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Response of four agricultural seeds and crops to allelopathic effect of some medicinal plant species in Ghana

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Rural and urban communities in Ghana depend on medicinal plant species for their primary health care. The main source of these medicinal plant species are the forests. However, the country's forest cover is declining at fast rate and there is serious competition for space among medicinal plant species, food crops and housing. The most sustainable way to preserve the medicinal plant species is to integrate them with agricultural crops in agroforestry systems. A laboratory and field research was conducted to determine the allelopathic effect of twelve medicinal plant species on four agricultural crops. Seeds of cowpea(*Vigna unguiculata*), maize (*Zea mays*), okra (*Hibiscus esculentus*) and tomato (*Lycopersicon esculentum*) were germinated in aqueous leaf and/or bark extracts of thirteen medicinal plants. The crops were also grown in soil amended with the various plant extracts in polythene pots. Length and dry weight of the plant shoots and roots were measured after 90 days of sowing. Allelopathic interactions existed between the extracts and the agricultural crops. Okra was most inhibited by the leaf and bark extracts. *Mezeneuron benthamianum* and *Vernonia amygdalina* leaf extracts however, promoted germination of Okra by 6.67% and 5%, respectively. The highest bark extract inhibition in seed germination (48.33%) was on Okraby *Rauvolfia vomitoria*. Bark extracts of *R. vomitoria* and *Trema orientalis* suppressed germination of Cowpea seeds by 41.67% and 30%, respectively. *Baphia nitida* leaf extracts, however promoted radicle and plumule development of maize. Bark extracts of *Voacanga africana* also promoted plumule and radicle development of all the crops with the exception of Okra whose radicle development was inhibited. When the crops were grown in pots maize (root and shoot) was most suppressed by the extracts followed by okra; *Lycopersicon esculentum* was the least suppressed. Dry weight of tomato (root and shoot) was the most inhibited followed by those of cowpea.

Keywords: Medicinal plants, plant extracts, allelopathy, agricultural crops, seeds, Ghana

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Introduction

Medicinal plants have been extremely used worldwide in traditional and modern medicine. Traditional medicine has developed and combined with orthodox medicine in the medical field to cure various human ailments. The use of natural medicinal products in modern medicine as complementary and alternative therapies is on the increase globally (WHO, 2001). In developing countries, the cost of research and development of synthetic drugs is prohibitive and technological facilities as well as expertise are lacking (Muhammad and Awaisu, 2004). More than 80% of the population of Africa use traditional medicine for their primary health care needs (AACHRD, 2000).

In Ghana, 65% of the population, particularly the rural communities are dependent on traditional medicine for their health care delivery. In the Kwahu district of Ghana for every traditional practitioner there are 224 people compared to one university trained medical doctor for nearly 21,000 people (Ojanji, 2010). With the growing popularity of herbal medicines the demand is expected to increase, putting pressure on medicinal plant resources.

Trade in medicinal plants is on the increase in Ghana. Studies carried out on trade in medicinal plants indicated that alongside the predominance of self-administered treatment in rural communities in the Ashanti and Eastern Regions, there were also people who occasionally collected plant medicine for trade (Falconer, 1991). This provides an important supplementary income for poor households at certain periods of the year. From October to December, women collected the fruits of *Piper guineensis*, *Monodora myristica*, *Voacanga africana,* etc. often found in abundance in cocoa farms and forests for sale. The returns per day could range from US $ 0.03 and US $ 4.00 or US $ 0.10 to US $ 0.60 per week. Marketing is done mainly by women who sell the products to traders in the local markets although occasionally traders from Côte d'Ivoire come to purchase large consignments from the villages.

Medicinal plants constitute a source of variable foreign exchange for many developing countries and the global market, for trade in herbs and medicinal plants runs into several billion dollars per annum (WHO, 2003). However, continuous overexploitation, reckless collection by unskilled labour and dwindling of the forest landscape, coupled with the extinction of some known and unknown plant species seek to rob Africa of these valuable sources of foreign income. Over the past 15 years, Ghana has lost roughly 25% of its forest cover leading to a decline in medicinal plant species (Caldwell, 2007). There are about 300,000 medicinal plants in the world, 12,000 of which are in Ghana (Oppong-Boakye, 2005). However, no efforts have so far been made to domesticate these herbs and medicinal plants in Ghana.

There is a serious competition for space among medicinal plant species, food crops and housing. The immediate need for food has often jeopardized the desire for the conservation of the medicinal plant resources, so the scale has often tilted in favour of food crop production. The clearance of the forest for agriculture, increase in urbanization and other economic developments make the need to domesticate this high value forest resource imperative in home gardens (Abbiw, 1990).

In the light of all these, it is important for man to look for ways of satisfying both interests by incorporating food and medicinal plants, possibly on the same piece of land. Before this goal can be realized, one has to understand the relationship between these important natural resources and how they interact with immediate staple food crops in the field. Several interactions exist between plant species, such as parasitism, commensalism, mutualism and allelopathy. Allelopathy refers to the beneficial or harmful effects of one plant on another plant by the release of chemicals from plant parts through leaching, root exudation, volatilization, residue decomposition and other processes in both natural and agricultural systems. It is also considered as the secretion of chemical agents by plants to suppress other plants from development and growth. Some plants will often not grow underneath black walnut trees since these produce juglone, a chemical inhibiting plant respiration (Regiosa *et al*., 2002). This means that certain medicinal plant species will naturally not tolerate the proper growth of food crops close to them or vice versa. Hence, there is need to study the allelopathic behaviour of some medicinal plant species on seeds of four agricultural crops. Assessing the compatibility of medicinal plants with the agricultural crops would justify their use in an agroforestry system.

Materials and methods

Fresh, mature leaves and/or bark of *Alchornea cordifolia, Baphia nitida, Cassia alata, Clerodendron capitatum, Carapa procera, Huslundia opposita, Mezeneuron benthamianum, Newbouldia laevis, Rauvolfia vomitoria, Trichilia monadelpha, Trema orientalis, Vernonia amygdalina and Voacanga africana* were collected. The leaves and barks were dried in shade separately and ground into powder.

