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Effects of aqueous leachates of multipurpose trees on test crops

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Abstract. The allelopathic potential of the agroforestry trees *Ficus subincisa* Buch.-Ham. ex J. E. Smith, *Bauhinia purpurea* L., and *Toona hexandra* Wallich ex Roxb. was investigated on *Triticum aestivum* L., *Brassica campestris* L., and *Hordeum vulgare* L. test crops. The leaf and bark leachates of trees were both toxic to the germination of the test crops. The inhibition of the germination of test crops was significant. The effects of leachates on test crops were concentration dependent. So, higher concentrations of leaf and bark leachates showed stimulatory effects on the radicle and plumule growth of all test crops. The acceptance of these multipurpose tree species as agroforestry trees in association with field crops decreased in the order *Ficus subincisa, Bauhinia purpurea,* and *Toona hexandra*.

Key words: multipurpose trees, test crops, germination, radicle growth, plumule growth, leaf leachate, bark leachate.

INTRODUCTION

In traditional agroforestry systems of Garhwal Himalaya, farmers grow along with agricultural crops various multipurpose trees on boundaries between agricultural fields. With the increasing recognition of agroforestry as an alternative land use, many scientists have focused their attention on trees. These trees contribute to sustainability of food production and are essential for the survival of local population (Tripathi et al., 2000, Sachan, 2006). The goal of agroforestry is to maintain sustainable land use by incorporating woody species with agriculturally important crops that can help to decrease soil erosion while providing unique allelopathic benefits to the system. Temporal sequences and tactical spatial arrangements with respect to allelopathic contributions must be carefully considered to encourage both the production of food and sustainability of the land as a resource (Razvi et al., 1999). Agroforestry includes numerous land use systems, ranging from planting of trees on agricultural lands to those in which agriculture is practiced on forestlands without deforestation. *Ficus subincisa*, *Bauhinia purpurea*, and *Toona hexandra* are important multipurpose tree species in the traditional agroforestry system of the Garhwal Himalayan region, India (Bhatt & Verma, 2002). The suitability of these species in agri-silvicultural, silvi-horticultural, and silvi-pastoral practices is discussed in (Sachan, 2006). The phytotoxic substances exuded by agroforestry tree species retard the germination and growth of weed and crop species (Bhatt et al., 1997; Todaria et al., 2005; Singh et al., 2006). Chemicals released by plants might be beneficial or detrimental to the growth of receptor plants (Chou, 1989; Thapaliyal et al., 2007).

Allelopathy plays a significant role under both natural and managed ecosystems (Rice, 1984), mainly by adversely affecting seed germination and seedling growth. Although the research on allelopathy in cropping systems has increased in the last two decades, the allelopathic influences of multipurpose trees on crops in the traditional agroforestry system in Garhwal Himalaya have been little investigated. Hence, the present investigation was undertaken to assess the allelopathic potential of these three promising multipurpose agroforestry tree species on field crops in Garhwal Himalaya, Uttarakhand, India.

MATERIALS AND METHODS

The study was conducted in the experimental garden of the Forestry Department of H.N.B. Garhwal University, Srinagar Garhwal, (Chauras) Uttarakhand (long. 78°48′ E, lat. 30°3′ N, mean height about 530 m above sea level).

Bioassay

The study consisted of three factors: (i) three tree species, viz., *Ficus subincisa* Buch.-Ham. ex J. E. Smith, *Bauhinia purpurea* L., and *Toona hexandra* Wallich ex Roxb., (ii) two leachate types (leaf and bark leachate), and (iii) three test crops (*Triticum aestivum* L., *Brassica campestris* L., and *Hordeum vulgare* L.); local varieties were taken. For bioassay studies, leaf and bark were collected from fully-grown, mature trees of *Ficus subincisa*, *Bauhinia purpurea*, and *Toona hexandra* growing naturally in agroforestry systems.

