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Allelopathic effects of ten tree species on germination and growth of four traditional food crops in Ghana

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Tree species selection to inter-cultivate with food crops has often been made on the basis of traditional knowledge by farmers in Ghana. Lately, Taungya system has been introduced to enable farmers produce food and at the same time retain the forest cover in communities bordering forest reserves. Fresh matured leaves and roots extracts of ten tree species were examined for their allelopathic effects on four agricultural crops to explore the allelopathic potential of the tree species and to recommend the appropriate tree species to be used under the Modified Taungya System in Ghana. Germination of *Hibiscus esculentus* seeds was significantly reduced in all the root and leaf extracts while germination of *Zea mays* seeds increased in all the root extracts except in that of *Terminalia superba*. Roots extract of *Senna siamea* promoted germination of both *Zea mays* and *Lycopersicon esculentum* seeds. Plumule and radicle extension of seedlings of the four crops were significantly reduced by all the root and leaf extracts with the exception of *Zea mays* whose plumule and radicle development was increased by *Eucalyptus grandis* leaf extracts. On the basis of the results obtained in this study the following tree species (*Senna siamea*, *Albizzia lebbeck, and Jatropha curcas*) could be recommended for planting.

Key words: agroforestry system, allelopathy, leaf extracts, root extracts, seed germination, Seedling growth

Introduction

The rapidly increasing population of Ghana has led to changes in the land use system with the aim of increasing agricultural production (IUCN, 1990). Ghana's forest is thus disappearing at an alarming rate with the forest cover reducing from 8.2 to 1.64 million ha between 1900 and 1990. This reduction was due to over exploitation, farming, mining, wild fires and illegal harvesting of timber (Anon, 1992). There was therefore the need for plantation

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establishment to meet the high demand for wood, rehabilitation of degraded lands and to create suitable environment for non-timber forest products. The various plantation schemes that have been adopted to meet this demand for wood include Modified Taungya System, Small-farmer Agroforestry-off-reserve, Employment Focused (HIPC) plantations and private sector-led commercial plantation development.

The Taungya system has been introduced to enable farmers produce food and at the same time retain the forest cover. In this system, trees are established on a plot of land which is being cultivated with annual crops. Through this technology, large areas of government and communal lands can be reforested (Agyeman *et al*., 2003). Several alternatives and improvements to Taungya have been attempted in different places, most of them with the objective of providing better living and social conditions for the tenants. The intention of the Taungya system was to produce a mature crop of commercial timber in a relatively short time, while also addressing the shortage of farmland in communities bordering forest reserves (Agyeman *et al*., 2003).

The Modified Taungya System (MTS) in Ghana was basically introduced to replace the old Taungya System which was abused by farmers. Under this system farmers will carry out most of the labour including pruning, maintenance and receive 40% of the benefit accruing from the MTS. The Forestry Commission (FC) will contribute technical expertise, training, equipment, tools for the farmers to carry out their functions efficiently and will be responsible for stock inventory, marketing of products and take 40% of the products (Agyeman *et al*., 2003). The success of the MTS would largely depend on revenue accrued from the agricultural crops because farmers own 100% of benefits from the crops. The use of tree species that would reduce the yield of the companion crops might not augur well for the acceptability of the MTS.

Land use systems involving trees and crops are complex because both trees and crops appear on the same piece of land, a lot of complex interactions occur between the components. These interactions, among which is allelopathy either promote or inhibit growth and development of the components (El-khatib, 1997). Allelopathy arises from the release of chemicals by one plant species, which may affect other species in its vicinity, usually, to their detriment. The allelochemicals are released by leaching, root exudation, volatilization, residue decomposition and other processes in both natural and agricultural systems (Rice, 1984). Allelochemicals are species specific since different chemicals affect different crops. Earlier findings pointed out that over planting of Eucalyptus trees in South China has brought in many problems to the local eco-environment. Among these problems is decrease in biodiversity, which is reported by its allelopathic effect (Qiu *et al*., 2007). Florentine and Fox