Two experiments were carried out to establish the allelopathic potential of the medicinal plants and four agricultural crops. In the laboratory experiment, two grammes each of ground sample was added to 100 ml distilled water and kept for 48 hrs at room temperature (20-30ºC). The mixtures were filtered through crucibles using a pressure pump to obtain 2% aqueous extract. The filtered extracts were 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 3-5 ml of each of the aqueous extracts. Ten to twenty-five seeds of each food crop [(*Zea mays* (Maize), *Vigna unguiculata* (Cowpea), *Lycopersicon esculentum* (Tomato) and *Hibiscus esculentus* (Okra)] (depending on the size of the seed) in four replicates were placed in the sterilized Petri dishes. A separate control series was set up using distilled water. Moisture in the Petri dishes was maintained by adding about 1.0 ml of the extract when required. Germinated seeds were counted and the radicle and plumule lengths measured after seven days for maize and okra, five days for cowpea and ten days for tomatoes.

In the second experiment, Polyethylene pots (15cm diameter, 22cm high) were filled with 250g sieved dry loamy soil (5 mm mesh screen) and ten seeds of the food crops were sown in each pot. The seedlings were thinned after emergence and fivehealthy seedlings were left in each pot. According to Fragasso *et al*. (2012), in a given soil volume containing a finite amount of toxins, plants growing at low density have greater amounts of toxins available per plant for uptake. At high plant densities the toxins is shared among many plants and thus effectively diluted, so a proportionally smaller dose are absorbed by each plant. In order to test for allelopathic potential this study employed five (5) seeds/pot. The pots were watered with stock solution of leaf and bark powder of the medicinal plants mixed with the upper layer of the soil. The control treatment was watered with tap water. There were three replicates for each treatment. All the pots were kept in a net house and watered as and when required to avoid water stress. Growth characteristics (length and dry weight of roots and shoots) for each crop were measured 90days after sowing. The data were statistically analyzed using ANOVA and differences between means under different treatments were separated by Least Significant Differences (LSD) test at 5% significant level.

Results

Effect of leaf and bark extracts on germination of seeds

The effect of the leaf and bark extracts on germination of the seeds were variable. All the leaf extracts inhibited germination of *Vigna unguiculata, Zea mays, Hibiscus esculentus* and *Lycopersicon esculentum* with the exception of *Mezeneuron benthamianum* and *Vernonia amygdalina*. *Mezeneuron benthamianum* and *V. amygdalina* extracts promoted germination of *Hibiscus esculentus* by 6.67% and 5% respectively (Table 1).

The highest inhibition of seed germination (48.33%) was on*Hibiscus esculentus* by *Rauvolfia vomitoria* leaf extract (Table 1) and the least inhibition

(1.67%) was by *Voacanga africana* bark extract on *Vigna unguiculata* (Table 2). With the exception of *Trema orientalis* whose bark extract had no effect on germination of *Zea mays*, all the bark extracts either inhibited or promoted germination of the seeds (Table 2). *Rauvolfia vomitoria* and *Trema orientalis* suppressed germination of *Vigna unguiculata* seeds by 41.67% and 30%, respectively. The bark extract of *Voacanga africana* promoted germination of *Vigna unguiculata* seeds by 1.67%. With the exception of the bark extract of *Trichilia monadelpha* (with 20% inhibition) all the bark extracts had minimal inhibition of *Zea mays* (2.5%-10%) and *Lycopersicon esculentum* (6.25%-16.25%) germination.

Effect of leaf and bark extracts on radicle and plumule development of germinated seeds

The leaf extracts of *Alchornea cordifolia* highly suppressed both radicle and plumule development of *Lycopersicon esculentum* by 82.92% and 84.91%, respectively. All the leaf extracts promoted radicle development of *Vigna unguiculata* with the exception of those of *Carapa procera, Newbouldia laevis, Rauvolfia vomitoria* and *Trichilia monadelpha* which inhibited growth by 27.31%, 2.02%, 11.67% and 4.17%, respectively (Table 3). Radicle development of *Zea mays* was promoted most by *Newbouldia laevis* (90.19%), followed by *Mezeneuron benthamianum* (65.31%) and *Baphia nitida* (50.97%). All the leaf extracts suppressed radicle development of *Hibiscus esculentus* whiles those of *Clerodendron capitatum, Mezeneuron benthamianum* and *Vernonia amygdalina* promoted radicle growth of *Lycopersicon esculentum*.

Effect of leaf extracts on plumule development of crops were also varied (Table 3). *Vernonia amygdalina* promoted plumule development of *Vigna unguiculata* by 67.32%, while *Mezeneuron benthamianum* and *Clerodendron capitatum* promoted its development by 55.46% and 37.83%, respectively. Leaf extracts of *Alchornea cordifolia*, *Carapa procera, Newbouldia laevis, Rauvolfia vomitoria, Trichilia monadelpha* and *Trema orientalis* suppressed plumule development of *Zea mays* while those of *Mezeneuron benthamianum* and *Vernonia amygdalina* promoted plumule development of *Hibiscus esculentus*. Plumule development of *Lycopersicon esculentum* was severely suppressed by leaf extract of *Alchornea cordifolia* (84.91%), followed by extracts of *Baphia nitida* (60.61%) and *Carapa procera* (56.68%).

All the bark extracts inhibited plumule and radicle development of *Vigna unguiculata* with the exception of that of *Voacanga africana* (Table 4). Bark extracts of *Baphia nitida* and *Voacanga africana* promoted radical and plumule development of *Zea mays* whiles the rest of the bark extracts inhibited radicle and plumule development of the crop. Radicle and plumule development of

Hibiscus esculentus was most suppressed by bark extract of *Newbouldia laevis* (70.99% and 65.54% respectively). Bark extract of *Baphia nitida*, *Carapa procera*, *Rauvolfia vomitoria*, *Trichilia monadelpha* suppressed both radicle and plumule growth of *Lycopersicon esculentum* while extracts of *Voacanga africana* promoted their growth.