The sun-dried leaves and bark of trees were ground separately in a mechanical grinder. By adding 1, 2, and 5 g of leaf and bark powder from each species to 100 mL double distilled cold water 1%, 2%, and 5% aqueous leachates were made separately for each component. The leachates were left for 24 h at room temperature (25 ± 2 °C). The resulting leachates were filtered through three layers of Whatman No. 1 filter paper and stored in a dark and cool place in conical flasks. The effect of leachates on seed germination and radicle and plumule growth was tested by placing 100 seeds (five replications of 20 seeds each) of each test crop in petri dishes (9 cm diameter) containing three layers of Whatman No. 1 filter paper saturated with a particular leachate and kept at room temperature. A separate control series was set up using double distilled water. Moisture in the petri dishes was maintained by adding about 1 mL of leachate or distilled water as required. The number of germinated seeds was counted daily for up to 7 days because after this radicles and plumules in petri dishes normally start shrivelling at their tips. To assess the radicle and plumule growth, five seedlings of each leachate treatment in each of the five replicates were randomly measured with the help of a meter scaled in centimetres. All the data collected for germination and radicle and plumule growth were statistically analysed using Duncan's Multiple Range Test (Sharma, 1998).

RESULTS

Germination

The results on the allelopathic effect of leaf and bark (1%, 2%, and 5%) leachates of *Ficus subincisa*, *Bauhinia purpurea*, and *Toona hexandra* on the germination of test crops are shown in Figs 1 and 2. All treatments with both leaf and bark leachates had a negative effect on the germination of all test crops. The inhibition of germination was always the strongest in treatments with 5% extracts (except in *B. campestris* where 2% and 5% leaf leachates of *B. purpurea* and 2% and 5% bark leachates of *F. subincisa* had an almost equal effect).

The negative effect of leaf extracts on the germination of test crops was the strongest in *B. campestris* where treatment with 5% extract of *T. hexandra* reduced germination by 38% with respect to control. The germination of *H. vulgare* was most notably inhibited by the leaf leachates of *T. hexandra* (18.4%) and *B. purpurea* (12.2%).

The 5% bark leachate of *F. subincisa* caused greatest reduction of the germination of *T. aestivum* and *H. vulgare* as compared to control. The inhibitory effect of the bark leachate of *T. hexandra* was the highest (23.0%) on the germination of *T. aestivum*.

Radicle and plumule growth

The radicle and plumule length of test crops were measured and compared with those of control. In radicle and plumule growth both inhibition and stimulation by leaf and bark leachate treatments were observed (Table 1). *Ficus subincisa* 2% leaf leachate inhibited the radicle length in *B. campestris* by 18.4% while 1% leaf leachate of the same species reduced most strongly (26.6%) the plumule length of *T. aestivum*.

The maximum stimulation of the radicle and plumule length (60.8% and 95.2%, respectively) was observed in *B. campestris* treated with 5% leaf leachate of *F. subincisa*. The 2% leaf leachate of *B. purpurea* was toxic for the growth of *B. campestris* while, interestingly, its 5% leachate caused maximum stimulation in the radicle and plumule length (48.7% and 58.1%, respectively) of *B. campestris*. The 2% *T. hexandra* leaf leachate caused maximum reduction in the radicle length of *T. aestivum* (33.9%) and the plumule length of *B. campestris* (58.1%) as compared to control. The 5% leaf leachate of *T. hexandra* stimulated most notably the radicles and plumules length (51.9% and 78.1%) of *B. campestris*.