(2001) found that *Eucalyptus victrix* foliage leachates had the greatest inhibitory influence on germination of *Lactuca sativa* and the growth of native species. Qiu *et al*. (2007) examined the allelopathic effect of *Eucalyptus urophylla* on four planted legume species, and found that the seedlings of *Acacia confusa* and *Albizzia falcataria* were remarkably inhibited by 400g leaf weight. A study of *Parthenium hysterophorus* demonstrated that leaf aqueous extracts exhibited significant inhibitory effects on seed germination and seedling growth of all test crops (*Oryza sativa* L., *Zea mays* L., *Triticum aestivum* L., *Raphanus sativus* L., *Brassica campestris* L. and *Brassica oleracea* L.) (Mahajan *et al.*, 2007). El-Khawas and Shehata (2005) reported that the leaf leachates of *Acacia nilotica* inhibited germination and growth of *Zea mays* and *Phaseolus vulgaris.* This differential sensitivity has been observed in the field, greenhouse and laboratory experiments with residues, extracts and purified allelochemicals (Leslie, 1996).

The inhibitory effect of allelochemicals can reduce crop yield and therefore, the intended goal of the Taungya system might not be achieved. Therefore, study was performed to test allelopathetic effects of leaf and root extracts of ten species on germination, plumule and radicle elongation of four agricultural food crops in Modified Taungya System in Ghana.

Material and methods

To identify suitable combinations of trees and crops, fresh, matured leaves and roots of *Senna siamea, Albizia lebbeck*, *Azadirachta indica, Cedrela odorata, Leucaena leucocephala, Gliricidia sepium, Eucalyptus grandis, Terminalia superba* and *Tectona grandis* were collected and dried separately in shade and grounded into powder. Plant material was collected in Bobiri Forest Reserve (lat. 6^{o}40′ and 6^{o}44′ N and long. 1^{o}15′ and 1^{o}22′ W) and the laboratory experiment was carried out at the Forestry Research Institute of Ghana.

Two grams of each of the powdered sample was added to 100ml distilled water and kept for 48 hrs at room temperature (25ºC). The mixture was filtered through crucibles using a pressure pump to obtain 2% aqueous extract. The filtered extract was stored in the dark until used. Petri dishes were lined with two layers of Whatman No.1 filter paper and sterilized. The Petri dishes were saturated with 5 ml of each of the aqueous extracts. Ten seeds each of *Zea mays* (Maize)*, Vigna unguiculata* (Cowpea) and twenty seed each of *Lycopersicon esculentum* (Tomatoes), *Hibiscus esculentus* (Okra) in four replicates were placed in the sterilized Petri dishes in a Randomized Complete Block Design (RCBD) layout. These species are common among the agricultural crops frequently planted under the Modified Taungya system. A separate control series was set up where the seeds were saturated with distilled water. Seeds were considered as germinated when the radicle emerged. Germinated seeds were counted while radicle and plumule lengths were measured and recorded after seven days for maize and okra, five days for cowpea and ten days for tomatoes. Moisture in the Petri dishes was maintained by adding about 1.0 ml of the extracts or distilled water as required to wet the seeds.

Data were statistically analyzed using the Genstat Discovery Edition 2 software. The Analysis of Variance (ANOVA) was used to determine significant differences between the treatments. The treatment means were separated using the Least Significant Difference (LSD) at P = 0.05.

Results and discussion

Effect of root and leaf extracts on germination of seeds

The effect of the 2% root extracts of trees on germination of seeds of *Vigna unguiculata*, *Zea mays*, *Hibiscus esculentus* and *Lycopersicon esculentum* varied (Table 1). All the root extracts of the trees suppressed germination of *Vigna unguiculata*, *Hibiscus esculentus* and *Lycopersicon esculentum* but promoted germination of *Zea mays* (except that of *Terminalia superba)*. Seeds of *H. esculentus* were most sensitive to the root extracts followed by those of *V. unguiculata* and *L. esculentum*. Extracts of *Jatropha curcas* inhibited germination of *H. esculentus* the most (53.3%) followed by the extracts of *Terminalia superba* (46.7%), *Gliricidia sepium* (38.3%) and *Albizia lebbeck* (35.0%).

Table 1. Effect of 2% aqueous root extracts of plants on germination of seeds of four agricultural crops.