Effect of leaf extracts on root and shoot growth (elongation) of potted crops

Growth of *Vigna unguiculata* roots was promoted by all the leaf extracts except by those of *Menzeneuron benthamianum* (12.45cm), *Trichilia monadelpha* (13.40cm), *Vernonia amygdalina* (16.85cm) and *Hoslundia opposita* (17.30cm) (Table 5a). The highest promotion was by *Cassia alata* (23.88cm), *Trema orientalis* (22.10cm) and *Clerodendrum capitatum* (21.00cm). Shoot growth of *Vigna unguiculata* was promoted by all the extracts except for those of *Hoslundia opposita* (24.78cm), *Trichilia monadelpha* (27.13cm), *Baphia nitida* (27.50cm) and *Menzeneuron benthamianum* (27.73cm).

All the leaf extracts suppressed root growth of *Zea mays* except that of *Clerodendrum capitatum* (33.7cm). The highest suppression was by *Trema orientalis* (21.63cm) followed by *Carapa procera* (23.45cm). Shoot growth was suppressed by all the leaf extracts except for those of *Baphia nitida* (55.65cm), *Alchornea cordifolia* (55.05cm) and *Menzeneuron benthamianum* (54.45cm). The highest suppression was by *Carapa procera* (35.0) followed by *Clerodendrum capitatum* (41.33cm) and *Hoslundia opposita* (42.28cm).

Growth of *Hibsicusesculentus* roots was suppressed by all extracts except for those of *Trichilia monadelpha* (20.70cm), *Baphia nitida* (18.35cm), *Cassia alata* (17.05cm) and *Menzeneuron benthamianum*.The highest suppression was by *Trema orientalis* (9.78cm) followed by *Carapaprocera* (11.47cm) and *Alchornea cordifolia* (12.80cm). With *Hibiscus esculentus* shoot all the extracts suppressed its growth except for those of *Hoslundia opposita* (23.88cm) and *Cassia alata* (21.95cm).

All the extracts promoted root growth of *Lycopersicon esculentum* except for that of *Baphia nitida* (4.10cm). The highest promotion was by the extracts of *Carapa procera* (19.33cm), *Clerodendrum capitatum* (17.00cm) and *Menzeneuron benthamianum* (15.83cm).Shoot growth was promoted by all the extracts except for that of *Trema orientalis* (8.85cm). The highest promotion was by the extracts of *Cassia alata* (17.90cm) followed by *Clerodendrum capitatum* (17.45cm) and *Menzeneuron benthamianum* (15.83cm).

Effect of bark extracts on root and shoot growth (elongation) of potted crops

All the bark extracts promoted growth of *V. unguiculata* roots except those of *Voacanga africana* (18.13cm) and *Trichilia monadelpha* (18.55cm) (Table 5b). The highest growth promotion was by *Baphia nitida* (22.45cm), *Carapa procera* (21.85cm) and *Newboudia laevis* (20.85cm). Shoot growth was also promoted by all the extracts except by that of *Voacanga africana* (26.38cm). The highest suppression was by *Carapa procera* (38.53cm) followed by those of *Trichilia monadelpha* (34.68cm) and *Baphia nitida* (34.23cm).

Zea mays roots were suppressed by all the extracts, the highest being by those of *Newboudia laevis* (21.80cm), *Carapa procera* (24.45cm) and *Trichilia monadelpha* (24.53cm). Shoot growth was also suppressed by the extracts except for those of *Rauvolfia vomitoria* (59.05cm) and *Voacanga africana* (55.55cm). *Carapa procera* (43.65cm) and *Newboudia laevis* (44.53cm) gave the highest suppression.

Root growth of *H. esculentus* was promoted by extracts of *Carapa procera* (18.83cm), *Rauvolfia vomitoria* (17.33cm) and *Baphia nitida* (16.20cm) while those of *Newboudia laevis* (14.93cm), *Voacanga africana* (15.00cm) and *Trichilia monadelpha* (15.08cm) suppressed it. The shoots were promoted by *Baphia nitida* (25.38cm), *Newboudia laevis* (24.75cm) and *Voacanga africana* (23.18cm) while those of *Carapa procera* (18.30cm), *Trichilia monadelpha* (18.53cm) and *Rauvolfia vomitoria* (19.55cm) suppressed them.

Lycopersicon exculentum roots were promoted by all the extracts except for that of *Rauvolfia vomitoria* (4.13cm). Highest growth promotion was by *Voacanga africana* (13.45cm), *Carapa procera* (9.13cm) and *Baphia nitida* (7.73cm). The shoots were promoted by all the extracts except for that of *Rauvolfia vomitoria* (9.25cm). The highest growth promotions were by *Voacanga africana* (21.30cm), *Trichilia monadelpha* (14.75cm) and *Newboudia laevis* (13.25cm).

Effect of leaf extracts on dry weight of roots and shoots of potted crops

The root weight of *V. unguiculata* was suppressed by all the leaf extracts (Fig. 6a). The highest suppression was by *Hoslundia opposita* (0.26g) followed by those of *Baphia nitida* (0.30g) and *Vernonia amygdalina* (0.30g). Shoot weight of the crop was suppressed most by extracts of *Menzeneuron benthamianum* (0.60g), *Hoslundia opposita* (0.60g) and *Trema orientalis* (0.66g) whilst highest promotion of weight was by *Vernonia amygdalina* (1.47g), *Cassia alata* (1.20g) and *Carapa procera* (1.00g).

For *Zea mays* about half of the extracts suppressed weight of the roots, while about half promoted its weight. The highest suppression was by *Clerodendrum capitatum* (0.50g), *Menzeneuron benthamianum* (0.59g) and *Cassia alata* (0.60g) while highest promotion was by *Vernonia amygdalina* (1.22g), *Hoslundia opposita* (1.00g) and *Carapa procera* (0.88g). The shoot was mostly suppressed by the extracts, the highest suppression being by *Trichilia monadelpha* (0.39g), *Carapa procera* (0.46g) and *Clerodendrum capitatum* (0.53g). The shoot promotion was by extracts of *Menzeneuron benthamianum* (1.10g) and *Vernonia amygdalina* (0.91g).