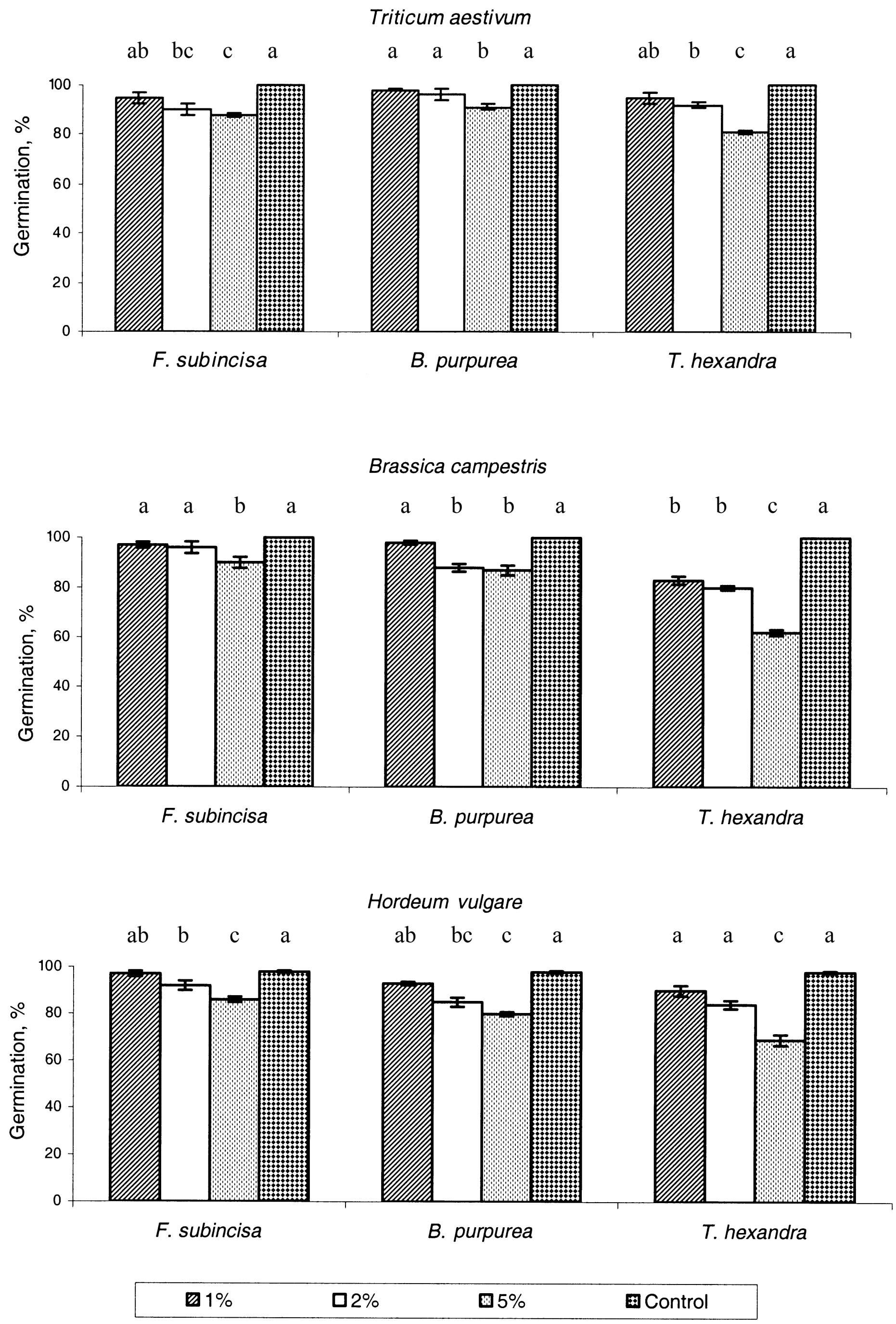

Fig. 1. Effects of tree leaf leachates on the germination of test crops (bars followed by the same letter within treatment are not significantly different at $p < 0.05$).