Tree Species	Germination (%) of seeds			
	Vigna unguiculata	*Zea mays*	*Hibiscus esculentus*	*Lycopersicon esculentum*
Senna siamea	90.0 (-8.3)	100 (5.0)	73.3 (-21.7)	98.8 (2.5)
Albizia lebbeck	88.3 (-10.0)	97.5 (2.5)	60 (-35.0)	91.3 (-5.0)
Jatropha curcas	90.0 (-8.3)	100 (5.0)	41.7 (-53.3)	86.3 (-10.0)
Azadirachta indica	93.3 (-5.0)	95.0 (0.0)	65.0 (-30.0)	87.5 (-8.8)
Cedrela odorata	96.7 (-1.6)	95.0 (0.0)	65.0 (-30.0)	90.0 (-6.3)
Leucaena leucocephala	93.3 (-5.0)	97.5 (2.5)	61.7 (-33.3)	92.5 (-3.8)
Gliricidia sepium	93.3 (-5.0)	100 (5.0)	56.7 (-38.3)	93.8 (-2.5)
Eucalyptus grandis	76.7 (-21.6)	97.5 (2.5)	65.0 (-30.0)	95.0 (-1.3)
Tectona grandis	90.0 (-8.3)	95.0 (0.0)	63.3 (-31.7)	92.5 (-3.8)
Terminalia superba	91.7 (-6.6)	92.5 (-2.5)	48.3 (-46.7)	95.0 (-1.3)
Control	98.3	95.0	95.0	96.3
LSD (0.05)	0.44	0.14	0.59	0.34

Values in parenthesis indicate the reduction/increment percentage in germination as compared to control.

All the leaf extracts inhibited germination of seeds of *H. esculentus*, the highest being (68.3%) by *Jatropha curcas* and followed by *Senna siamea* and *Gliricidia sepium* (51.7%) and *Albizia lebbeck* (50.0%) (Table 2). Leaves and roots of *J. curcas* are reported to contain hydrogen cyanide (HCN) (Duke, 1993) and this could have accounted for the inhibitory effect observed on germination of *H. esculentus*. Leaf extracts of the other plants affected germination of the seeds variably. The extracts of *S. siamea, Albizia lebbeck, Tectona grandis* had no effect on germination of *Vigna unguiculata*; those of *J. curcas* and *Eucalyptus grandis* had no effect on germination of *Zea mays* and those of *A. lebbeck* and *Leucaena leucocephala* also had no effect on germination of *Lycopersicon esculentum*.

Table 2. Effect of 2% aqueous leaf extracts of plants on germination of seeds of four agricultural crops.

Tree Species	Germination (%) of seeds			
	Vigna unguiculata	***Zea mays***	***Hibiscus esculentus***	***Lycopersicon esculentum***
Senna siamea	98.3 (0.0)	90.0 (-5.0)	43.3 (-51.7)	95.0 (-1.3)
Albizia lebbeck	98.3 (0.0)	97.5 (2.5)	45.0 (-50.0)	96.3 (0.0)
Jatropha curcas	93.3 (-5.0)	95.0 (0.0)	26.7 (-68.3)	93.8 (-2.5)
Azadirachta indica	96.7 (-1.6)	92.5 (-2.5)	51.7 (-43.3)	88.8 (-7.5)
Cedrela odorata	95.0 (-3.3)	92.5 (-2.5)	53.3 (-41.7)	93.8 (-2.5)
Leucaena leucocephala	93.3 (-5.0)	92.5 (-2.5)	56.7 (-38.3)	96.3 (0.0)
Gliricidia sepium	95.0 (-3.3)	100 (5.0)	43.3 (-51.7)	95.0 (-1.3)
Eucalyptus grandis	100 (1.7)	95.0 (0.0)	58.3 (-36.7)	40.0 (-56.3)
Tectona grandis	98.3 (0.0)	92.5 (-2.5)	61.7 (-33.3)	93.8 (-2.5)
Terminalia superba	90.0 (-8.3)	97.5 (2.5)	80.0 (-15.0)	95.0 (-1.3)
Control	98.3	95.0	95.0	96.3
LSD (0.05)	*0.23*	*0.21*	*0.53*	*0.27*

Values in parenthesis indicate the reduction/increment percentage in germination as compared to control

Water soluble leachate from the fresh leaves of *A. lebbeck* has the allelopathic potential that reduced the germination as well as suppressed the growth and development of some agricultural crops (*Brassica juncea*, *Cucumis sativus, Phaseolus mungo*, *Raphanus sativus* and *Vigna unguiculata*) (Uddin, 2007). Leaves of *A. lebbeck* contain 4% tannins and saponnins (Mitchell and Rook, 1979), and these phytochemicals are reported to have inhibitory effect (Swaminathan *et al.*, 1989).