Root weight of *Hibiscus esculentus* was suppressed by the extract of *Cassia alata* (0.07g) only. The other extracts promoted its weight, the most significant being by the extracts of *Hoslundia opposita* (0.15g), *Trema orientalis* (0.15g) and *Vernonia amygdalina* (0.15g). The weight of the shoot was suppressed by most of the extracts, the highest suppression being by the extract of *Clerodendrum capitatum* (0.15g) followed by those of *Trichilia monadelpha* (0.23g) and *Hoslundia opposita* (0.24g). The highest growth promotion was by the extract of *Vernonia amygdalina* (0.37g) followed by those of *Baphia nitida* (0.34g) and *Menzeneuron benthamianum* (0.32g).

The root weight of *Lycopersicon esculentus* was promoted by all of the extracts except by those of *Trema orientalis* (0.07g), *Cassia alata* (0.07g) and *Alchornea cordifolia* (0.08g). The highest promotion was by *Baphia nitida* (0.21g), *Clerodendrum capitatum* (0.15g) and *Hoslundia opposita* (0.14g). Shoot weight was suppressed by three of the extracts while five promoted its growth. The highest suppression was by the extract of *Trema orientalis* (0.09g) while the highest promotion was by *Clerodendrum capitatum* (0.25g), *Baphia nitida* (0.25g) and *Menzeneuron benthamianum* (0.25g).

Effect of bark extracts on dry weight of roots and shoot of potted crops

All the bark extracts suppressed growth of *V. unguiculata* roots except those of *Carapa procera* (0.49cm) (Table 6b). Root growth suppression was highest by *Voacanga africana* (0.22cm), *Baphia nitida* (0.23cm) and *Rauvolfia vomitoria* (0.29cm). Shoot growth was promoted by all the extracts, the highest being by *Trichilia monadelpha* (1.13cm), *Carapa procera* (1.10cm) and *Voacanga africana* (0.22cm).

Zea mays roots were suppressed by *Carapa procera* (0.63cm), *Voacanga africana* (0.65cm) and *Rauvolfia vomitoria* (0.66cm) and promoted by *Newboudia laevis* (1.21cm), *Baphia nitida* (1.10cm) and *Trichilia monadelpha* (0.72cm). The shoot was suppressed by all the extracts except by *Rauvolfia vomitoria* (0.97cm). Highest suppression was by *Carapa procera* (0.59cm), *Baphia nitida* (0.61cm) and *Newboudia laevis* (0.72cm).

Roots of *Hibiscusexculentus* were promoted by all the extracts, the highest being by *Newboudia laevis* (0.19cm), *Voacanga africana* (0.16cm) and *Trichilia monadelpha* (0.16cm). The shoots were suppressed by *Baphia nitida* (0.21cm), *Newboudia laevis* (0.19cm) and *Carapa procera* (0.11cm) but promoted by *Voacanga africana* (0.45cm), *Trichilia monadelpha* (0.35cm) and *Rauvolfia vomitoria* (0.31cm).

Rauvolfia vomitoria (0.04cm), *Voacanga africana* (0.07cm) and *Trichilia monadelpha* (0.08cm) suppressed root growth of *Lycopersicon exculentum* while *Baphia nitida* (0.13cm), *Carapa procera* (0.10cm) and *Newboudia laevis* promoted it. Shoot growth was promoted by all the extracts, except for those of *Newboudia laevis* (0.11cm) and *Baphia nitida* (0.12cm). The highest promotion was by *Voacanga africana* (0.23cm), *Trichilia monadelpha* (0.23cm) and *Rauvolfia vomitoria* (0.22cm).

Table 1. Effect of 2% aqueous leaf extract of medicinal plants on germination of seeds of four agricultural crops

Tree Species	**Germination (%) of seeds**			
	Vigna unguiculata	*Zea mays*	*Hibiscus esculentus*	*Lycopersicon esculentum*
Alchornea cordifolia	83.33 (-10.0)	87.5 (-7.5)	58.33 (-16.67)	47.5 (-47.5)
Baphia nitida	78.33 (-15.0)	85.0 (-10.0)	40.0 (-35.0)	81.25 (-13.75)
Cassia alata	86.67 (-6.67)	80.0 (-15.0)	48.33 (-26.67)	77.5 (-17.5)
Clerodendron capitatum	83.33 (-10.0)	85.0 (-10.0)	70.0 (-5.0)	92.5 (-2.5)
Carapa procera	78.33 (-15.0)	82.5 (-12.5)	50.0 (-25.0)	87.5 (-7.5)
Hoslundia opposita	75.0 (-18.33)	85.0 (-10.0)	41.67 (-33.33)	91.25 (-3.75)
Mezeneuron benthamianum	86.67 (-6.67)	90.0 (-5.0)	81.67 (6.67)	93.75 (-1.25)
Newbouldia laevis	85.0 (-8.33)	85.0 (-10.0)	63.33 (-11.67)	78.75 (-16.25)
Rauvolfia vomitoria	85.0 (-8.33)	85.0 (-10.0)	26.67 (-48.33)	68.75 (-26.25)
Trichilia monadelpha	83.33 (-10.0)	82.5 (-12.5)	61.67 (-13.33)	90.0 (-5.0)
Trema orientalis	75.0 (-18.33)	80.0 (-15.0)	53.33 (-21.67)	83.75 (-11.25)
Vernonia amygdalina	83.33 (-10.0)	90.0 (-5.0)	80 (5.0)	90.0 (-5.0)
Control	93.33	95.0	75.0	95.0
LSD (0.05)	0.31	0.22	0.42	0.43

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

Table 2. Effect of 2% aqueous bark extract of medicinal plants on germination of seeds of four agricultural crops