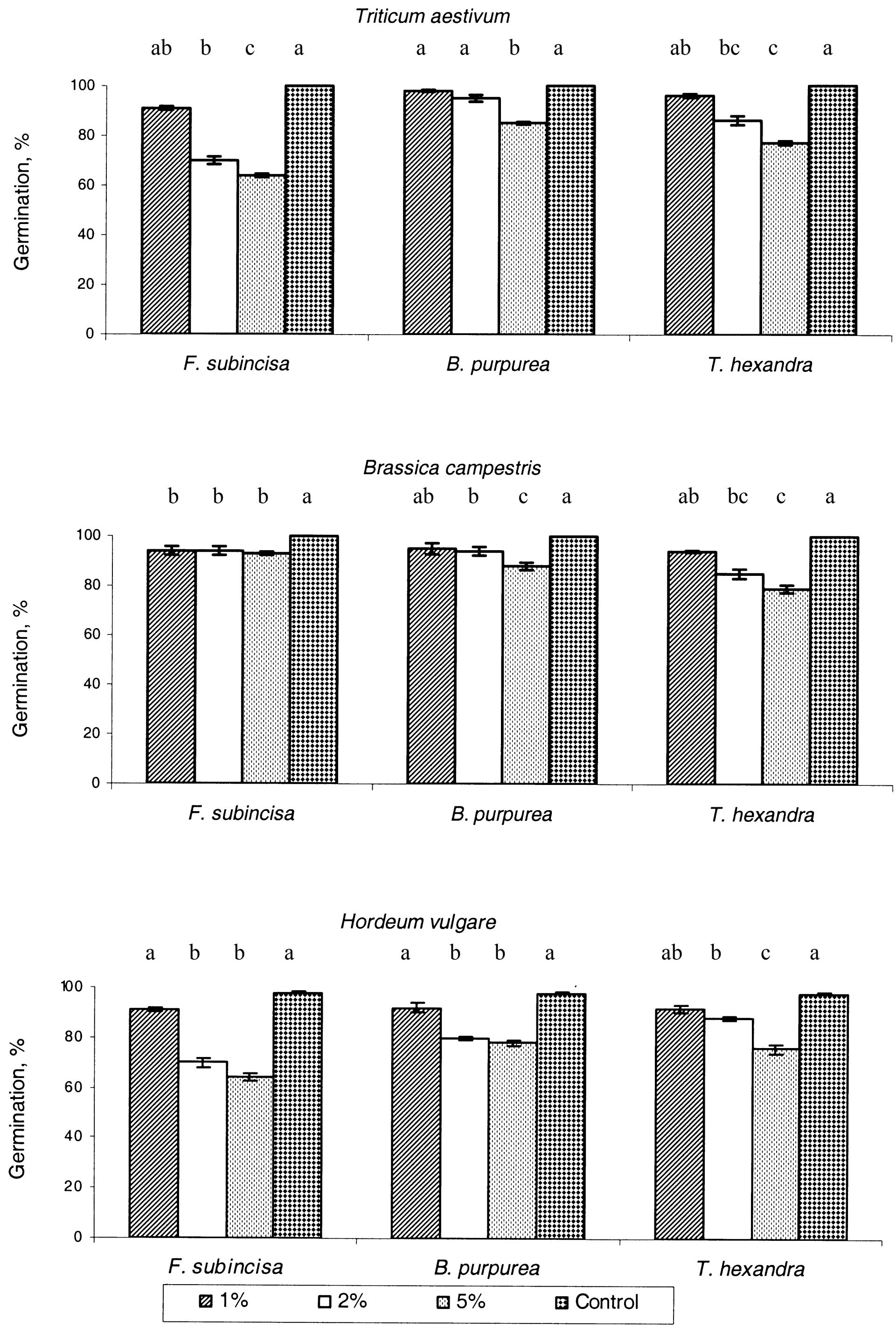

Fig. 2. Effects of tree bark leachates on the germination of test crops (bars followed by the same letter within treatment are not significantly different at $p < 0.05$).

Table 1. The effect of leaf and bark extracts of selected tree species on radicle (cm) and plumule (cm) growth of three food crops