Growth of maize seedlings was significantly depressed by addition of leachates of *Gliricidia* prunings in a laboratory test (Tiang and Khang, 1994). *Gliricidia sepium* leaf leachates inhibited seed germination as well as seedling growth of maize in proportion that was related to the concentration of leachates (Oyun, 2006). Leaves of *G. sepium* are known to contain tannins (Devendra, 1993; Lowry, 1990).

Generally, the root extracts suppressed germination of *Vigna unguiculata* seeds more than the leaf extracts whilst the leaf extracts suppressed germination of *Hisbiscus esculentus* seeds more than the roots extracts. With regard to germination of *Lycopersicon esculent*um seeds, except for the extracts of *Gliricidia sepium* and *E. grandis*, the root extracts were more suppressive than the leaf extracts (Tables 1 and 2).

Reduction in seed germination might be due to the presence of allelochemicals that inhibited the process of seed germination. According to El-Khatib (1997), an indirect association between lower seed germination and allelopathic inhibition may be the consequence of the inhibition of water uptake. Lower seed germination was recorded partly due to the fact that the presence of some allelochemicals in the extracts prevented the growth of seed embryo or caused its death.

Leaf extracts of *Gliricidia sepium, Albizia lebbeck* and *Terminalia superba* however promoted germination of seeds of *Zea mays* by 5%, 2.5%, and 2.5% respectively while that of *Eucalyptus grandis* promoted germination of *Vigna unguiculata* by 1.7%. Increase in germination might have been due to the presence of chemicals in the extracts that stimulated growth of the seed embryo and break the dormancy of the seeds with ease.

Effect of root and leaf extracts on radicle and plumule development

All the root extracts of the plants inhibited radicle and plumule growth of seeds of *Vigna unguiculata* and *Zea mays* (Table 3). They also inhibited radicle and plumule growth of *Hibiscus esculentus* except for the radicle which was promoted by the extracts of *Senna siamea.* All of them except those of *Eucalyptus grandis* and *Teminalia superba* promoted plumule growth of *Lycopersicon esculentum*. Radicle and plumule growth of *Vigna unguiculata* and *Zea mays* were inhibited by all the root extracts of the plants.

All the leaf extracts of the plants suppressed growth of radicle and plumule of *Zea mays* and *Hibiscus esculentus*. Application of leaf leachates of *Jatropha curcas* in the soil significantly inhibited the shoot and root length of marigold compared to no amended soils (Inderjit and Duke, 2003). The extracts of *Eucalyptus grandis* promoted development of *Vigna unguiculata* radicle and plumule whiles that of *Terminalia superba* promoted growth of the radicle only (Table 4). With *Lycopersicon esculentum* all the leaf extracts except that of *Eucalyptus grandis* promoted development of the plumule but suppressed growth of the radical.

Both leaf and root extracts suppressed radicle and plumule development of the germinated seeds with the exception of the plumule of *Lycopersicon esculentum* where the extracts promoted development (Tables 3 and 4).

Einhelling (2002) reported that individual compounds can have multiple phytotoxic effects on a plant. There was a reduction in radicle growth of the germinating seeds because the extracts might have contained allelochemicals that affected the enzymes responsible for plant hormone synthesis, in addition to nutrient and ion absorption by affecting the plasma membrane permeability of the roots (Fujii *et al*., 1991). There is an inhibitory effect on root elongation when the roots come into contact with the extract and for that matter with inhibitory chemicals as described in early works with various crops and weeds (Bhowmik and Doll, 1984; Qasem, 1995).

Table 3. Effect of 2% aqueous root extracts of plants on radicle and plumule growth of four agricultural crops.