Tree Species	**Germination (%) of seeds**			
	Vigna unguiculata	*Zea mays*	*Hibiscus esculentus*	*Lycopersicon esculentum*
Baphia nitida	78.33 (-15.0)	90.0 (-5.0)	48.33 (-26.67)	78.75 (-16.25)
Carapa procera	83.33 (-10.0)	85.0 (-10.0)	63.33 (-11.67)	78.75 (-16.25)
Newbouldia laevis	68.33 (-25.0)	85.0 (-10.0)	41.67 (-33.33)	86.25 (-8.75)
Rauvolfia vomitoria	51.67 (-41.67)	87.5 (-7.5)	66.67 (-8.33)	88.75 (-6.25)
Trichilia monadelpha	76.67 (-16.67)	75.0 (-20.0)	53.33 (-21.67)	73.75 (-21.25)
Trema orientalis	63.33 (-30.0)	95.0 (0.0)	58.33 (-16.67)	85.0 (-10.0)
Voacanga africana	95.0 (1.67)	92.5 (-2.5)	68.33 (-6.67)	86.25 (-8.75)
Control	93.33	95.0	75.0	95.0
LSD (0.05)	0.55	0.30	0.88	0.63

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

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

Tree Species	**Radicle (R) and plumule (P) length extension (cm) in germinated seeds of**							
	Vigna unguiculata		*Zea mays*		*Hibiscus esculentus*		*Lycopersicon esculentum*	
	R	P	R	P	R	P	R	P
Alchornea cordifolia	4.46 (31.17)	1.40 (-41.84)	4.31 (-27.12)	1.86 (-47.76)	1.80 (-39.74)	1.20 (-35.63)	0.64 (-82.92)	1.06 (-84.91)
Baphia nitida	4.82 (41.8)	2.03 (-15.61)	8.92 (50.97)	3.69 (3.65)	1.01 (-66.13)	0.71 (-61.79)	2.08 (-44.61)	2.76 (-60.61)
Cassia alata	5.64 (65.82)	2.11 (-12.14)	7.55 (27.75)	3.59 (0.77)	1.62 (-45.84)	1.09 (-41.70)	2.39 (-36.47)	4.32 (-38.34)
Clerodendron capitatum	4.02 (18.23)	3.31 (37.83)	10.73 (81.60)	4.66 (30.71)	2.00 (-32.81)	1.75 (-6.43)	5.28 (40.65)	6.96 (-0.61)
Carapa procera	2.47 (-27.31)	1.32 (-45.10)	4.30 (-27.28)	2.18 (-38.99)	2.67 (-10.45)	0.96 (-48.39)	2.81 (-25.07)	3.03 (-56.68)
Hoslundia opposita	3.79 (11.36)	1.89 (-21.44)	8.41 (42.22)	3.82 (7.29)	1.30 (-56.46)	0.92 (-50.63)	2.32 (-38.15)	4.30 (-38.57)
Mezeneuron benthamianum	4.21 (23.72)	3.73 (55.46)	9.77 (65.31)	4.1 (15.01)	2.79 (-6.43)	2.98 (59.64)	4.17 (11.15)	6.65 (-4.98)
Newbouldia laevis	3.33 (-2.02)	1.94 (-19.22)	11.24 (90.19)	3.53 (-0.98)	2.42 (-18.73)	1.69 (-9.73)	2.32 (-38.32)	4.24 (-39.46)
Rauvolfia vomitoria	3.0 (-11.67)	1.81 (-24.70)	8.52 (44.16)	3.39 (-4.91)	1.14 (-61.77)	0.81 (-56.43)	2.88 (-23.40)	3.71 (-46.95)
Trichilia monadelpha	3.26 (-4.17)	2.15 (-10.27)	5.41 (-8.42)	3.5 (-1.68)	2.34 (-21.63)	1.51 (-19.11)	2.34 (-37.82)	3.76 (-46.23)
Trema orientalis	4.49 (31.9)	1.60 (-33.24)	5.10 (-14.09)	2.81 (-21.11)	0.96 (-67.80)	0.64 (-65.54)	2.08 (-44.67)	4.11 (-41.34)
Vernonia amygdalina	3.53 (3.91)	4.02 (67.32)	8.56 (44.88)	4.46 (25.04)	2.28 (-23.70)	2.52 (34.82)	4.68 (24.53)	7.17 (2.45)
Control	3.4	2.4	5.91	3.57	2.98	1.87	3.76	7
LSD (0.05)	0.23	0.11	0.41	0.14	0.14	0.10	0.12	0.16

*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 bark extract of plants on radicle and plumule growth of germinated seeds 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
Baphia nitida	1.90 (-44.22)	1.58 (-34.42)	6.26 (5.92)	3.66 (2.60)	1.05 (-64.95)	1.23 (-34.29)	2.03 (-45.84)	4.7 (-32.86)
Carapa procera	2.35 (-30.99)	1.80 (-25.05)	4.81 (-18.57)	2.76 (-22.51)	2.29 (-23.37)	1.57 (-15.98)	3.72 (-0.90)	4.13 (-40.95)
Newbouldia laevis	1.14 (-66.42)	1.10 (-54.27)	4.78 (-19.08)	1.51 (-57.57)	0.87 (-70.99)	0.64 (-65.54)	3.82 (1.60)	3.77 (-45.91)
Rauvolfia vomitoria	0.71 (-79.22)	0.58 (-75.71)	5.90 (-0.17)	2.21 (-38.08)	2.20 (-26.10)	1.01 (-45.71)	1.79 (-52.33)	3.90 (-44.25)
Trichilia monadelpha	1.19 (-65.10)	1.42 (-41.01)	4.64 (-21.49)	2.19 (-38.50)	1.11 (-62.77)	1.00 (-46.70)	2.26 (-39.78)	3.11 (-55.63)
Trema orientalis	1.81 (-46.8)	0.94 (-61.07)	3.14 (-46.91)	2.35 (-34.15)	2.03 (-31.81)	1.04 (-44.55)	4.37 (16.44)	5.32 (-24.02)
Voacanga africana	4.88 (43.52)	3.74 (55.73)	7.22 (22.08)	4.40 (23.28)	1.91 (-36.05)	2.68 (43.30)	4.24 (12.85)	7.16 (2.25)
Control	3.4	2.4	5.91	3.57	2.98	1.87	3.76	7.0
LSD(0.05) =	0.20	0.11	0.48	0.27	0.23	0.22	0.37	0.37