Tree species	Extract	Organ	Leachate level, %			
			0	1	2	5
			Test crop *Triticum aestivum*			
Ficus subincisa	Leaf	Radicle	8.80^{b}	7.45^{b} (–15.3)	7.55^{b} (–14.2)	11.17^{a} (+26.9)
		Plumule	8.40^{ab}	6.17^{c} (–26.6)	6.42^{bc} (–23.6)	10.42^{a} (+24.1)
	Bark	Radicle	8.80^{b}	7.82^{bc} (–11.1)	6.46^{c} (–26.6)	11.40^{a} (+29.6)
		Plumule	8.40^{ab}	6.32^{b} (–24.8)	6.02^{b} (–28.3)	10.37^{a} (+23.5)
Bauhinia purpurea	Leaf	Radicle	8.80^{bc}	10.87^{ab} (+23.5)	7.50^{c} (–1.3)	11.75^{a} (+33.5)
		Plumule	8.40^{bc}	9.72^{ab} (+15.7)	6.17^{c} (–26.6)	10.90^{a} (+29.8)
	Bark	Radicle	8.80^{b}	10.82^{a} (+23.0)	7.52^{b} (–14.6)	11.57^{a} (+31.5)
		Plumule	8.40^{b}	11.05^{ab} (+31.6)	5.72^{c} (–31.9)	11.55^{a} (+37.5)
Toona hexandra	Leaf	Radicle	8.80^{ab}	8.15^{b} (–7.4)	5.82^{c} (–33.9)	10.90^{a} (+23.7)
		Plumule	8.40^{b}	6.60^{bc} (–21.4)	4.72^{c} (–43.8)	11.35^{a} (+35.1)
	Bark	Radicle	8.80^{ab}	6.67^{c} (–24.2)	7.15^{bc} (–18.8)	10.15^{a} (+15.3)
		Plumule	8.40^{ab}	5.60^{c} (–33.3)	6.12^{bc} (–27.1)	10.32^{a} (+22.9)
			Test crop *Brassica campestris*			
Ficus subincisa	Leaf	Radicle	3.70^{b}	3.45^{b} (–6.8)	3.02^{b} (–18.4)	5.95^{a} (+60.8)
		Plumule	3.10^{b}	2.90^{b} (–6.5)	1.00^{c} (–7.7)	6.05^{a} (+95.2)
	Bark	Radicle	3.70^{b}	3.42^{b} (–7.6)	2.95^{b} (–20.3)	5.55^{a} (+56.0)
		Plumule	3.10^{ab}	2.50^{bc} (–19.4)	0.87^{c} (–71.9)	4.87^{a} (+57.1)
Bauhinia purpurea	Leaf	Radicle	3.70^{b}	4.00^{b} (+8.1)	2.97^{b} (–19.7)	5.50^{a} (+48.7)
		Plumule	3.10^{b}	2.37^{b} (–23.6)	1.75^{b} (–43.6)	4.90^{a} (+58.1)
	Bark	Radicle	3.70^{b}	6.70^{a} (+81.0)	3.82^{b} (+3.2)	5.62^{a} (+51.9)
		Plumule	3.10^{bc}	6.30^{a} (+96.8)	2.52^{c} (–18.7)	4.57^{ab} (+47.4)
Toona hexandra	Leaf	Radicle	3.70^{b}	4.80^{b} (+29.7)	2.72^{c} (–26.6)	5.62^{a} (+51.9)
		Plumule	3.10^{bc}	4.07^{ab} (+31.3)	1.30^{c} (–58.1)	5.52^{a} (+78.1)
	Bark	Radicle	3.70^{bc}	4.12^{b} (+11.4)	2.82^{c} (–23.8)	5.22^{a} (+41.1)
		Plumule	3.10^{bc}	3.30^{ab} (+6.5)	1.45^{c} (–53.2)	5.30^{a} (+71.0)
			Test crop *Hordeum vulgare*			
Ficus subincisa	Leaf	Radicle	9.20^{b}	9.20^{b} (–)	7.85^{b} (–14.7)	11.6^{a} (+26.1)
		Plumule	8.90^{ab}	7.47^{bc} (–16.1)	6.72^{c} (–24.5)	10.62^{a} (+19.3)
	Bark	Radicle	9.20^{b}	8.32^{bc} (+9.6)	7.95^{c} (–13.6)	11.42^{a} (+24.1)
		Plumule	8.90^{a}	7.22^{b} (–18.9)	7.12^{b} (–20.0)	6.45^{b} (–27.5)
Bauhinia purpurea	Leaf	Radicle	9.20^{bc}	9.86^{b} (+7.2)	8.25^{c} (–10.3)	11.35^{a} (+23.4)
		Plumule	8.90^{b}	8.27^{b} (–7.1)	7.57^{b} (–14.9)	11.40^{a} (+28.1)
	Bark	Radicle	9.20^{b}	9.07^{b} (–1.4)	8.32^{b} (–9.6)	11.57^{a} (+25.8)
		Plumule	8.90^{b}	7.60^{bc} (–14.6)	6.30^{c} (–29.2)	11.50^{a} (+29.2)
Toona hexandra	Leaf	Radicle	9.20^{ab}	7.77^{c} (–15.5)	8.20^{bc} (–10.9)	10.07^{a} (+9.7)
		Plumule	8.90^{a}	6.57^{b} (–26.2)	6.92^{b} (–22.3)	10.32^{a} (+16.0)
	Bark	Radicle	9.20^{ab}	7.87^{bc} (–14.5)	6.97^{c} (–24.2)	10.00^{a} (+8.7)
		Plumule	8.90^{a}	6.12^{b} (–31.2)	6.30^{b} (–29.2)	10.57^{a} (+18.8)

Values in parentheses indicate percentage stimulation (+) or reduction (–) as compared with controls. Means for radicle and plumule length of a test crop within a row having the same letter indicate non-significant statistical difference between treatments at $p < 0.05$.

Similarly, maximum reduction in the radicle and plumule length was observed in *T. aestivum* (26.6%) and in *B. campestris* (71.9%) in response to bark leachate (2%) of *F. subincisa*. In general, maximum stimulation in radicle and plumule length was observed in *B. campestris* (56.0% and 57.1%) by bark leachate (5%) of *F. subincisa*. The 2% bark leachate of *B. purpurea* caused maximum (14.6% and 31.9%) reduction of radicle and plumule length in *T. aestivum* as compared to control and other treatments. Interestingly, the 1% bark leachate of *B. purpurea* caused maximum (81.0% and 96.8%) stimulation of radicle and plumule length of *B. campestris* as compared to control. The 1% *T. hexandra* bark leachate caused maximum reduction in the radicle length of *T. aestivum* (24.2%) and the plumule length of *B. campestris* reduced by 53.2% in 2% bark leachate of the same species as compared to control. The 5% bark leachate of *T. hexandra* stimulated most strongly the radicle and plumule growth of *B. campestris* (41.1% and 71.0%, respectively).