Tree Species	Radicle (R) and plumule (P) length extension (cm) in germinated seeds							
	Vigna unguiculata		*Zea mays*		*Hibiscus esculentus*		*Lycopersicon esculentum*	
	R	P	R	P	R	P	R	P
Senna siamea	4.87 (-21.07)	2.54 (-40.65)	12.88 (-14.08)	4.42 (-22.59)	2.88 (12.94)	1.44 (-34.84)	6.75 (-13.68)	6.48 (20.45)
Albizia lebbeck	4.72 (-23.5)	2.82 (-34.11)	13.52 (-9.81)	4.01 (-29.77)	1.99 (-21.96)	1.14 (-48.42)	6.33 (-19.05)	6.16 (14.5)
Jatropha curcas	4.49 (-27.23)	2.16 (-49.53)	13.38 (-10.74)	4.08 (-28.55)	0.76 (-70.20)	1.03 (-53.39)	5.05 (-35.42)	5.81 (7.99)
Azadirachta indica	4.45 (-27.88)	2.64 (-38.32)	11.5 (-23.28)	3.69 (-35.38)	1.81 (-29.02)	1.19 (-46.15)	5.04 (-35.55)	6.33 (17.66)
Cedrela odorata	5.69 (-7.78)	2.14 (-50.0)	10.99 (-26.68)	4.89 (-14.36)	2.03 (-20.39)	1.2 (-45.70)	5.1 (-34.78)	6.2 (15.24)
Leucaena leucocephala	3.61 (-41.49)	1.9 (-55.61)	11.37 (-24.15)	4.31 (-24.52)	1.33 (-47.84)	1.03 (-53.39)	4.58 (-41.43)	6.76 (25.65)
Gliricidia sepium	5.29 (-14.26)	2.39 (-44.16)	11.67 (-22.15)	5.25 (-8.06)	1.51 (-40.78)	0.85 (-61.54)	5.4 (-30.95)	6.42 (19.33)
Eucalyptus grandis	3.75 (-39.22)	1.6 (-62.62)	6.46 (-56.90)	3.38 (-40.81)	1.01 (-60.39)	1.29 (-41.63)	2.86 (-63.43)	3.55 (-34.01)
Tectona grandis	4.83 (-21.72)	2.86 (-33.18)	13.59 (-9.34)	4.39 (-23.12)	1.92 (-24.71)	1.34 (-39.37)	4.67 (-40.28)	6.56 (21.93)
Terminalia superb	5.16 (-16.36)	2.71 (-36.68)	12.6 (-15.94)	3.86 (-32.4)	1.34 (-47.45)	0.83 (-62.44)	2.38 (-69.57)	5.02 (-6.69)
Control	6.17	4.28	14.99	5.71	2.55	2.21	7.82	5.38
LSD(0.05)	0.22	0.12	0.59	0.18	0.15	0.11	0.2	0.17

Values in parenthesis indicate reduction/increment percentage in radicle and plumule growth as compared to control). P = Plumule length and R = Radicle length.

Table 4. Effect of 2% aqueous leaf extracts of plants on radicle and plumule growth of four agricultural crops.

Tree Species	Radicle (R) and plumule (P) length extension (cm) in germinated seeds							
	Vigna unguiculata		*Zea mays*		*Hibiscus esculentus*		*Lycopersicon esculentum*	
	R	P	R	P	R	P	R	P
Senna siamea	1.06 (-82.82)	2.7 (-36.92)	11.64 (-22.35)	3.47 (-39.23)	0.17 (-93.33)	0.26 (-88.24)	2.57 (-67.4)	5.96 (10.78)
Albizia lebbeck	5.11 (-17.18)	3.34 (-21.96)	12.59 (-16.01)	4.18 (-26.8)	0.96 (-62.35)	0.96 (-55.56)	4.66 (-40.41)	6.55 (21.75)
Jatropha curcas	4.43 (28.20)	2.17 (-49.30)	11.21 (-25.22)	4.61 (-19.26)	0.31 (-87.84)	0.37 (-83.26)	5.04 (-35.55)	6.42 (19.33)
Azadirachta indica	4.31 (-30.15)	3.9 (-8.88)	9.07 (-39.49)	2.91 (-49.04)	1.39 (-45.49)	0.95 (-57.01)	4.38 (-43.99)	6.22 (15.61)
Cedrela odorata	5.92 (-4.05)	3.6 (-13.79)	13.45 (-10.27)	4.25 (-25.57)	1.3 (-49.02)	1.2 (-45.70)	3.49 (-55.37)	6.0 (11.52)
Leucaena leucocephala	5.9 (-4.38)	3.39 (-20.79)	11.21 (-25.22)	4.18 (-26.80)	1.08 (-57.65)	1.04 (-52.94)	4.3 (-45.01)	7.26 (34.94)
Gliricidia sepium	5.19 (-15.88)	4.14 (-3.27)	13.8 (-7.94)	4.61 (-19.26)	0.71 (-72.16)	0.63 (-71.49)	4.64 (-40.66)	6.66 (23.79)
Eucalyptus grandis	9.55 (54.78)	4.61 (7.71)	8.49 (-43.36)	2.76 (-51.66)	0.6 (-76.47)	0.64 (-71.04)	1.17 (-85.04)	0.7 (-86.99)
Tectona grandis	6.0 (-2.76)	4.25 (-0.70)	11.94 (-20.35)	3.59 (-37.13)	1.29 (-49.41)	1.14 (-48.42)	5.39 (-31.07)	6.74 (25.28)
Terminalia superb	7.19 (16.53)	3.58 (-16.36)	7.32 (-51.17)	2.88 (-49.56)	1.62 (-36.47)	2.0 (-10.0)	5.0 (-36.06)	5.69 (5.76)
Control	6.17	4.28	14.99	5.71	2.55	2.21	7.82	5.38
LSD (0.05)	0.2	0.11	0.45	0.14	0.1	0.09	0.13	0.14