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

Table 5a. Effect of leaf stock extracts of medicinal plants on root and shoot growth of four agriculturalpotted crops

Tree Species	Root (R) and Shoot (S) length (cm) of four agricultural crops							
	Vigna unguiculata		*Zea mays*		*Hibiscus esculentus*		*Lycopersicon esculentum*	
	R	S	R	S	R	S	R	S
Carapa procera	19.63± 2.54b	29.55± 3.76a	23.45± 3.05b	35.0 ± 1.95b	11.47± 0.71b	18.42± 1.62a	19.33± 2.93a	15.08± 1.90a
Mezeneuron benthamianum	12.45± 0.76b	27.73± 4.47a	26.25± 2.60b	54.45± 8.83a	16.58± 0.27b	18.33± 0.89a	12.48± 0.62a	15.83± 1.74a
Clerodendrum capitatum	21.00± 2.19b	29.35± 2.77a	33.7± 2.83b	41.33± 3.88a	15.73± 1.00a	18.28± 1.22a	17.00± 4.44a	17.45± 1.25b
Hoslundia opposita	17.30± 1.55b	24.78± 1.79a	24.85± 4.15b	42.28± 3.29b	13.75± 1.08a	23.88± 0.10b	11.73± 1.49a	15.70± 2.04a
Cassia alata	23.88± 3.45b	36.75± 7.68a	25.08± 1.74b	48.55± 3.02b	17.05± 2.33a	21.95± 1.19a	10.20± 2.63a	17.90± 2.46a
Trema orientalis	22.10± 2.96b	29.88± 1.56b	21.63± 4.34b	43.40± 3.94a	9.78± 0.86b	21.25± 0.57a	9.85± 0.57a	8.85± 0.48b
Vernonia amygdalina	16.85± 0.89b	33.38± 3.68a	28.1± 4.03b	50.05± 3.25b	15.68± 2.30a	22.78± 0.53a	8.00± 1.15a	14.75± 0.82b
Baphia nitida	20.0± 3.23b	27.50± 1.46b	27.5± 6.68a	55.65± 5.88a	18.35± 1.44a	21.28± 0.69a	4.10± 0.40a	12.78± 1.49a
Alchornea cordifolia	20.70± 1.77b	29.98± 3.34a	28.75± 7.10a	55.05± 4.41a	12.80± 0.60b	13.18± 0.23b	8.60± 0.56a	13.05± 2.48a
Trichilia monadelpha	13.40± 2.99b	27.13± 1.43b	27.1± 4.20b	49.2± 3.05b	20.70± 2.80a	16.13± 0.77a	6.53± 1.49a	10.80± 1.00b
Control (Tap water)	19.10± 3.60b	29.05± 1.61a	32.88± 4.81a	53.83± 3.78b	15.93± 0.98a	21.95± 0.43a	4.70± 0.35a	10.45± 1.41b
LSD(0.05)	1.48	1.40	1.52	1.39	1.42	1.34	2.36	1.53

Table 5b. Effect of bark stock extracts of medicinal plants on root and shoot growth of four agricultural potted crops

Tree Species	Root (R) and Shoot (S) length (cm) of four agricultural crops							
	Vigna unguiculata		*Zea mays*		*Hibiscus esculentus*		*Lycopersicon esculentum*	
	R	S	R	S	R	S	R	S
Carapa procera	21.85± 1.33b	38.53± 5.45a	24.45± 2.82b	43.65± 5.85a	18.83± 0.61b	18.3± 1.24a	9.13± 1.10a	12.35± 0.23b
Voacanga africana	18.13± 2.14b	26.38± 2.46a	29.43± 2.33b	55.55± 5.76a	15.0± 1.91a	23.18± 0.85a	13.45± 4.29a	21.30± 0.43b
Newboudia laevis	20.85± 3.07b	30.10± 0.52b	21.8± 3.43b	44.53± 6.56a	14.93± 1.61a	24.75± 0.27b	7.18± 1.93a	13.25± 1.10b
Baphia nitida	22.45± 5.19a	34.23± 1.81a	27.35± 5.79a	47.88± 1.87b	16.20± 1.08a	25.38± 1.06a	7.73± 0.70a	11.15± 1.25b
Trichilia monadelpha	18.55± 3.06b	34.68± 1.98a	24.53± 5.97a	52.5± 5.80a	15.08± 1.96a	18.53± 1.10a	6.68± 0.89a	14.75± 2.86a
Rauvolfia vomitoria	20.33± 2.43b	29.85± 2.26a	28.28± 2.26b	59.03± 4.47a	17.33± 1.77a	19.55± 0.84a	4.13± 0.40a	9.25± 0.62b
Control (Tap water)	19.10± 3.60b	29.05± 1.61a	32.88± 4.81a	53.83± 3.78b	15.93± 0.98a	21.95± 0.43a	4.70± 0.35a	10.45± 1.41b
LSD(0.05)	1.48	1.40	1.52	1.39	1.42	1.34	2.36	1.53

Table 6a. Effect of leaf stock extracts of medicinal plants on dry weight of root and shoot growth of four agricultural potted crops