DISCUSSION

Most published work has revealed that foliage leachates are a potent source of toxic metabolites and their toxic effects are species specific (May & Ash, 1990; Bhatt et al., 1993; Todaria et al., 2005). In our study the acceptability of the trees studied decreased in the order *Ficus subincisa*, *Bauhinia purpurea,* and *Toona hexandra*. Our study revealed that both leaf and bark leachates of the multipurpose tree species tested significantly influenced the germination and radicle and plumule length of test crops. While the effect on germination was always inhibitory, in radicle and plumule growth both inhibition and stimulation were observed. Of the agricultural crops studied *B. campestris* was on average the most resistant to toxic effects of leaf and bark extracts of trees. Negi et al. (2007) reported that leaf and bark extracts of *Ougeinia oojeinensis* are equally toxic to the germination and plumule and radicle growth of *Brassica campestris*, *Hordeum vulgare*, and *Triticum aestivum*. The leaf and bark extracts of *Terminalia bellirica*, *T. chebula*, *Aegle marmelos*, and *Sapindus mukorossi* were also found to significantly inhibit the germination and radicle and plumule growth of test crops. Leaf extracts of these species are more toxic and influence more the germination and radicle growth of test crops as compared to bark extracts (Thapaliyal et al., 2007). Basotra et al. (2005) also reported an inhibitory effect of leachate from leaf and root/tubers of some medicinal plants on the germination and growth of food crops in Garhwal Himalaya. The present investigation shows that the three tree species studied have an allelopathic potential and contain water-soluble substances. Their effect on radicle and plumule length was inhibitory at lower concentrations but stimulatory at higher concentrations. Diverse allelochemicals such as phenolic acids, terpenoides, and alkaloids are leached from plants (Tukey, 1970; Inderjit, 1996; Blum et al., 1999). Gantzer (1960) reported that endogenous phenols possess only stimulatory properties and act as analogues of growth hormones and affect growth and physiological properties of plants. Singh et al. (1980) reported that phenolic treatment of plants increases the grain yield of chickpeas. In the present study, the stimulatory effects of higher concentrations may be due to the presence of phenolics in leachates. Appel (1993) reported that plant phenolics influence nutrient cycling. Different inhibitory or stimulatory effects of various parts of the same plant are likely due to variability in the amount of phytotoxic compounds in different plant tissues (Rice 1974; Nishimura et al., 1982; May & Ash, 1990).

The results of this study reveal that allelopathic influences are (i) species-specific, (ii) have different effects on germination and radicle and plumule growth, and (iii) the toxicity also depends on the concentration of allelochemicals in the medium. On average, the leaf leachate of *T. hexandra* was more toxic to the germination and radicle and plumule growth of *H. vulgare* and both its leaf and bark extracts inhibited *T. aestivum* while the leachate of *F. subincisa* was toxic to the growth of both these crops. The leaf and bark leachates of *B. purpurea* were the least toxic for the growth of the test crops. Among the test crops *B. campestris* was the most resistant and could be grown in association with all the tested tree species with least harmful effects.

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Agrometsanduses kasutatavate puude vesileotiste toime põllukultuuridele

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On uuritud agrometsanduses kasutatavate puude *Ficus subincisa* Buch.-Ham. ex J. E. Smith, *Bauhinia purpurea* L. ja *Toona hexandra* Wallich ex Roxb. allelopaatilist mõju *Triticum aestivum* L., *Brassica campestris* L. ja *Hordeum vulgare* L. seemnete idanemisele ja kasvule. Kõigi uuringus kasutatud puude lehtede ja koore leotised olid toksilised ja inhibeerisid kõigi kolme põllukultuuri seemnete idanemist. Leotiste toime idujuurte ja idupungade kasvule oli sõltuv leotise kontsentratsioonist. 1%- ja 2%-sed lahused pärssisid, suuremad kontsentratsioonid (5%) stimuleerisid idujuurte ja idupungade kasvu. Uuritud mitmeotstarbeliste puuliikide sobivus kasvatamiseks koos katsetes kasutatud põllukultuuridega vähenes järjekorras *Triticum aestivum*, *Brassica campestris*, *Hordeum vulgare*.