Values in parenthesis indicate reduction/ increment percentage in radicle and plumule growth as compared to control). P = Plumule length and R = Radicle length.

Leaf extract of *Eucalyptus grandis* inhibited plumule growth of *Lycopersicon esculentum* by 86.9%. With the exception of *E. grandis* leaf extract which promoted plumule growth of *V. unguiculata* all the leaf extracts inhibited its plumule growth. Reduction in plumule growth of the seeds might be a result of the presence of allelochemicals in the extracts that were able to inhibit the synthesis of growth hormones which in turn prevented cell division and differentiation to increase the length of the plumule. The chemicals might have stimulated the production and synthesis of growth hormones such as auxins. Allelochemicals are not only species specific but organ specific (Mahajan *et al*., 2007). Different allelochemicals have different sites of action in a plant. Thus, the sensitivity to allelochemicals and the extent of inhibition varied with species and organs (Mahajan *et al.*, 2007). Kanchan and Jayachandra (1980) observed that leaf extracts had more impact on the radicle growth of crops than root extracts. This implies that inhibitory chemicals had higher concentrations in leaves than in the roots. Macias *et al*. (2004) found higher phytotoxic effects of aqueous extracts from bark than from leaves of *Tectona grandis* on the germination, root and shoot lengths of five species namely *Lepidium sativum, Lactuca sativa*, *Lycopersicum esculentum, Allium cepa* and *Triticum aestivum*. The root length of *Lycopersicum esculentum, Allium cepa* and *Triticum aestivum* was the most affected parameter.

Effect of allelochemicals is also dependent on the concentration of plant extracts. Significant reductions in the germination and growth of the roots and shoots of *Amaranthus rotundus*, *Cirsium arvense*, *Digitaria sanguinalis*, *Sinapis arvensis*, *Lactuca sativa* and *Lolium ultiforum* were observed as the *Azadirachta indica* extract concentration increased (Ashrafi *et al*., 2008).

Seed germination of *Vigna unguiculata* was promoted by leaf extract of *Eucalyptus grandis* but radicle and plumule development were inhibited by root extracts of all the trees. Seed germination of *Zea mays* was promoted by root extracts of all the trees (except that of *Terminalia superb*a) as well as leaf extracts of *Gliricidia sepium, Albizia lebbeck* and *Terminalia superba*. However, the radicle and plumule growth of this crop was suppressed by leaf extracts of all the trees. Seed germination of *Hibiscus esculentus* was suppressed by all the root and leaf extracts of the trees as well as its radicle and plumule development (with the exception of the root extract of *Senna siamea* which promoted its radicle development). Seed germination together with the radicle development of *Lycopersicon esculentum* was suppressed by the root extracts of all the trees whereas plumule development was promoted by the root extract of all the trees (with the exception of those of *Eucalyptus grandis* and *Terminalia superba*). Allelopathy is species specific, however, on the basis of the results obtained in this study the following tree species (*Senna siamea*, *Albizzia lebbeck* and *Jatropha curcas*) could be incorporated with the test crops because it promoted most of the parameters measured.

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