Tree Species	Root(R) and Shoot (S) weight (g) in growth of four agricultural crops							
	Vigna unguiculata		*Zea mays*		*Hibiscus esculentus*		*Lycopersicon esculentum*	
	R	S	R	S	R	S	R	S
Carapa procera	0.32± 2.48a	1.00± 2.60a	0.88± 2.48a	0.46± 2.39b	0.11± 1.35b	0.25± 1.25b	0.12± 2.71a	0.14± 2.69a
Mezeneuron benthamianum	0.36± 1.44a	0.60± 2.36a	0.59± 2.36b	1.10± 2.73a	0.11± 1.90b	0.32± 1.72b	0.10± 2.73a	0.25± 2.56a
Clerodendrum capitatum	0.33± 2.48a	0.91± 2.50a	0.50± 2.38a	0.53± 2.37b	0.14± 2.68b	0.15± 2.67a	0.15± 2.67a	0.25± 2.55a
Hoslundia opposita	0.26± 1.50a	0.60± 2.36a	1.00± 2.58a	0.62± 2.36b	0.15± 2.67b	0.24± 2.56a	0.14± 2.69a	0.23± 2.58a
Cassia alata	0.33± 2.48a	1.20± 2.87a	0.60± 2.36b	0.66± 2.36b	0.07± 1.94b	0.28± 1.75b	0.07± 2.78a	0.13± 2.70a
Trema orientalis	0.39± 2.43a	0.66± 2.36b	0.67± 2.36a	0.64± 2.36b	0.15± 1.59b	0.50± 1.38b	0.07± 1.67b	0.09± 2.75a
Vernonia amygdalina	0.30± 1.48a	1.47± 1.85a	1.22± 1.93b	0.91± 1.67b	0.15± 1.86b	0.37± 1.69b	0.10± 2.74a	0.19± 2.62a
Baphia nitida	0.30± 1.48a	0.79± 1.36a	0.71± 2.74a	0.84± 2.45b	0.11± 1.90b	0.34± 1.71b	0.21± 1.54b	0.25± 1.51b
Alchornea cordifolia	0.31± 2.50a	0.73± 2.38a	0.68± 2.37a	0.74± 2.39b	0.14± 1.87b	0.25± 1.77b	0.08± 2.77a	0.14± 2.69a
Trichilia monadelpha	0.34± 0.94b	0.90± 0.84b	0.65± 2.36b	0.39± 2.43b	0.12± 1.89b	0.23± 1.79b	0.10± 2.73a	0.13± 2.70a
Control (Tap water)	0.45± 1.14	0.76± 1.09	0.67± 2.37	0.89± 2.49	0.09± 2.75	0.30± 2.50	0.09± 1.93	0.14± 1.87
LSD(0.05)	1.48	1.40	1.52	1.39	1.42	1.34	2.36	1.53

Table 6b. Effect of bark stock extracts of medicinal plants on dry weight of root and shoot growth offour agricultural potted crops

Tree Species	Root(R) and Shoot (S) weight (g) in growth of four agricultural crops							
	Vigna unguiculata		*Zea mays*		*Hibiscus esculentus*		*Lycopersicon esculentum*	
	R	S	R	S	R	S	R	S
Carapa procera	0.49± 2.38a	1.10± 2.70a	0.63± 2.36b	0.59± 2.36b	0.11± 1.90b	0.28± 1.75b	0.10± 1.91b	0.16± 1.85b
Voacanga Africana	0.22± 2.58a	1.02± 2.62a	0.65± 2.36b	0.74± 2.39b	0.16± 1.58b	0.45± 1.40b	0.07± 2.78a	0.23± 2.57a
Newboudia laevis	0.33± 1.71a	0.84± 1.64b	1.21± 1.92b	0.72± 1.61b	0.19± 2.62b	0.27± 2.53a	0.15± 2.67a	0.11± 2.72a
Baphia nitida	0.23± 2.58a	0.84± 2.44a	1.10± 2.72a	0.61± 2.35b	0.11± 2.72b	0.21± 2.59a	0.13± 2.70a	0.12± 2.71a
Trichilia monadelpha	0.34± 1.70a	1.13± 1.84a	0.72± 2.38a	0.73± 2.38b	0.16± 1.86b	0.35± 1.70b	0.08± 1.93a	0.23± 1.79b
Rauvolfia vomitoria	0.29± 2.51a	0.85± 2.45a	0.66± 2.36b	0.97± 2.56a	0.15± 1.86b	0.31± 1.73b	0.04± 1.69b	0.22± 1.53b
Control (Tap water)	0.45± 1.14	0.76± 1.09	0.67± 2.37	0.89± 2.49	0.09± 2.75	0.30± 2.50	0.09± 1.93	0.14± 1.87
LSD(0.05)	1.48	1.40	1.52	1.39	1.42	1.34	2.36	1.53

Discussions

Generally, all the agricultural crops were found sensitive to the aqueous leaf and bark extracts of the medicinal plants because there were significant differences in terms of the seed germination, plumule and radical development.

Effects of leaf and bark extracts on germination of seeds

All the leaf extracts except those of *Mezeneuron benthamianum* and *Vernonia amygdalina* inhibited germination of *Vigna unguiculata, Zea mays*, *Lycopersicon esculentum* and *Hibiscus esculentus* seeds. All the bark extracts inhibited germination of the seeds with the exception of those of *Voacanga africana* which promoted germination of *Vigna unguiculata* by 1.67% and *Trema orientalis* which had no effect on germination of *Zea mays*. Reduction in germination of seeds might be due to the presence of some allelochemicals in the extracts that caused death of the seed embryo and therefore prevented germination. El-Khatib (1997) noted that addition of aqueous extracts of the medicinal plant species *Rheum emodi*, *Saussuarea lappa* and *Potentilla fugens* strongly affected germination efficiency and growth characters of all food crops. Inhibition in germination might also be partly due to inability of the seeds to absorb water to help break their dormancy. An indirect association between low seed germination and allelopathic inhibition may be the consequences of the inhibition of water uptake in seeds.

Mezeneuron benthamianum and *Vernonia amygdalina* leaf extracts promoted germination of *Hibiscusesculentus* while *Voacanga africana* bark extracts increased germination percentage of *Vigna unguiculata* seeds. Promotion in germination might have been due to the presence of chemicals in the extracts that facilitate the breaking of seed dormancy. Ferguson and Rathinasabapath (2003) said allelopathy refers to the beneficial or harmful effects of one plant on another plant or weed species, by the release of chemicals from the plant parts through leaching, root exudation, volatization, residue decomposition and other processes in both natural and agricultural systems. Germination of *Hibiscusesculentus* seeds was the most inhibited by almost all the extracts whiles *Lycopersicon esculentum* was most suppressed by *Alchornea cordifolia* leaf extracs. Effect of the extracts on crops varied because allelochemicals are specific. Report by Tahir *et al.* (2007) on allelopathic behaviour did indicate that *Rheum emodi* was found allelopathically less effective compared to *Saussuarea lappa* and *Potentilla fugens* on *Triticum aestivum, Eleusine coracana, Fagopyrum esculantum, Amarathus caudatus, Phaseolus mungo* and *Phaseolus vulgaris* crops.

