandra* and *A. procera* had a negative effect on the dry matter production of *B. campestris*; however, *A. chinensis* had a positive influence on dry matter production except in topsoil (Fig. 6b).

Glycine max had the maximum dry matter production in topsoil followed by soil mulched with leaf and soil mulched with bark compared with control. Of the trees *A. chinensis* was the least toxic (Fig. 6c).

The dry matter production was significantly ($P < 0.05$) influenced by different growth media.

DISCUSSION

The maximum length (86.39 cm) of crops (irrespective of crops and growth media) was in *A. chinensis* followed by *A. procera* (83.85 cm) and the minimum (81.85 cm) in *A. octandra*. Similarly, the dry matter production was highest in *A. chinensis* (1.05 g/plant) but followed by *A. octandra* (0.83 g/plant) and *A. procera* (0.81 g/plant).

Irrespective of trees and growth media, the maximum length was shown by *G. max* (128.54 cm) followed by *O. sativa* (119.12 cm) and *B. campestris* (4.43 cm). The dry matter production was also highest for *G. max* but lowest for *O. sativa.* When these values were compared with control, it was observed that the length and dry matter production of *O. sativa* were stimulated over control. *Brassica campestris* was stimulated for length but no stimulation was found in its dry matter production while *G. max* was suppressed both in length and dry matter production over control.

The lower germination and allelopathic inhibition may be the consequence of the inhibition of water uptake (El-Khatib, 1997). The radicle length of all test crops in the present study was depressed by all tree types compared with control except for *G. max*, which was stimulated 30.03% over control in the bark aqueous extract of *A. chinensis*. Allelopathic effects of a given compound or plant metabolites may be inhibitory or stimulatory depending on their concentration in the surrounding medium (Khailov, 1974; Tukey, 1969; Basotra et al., 2005). Various bioassay studies have also proved that different plant parts release toxic metabolites into the soil that affect adversely germination and growth of food crops (Qusem, 2002). Singh & Bawa (1982) found that leaf leachates of *Eucalyptus globulus* have an inhibitory effect on the seed germination of *Glaucium flavus*. Many species, e.g. *Rhododendron albiflorum*, *Quercus falcata*, *Q. alba*, *Q. leucotrichophora*, *Cedrus deodara*, and *Myrica esculenta* have been reported to show allelopathic effects (Rice, 1974, 1979; Melkania, 1983). Aqueous extracts of leaf and bark of *Grewia oppositifolia*, *Ficus roxburghii*, *Bauhinia variegata*, and *Kydia calycina* were tested on *Echinochloa frumentacea*, *Eleusine coracana*, *Zea mays*, *Vigna unguiculata*, and *Glycine max* test crops and it was found that the bark and leaf are most toxic to food crops (Kaletha et al., 1996). Similarly, Bhatt & Chauhan (2000) found an allelopathic influence of

Quercus species on *Triticum aestivum*, *Brassica campestris*, and *Lens culinaria*, whose germination and plumule and radicle length were suppressed by leaf and bark extracts of all these trees.

CONCLUSIONS

The results of the experiments showed that the most suitable trees for agricultural crops were *A. chinensis* followed by *A. procera* and *A. octandra*. Of the crops tested the most tolerant to trees was *O. sativa* followed by *G. max* and *B. campestris*. The best suitability of *O. sativa* and *A. chinensis* could be due to long-standing traditional cultivation of this crop so that it has acclimatized genetically in the environmental conditions. In general, all the tree species tested inhibited the growth and development of the tested agricultural crops. Therefore it is recommended that the trees should be lopped before leaf shedding to minimize their toxic effect on crop growth. The lopped leaves could be used for various purposes, e.g. as fodder, bedding material, or firewood.

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Pärismaiste puuliikide võrdlusuuring, leidmaks sobilikku puu- ja viljakultuuri kombinatsiooni agrometsanduslikus süsteemis Mizoramis Indias

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Indias Mizorami osariigis uuriti puude allelopaatilist mõju põllumajanduskultuuridele katsekultuuri- ja potikatsetestides. Saadud tulemused näitasid, et katsekultuuris olid idanemine ja idujuure pikkus kõikidel viljakultuuridel (kontrolliga võrreldes) vähenenud, kui oli lisatud lehtede ning koore ekstrakti puudelt *Aporosa octandra*, *Anthocephallus chinensis* ja *Albizzia procera*, vaid sojaoa (*Glycine max*) idujuure pikkus *Anthocephallus chinensis*'e koore ekstraktis ei vähenenud. Potikultuuris oli soja kõige vastupidavam kultuur idanevusega 75,28%, millele järgnesid riis *Oryza sativa* 68,33% ja kapsas *Brassica campestris* 54,44%. Kultuuride juurte pluss võrsete pikkus (sõltumata kultuurist ja kasvukeskkonnast) andis parima tulemuse kombinatsioonis puuliigiga *Anthocephallus chinensis* (86,39 cm), järgnesid *Albizzia procera* (83,85 cm) ning *Aporosa octandra* (81,85 cm). Suurim viljakultuuride kuivaine produktsioon oli seotud puuliigiga *Anthocephallus chinensis* (1,06 g/taim), järgnesid *Aporosa octandra* (0,83 g/taim) ja *Albizzia procera* (0,81 g/taim). Seega näidati, et puuliikide sobivuse rida kultuuride jaoks on *Anthocephallus chinensis* > *Albizzia procera* > *Aporosa octandra* ja viljakultuuride sobivuse rida puude suhtes on *Glycine max* > *Oryza sativa* > *Brassica campestris*.