Effect of leaf and bark extracts on radicle and plumule development

All the leaf extracts inhibited both radicle and plumule development of *Hibiscus esculentus* except those of *Mezeneuron benthamianum* and *Vernonia amygdalina* which promoted its plumule development. *Newbouldia laevis, Rauvolfia vomitoria* and *Trichilia monadelpha* suppressed radicle and plumule growth of *Vigna unguiculata*. *Alchornea cordifolia, Carapa procera, Trichilia monadelpha* and *Trema orientalis* also inhibited plumule and radical development of *Zea mays*. All the leaf extracts inhibited plumule development of *Lycopersicon esculentum* with the exception of those of *Vernonia amygdalina*. All the bark extracts inhibited radicle and/or plumule development of *Vigna unguiculata*, *Abelmoschus esculentus* and *Lycopersicon esculentum* with the exception of the *Voacanga africana* extract. *Carapa procera, Newbouldia laevis, Rauvolfia vomitoria, Trichilia monadelpha* and *Trema orientalis* leaf extracts suppressed plumule and radicle development of *Zea mays*.

Suppression in growth might have been due to the presence of chemicals in the extracts that exhibited various levels of inhibition. Fujii *et al*. (1991) confirmed that extracts of many plant species including medicinal herbs contain allelochemicals which affect enzymes responsible for plant hormone synthesis in addition to inhibition of nutrient and ion absorption by affecting plasma membrane permeability.

Clerodendron capitatum, Mezeneuron benthamianum and *Vernonia amygdalina* leaf extracts promoted radicle and plumule development of both *Vigna unguiculata* and *Zea mays*. Development of *Lycopersicon esculentum* was promoted by *Vernonia amygdalina* leaf extract. *Voacanga africana* bark extract also promoted radicle and plumule development of *Vigna unguiculata, Zea mays* and *Lycopersicon esculentum*. Promotion in growth might have been due to the presence of allelochemicals which facilitated the synthesis of plant hormones for growth.

Effect of medicinal plant extracts on roots and shoots of potted crops

It is difficult to separate allelopathy and resource competition under field conditions, and therefore there is the need for a laboratory screening system that is reliable, rapid, cheap and space-limiting (Fragasso *et al*., 2012). The majority of conventional methods used in studying plant-plant interactions do not involve soil or artificial soil substrate (Fragasso *et al*., 2012). These methodologies have led to the isolation of a number of phytotoxins that are secreted by invasive plants. However, the full complexity of interactions that occur in the natural rhizosphere is eliminated in such a system, and so the obtained results should be analyzed with caution (Fragasso *et al*., 2012).

Studies concluded without using soil might not reproduce the conditions that are needed for the expression of such allelochemicals in nature (Inderjit and Callaway, 2003). In the laboratory experiment conducted, *Carapa procera, Newbouldia laevis, Rauvolfia vomitoria* and *Trichilia monadelpha* inhibited growth of *Vigna unguiculata*. When a comparison was made with the field experiment it was realized that only *Trichilia monadelpha* suppressed growth of *Vigna unguiculata*. Under field conditions it would not be advisable to grow *Vigna unguiculata* with *Trichilia monadelpha* in an agroforestry system. Under *Hibiscusesculentus*, it was realized that all the medicinal plants suppressed its growth. Field studies identified seven medicinal plants that suppressed growth of *Hibiscus esculentus*. These include *Trichilia monadelpha, Vernonia amygdalina,Newbouldia laevis, Voacanga africana,Alchornea cordifolia, Trema orientalis* and *Carapaprocera*. A further analysis showed that even though *Trichilia monadelpha, Vernonia amygdalina,Newbouldia laevis* and *Voacanga Africana* suppressed growth of *Abelmoschus esculentus* it did not differ significantly from the control. However, *Alchornea cordifolia, Trema orientalis* and *Carapa procera* did significantly suppress growth. Thus *Alchornea cordifolia, Trema orientalis* and *Carapa procera* have inhibitory properties that suppress growth of *Hibiscus esculentus*. The suppression of growth under natural conditions confirms the allelopathic effects of these medicinal plants as stipulated by Inderjit and Callaway (2003). Also, in the field experiment only the bark extract of *Rauvolfia vomitoria* suppressed both roots and shoots of *Lycopersicon esculentus*. In the case of *Zea mays*, *Trichilia monadelpha*, *Vernonia amygdalina, Carapa procera, Cassia alata and Hoslundia opposita* and *Cassia alata* were identified to have allelopathic effect. This suggested the potential to these species to have allelochemicals that could suppress growth of *Zea mays*.

Conclusion

The effect of the plant extracts on germination of crop seeds, development of radicle and plumule, as well as root and shoot growth and weight was found to have varied actions on crops. All extracts with the exception of the bark extract of *Trema orientalis* on *Zea mays*, leaf extract of *Trema orientalis* on *Vigna unguiculata* shoot, *Carapa procera* and *Alchornea cordifolia* leaf extracts on *Lycopersicon esculentum* shoots suppressed or promoted germination and/or development of the crops. *Baphia nitida* extracts promoted radicle and plumule development of *Zea mays*. Bark extracts of *Voacanga africana* promoted growth of all the crops with the exception of *Hibiscusesculentus* whose radicle development was inhibited by the extract.

With regard to *Hibiscus esculentus*, it was realized from the laboratory studies that all the medicinal plants suppressed its growth; however, field studies identified *Alchornea cordifolia*, *Trema orientalis* and *Carapa procera* to suppress growth. Thus *Alchornea cordifolia*, *Trema orientalis* and *Carapaprocera* have inhibitory properties and should not be grown with *Hibiscus esculentus*. *Trichilia monadelpha*, *Vernonia amygdalina*, *Carapaprocera, Cassia alata and Hoslundia opposita* were identified as medicinal plants that inhibited growth of *Zea mays*. Suppression in the development of the crops indicates that cultivating them on the same piece of land may result in low productivity. It will be of importance to carry out further laboratory and field research to examine effect of different concentrations of the extracts on crops.

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