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Allelopathic and shading effects of *Mangifera indica* L. on germination and early growth performance of associated crops

Aman Abeje*, Agena Anjulo and Rajesh Chauhan

[1]Departement of Forestry, Aman Abeje-College of Agricultural Sciences, Arba Minch University, Ethiopia.
[2]Agena Anjulo-Ethiopian Environment and Forest Research Institute, Ethiopia.
[3]Department of Forestry, Rajesh Chauhan-College of Agricultural Scinces, Arba Minch University, Ethiopia.

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Mango (*Mangifera indica* L.) is widely grown as an agroforestry tree in different parts of the world especially in Ethiopia. However, its dense canopy and expected allelopathic effect make it very difficult to survive for many of the associated crops grown under it. Therefore, current study was undertaken with the main objective to investigate the allelopathic and shading effects of mango on the germination and early growth performance of food crops and medicinal plants. Leaf extract of mango was tested to find out its inhibitory or stimulatory effect on maize, pea nut and haricot bean with varying concentration of extracts (0, 10, 15 and 20%) at lab and pot study. Results of the study witnessed the inhibitory effects of its extract on germination and early growth performance of cereal and pulse crops for most of the parameters studied. However, severity of inhibition was more pronounced with increase in concentration of the extract. Similarly, shading intensity of mango tree on two Hibiscus varieties WG-H Jamaica and WG-S were tested at a certain canopy distances (1/3rd, 1/2 and at tree periphery) from the bole of mango tree. Results reflect the increase in growth performance of both the varieties with increase in canopy distances from the bole of the tree probably due to better transmission of light. It is recommended that Hibiscus varieties should not be planted at the very closest distance from the mango trees stem due to allelopathic and shading effects, respectively.

Key words: Allelopathic, bioassay, inhibition, leaf extract, *Mangifera indica,* shading effect.

INTRODUCTION

Agroforestry is an integrated approach to land use that is characterized by deliberate maintenance of trees and other woody perennials in crop fields and pastures (Bargali et al., 2004, 2009; Parihaar et al., 2015; Karki et al., 2021) and known as one of the best traditional practices for livelihood, suitable land management and sustainable development (Kittur and Bargali, 2013; Parihaar et al., 2014). To maintain the sustainable agricultural production system and to alleviate forest deprivation, it is essential to systematically understand the intensive farming arrangement. Garrity (2004) defined it is an alternative land management system which addresses many of the global challenges, including deforestation, unsustainable cropping practices, loss of

*Corresponding author. E-mail: amanabeje1@gmail.com

biodiversity, increased risk of climate change, as well as rising hunger, poverty and malnutrition, which have been highlighted by the United Nations Millennium Development Goals (MDGs). It is a more diverse and sustainable system with range of products and services that it offer to its adopter. Thus, agroforestry is an integrated science that helps in bridging the gap between the need for conservation and meeting people's demand at the same time.

Agroforestry possess huge potential to be climate and livelihood smart practices (Verchot et al., 2007) but its associated issues that are there still remain to be solved. It include tree-crop competition for resources, allelopathic effects of trees on crops, rapid growth of some tree species within agricultural fields occupying the space of crops, entry of invasive species in the agricultural land and trees serving as habitat for harmful pests and diseases. Among these challenges allelopathy and tree crop competition is widely debated issue among researchers all over the world. These issues are interlinked with tree crop interaction which may be complementary (+ve), supplementary (neutral) or competitive (-ve) (Khatri et al., 2022a, b). Thus allelopathy is the result of tree crop interaction and is considered as biological phenomenon in which an organism produces biochemical that influences the growth, survival, and reproduction of other organisms (Khatri et al., 2022c). Whole organs of the woody plant may be source of allelopathy (Weir et al., 2004) but leaves are the most consistent source of allelopathic substances and produced the greatest allelopathic effects on target species (Dorning and Cipollini, 2006; Tanveer et al., 2010). Mango (*Mangifera indica*) is one of the major tropical evergreen economic fruit trees and serves as a component of agroforestry practices like agri-horticulture and agri-horti-silviculture (Karki et al., 2022). It is a multipurpose tree in addition to fruit, the tree is also known for its medicinal (Shah et al., 2010), antioxidant properties (Ajila et al., 2007), anti-inflammatory (Garrido et al., 2004), anti-allergic, anthelmintic (Garcia et al., 2003), antiviral (Makare et al., 2001), anti-fungal, and antibacterial properties (Kanwal et al., 2010). However, allelopathic potential of mango required to be studied as few reports are available in the literature about the allelopathic potential of mango. Some of these studies include Yang et al. (2006), El-Rokiek et al. (2010) and Ashafa et al. (2012).

Mango produce compound like Mangiferin (a polyphenolic antioxidant) and a glucosyl xanthone which has major bioactive components isomangiferin, tannins and gallic acid derivatives which are identified as phenolic components that can inhibit weed growth. Mango leaves are reported to contain 43 to 46.7% zeaxanthin acid (C40 H_{56} O_2) and also some euxanthon ($C_{13}H_8O_4$), hippuric acid and benzoic acids and 4% mangin (Bhatt and Todaria, 1990). The dried mango leaf powder was reported to significantly inhibit sprouting of purple nut sedge tubers (James and Bala, 2003) and its aqueous extract inhibiting germination and growth of some crops (Yang et al., 2006).

The other problem associated with mango as agroforestry tree is that it has dense canopy and the dense canopy allows through little photosynthetically active radiation which is not enough for successful growth of many associated crops. The leaves falling under are also claimed to have allelopathic effect to crop combinations. Many of the allelopathic substances suspected of causing germination and growth inhibition have been identified from plant tissues and soil.

In recent years' decline in crop yield under mango tree is reportedly attributed mostly either to its leaves allelopathic effects or shade intensity. As the tree is the prominent feature of agroforestry in Ethiopia particularly in Southern region, thus it becomes imperative to investigate the allelopathic effects of different concentrations of its aqueous leaf leachates and its light transmission ratios on the germination and early growth performance of associated crops growing beneath it.

METHODOLOGY

Description of study area

The study was conducted during 2019 at Chano Mille Kebele (town) of Arba Minch Zuria district. The study area is situated at an elevation range of 1100 to 1400 m.a.s.l. and located between 5˚42' and 6˚13'N and 37˚19' and 37˚41'E latitude and longitude, respectively having the total area of 922.2 ha (Figure 1).

The annual rainfall of the place ranges from 800 to 1000 mm. Mixed crop-livestock farming is typical for the study area. Teff and maize are the main crops growing in the study area beside cultivation of fruit tree like mango, papaya, and avocado.

Three dominant associated food crops with *M. indica* viz. maize (*Zea mays L.*), peanut (*Arachis hypogaea* L.) and haricot bean (*Phaseolus vulgaris* L.) and two roselle varieties (*WG-Hibiscus-Jamaica* and *WG- Hibiscus-Sudan*) were selected and tested for its allelopathic and shading effects on the crop. The entire study was carried out in laboratory, pots and in field.

Laboratory study

Extract preparation

Matured mango leaves were collected and washed several times in distilled water followed by shade drying for 2 days and subsequent drying in an oven at 60°C for 24 h. These dried leaves were ground into fine powder and then sieved by mesh consecutively. The water extract of the powder were prepared as par Norsworthy (2003). 100 g of leaf powder was mixed with 1000 ml of distilled water and kept for 24 h at room temperature. The filtered mixture was used to get final concentrations of 10, 15 and 20% (100,150 and 200 g leaf powder/L) and distilled water as a control (Hussain and Gadoon, 1981).

Bioassays

Sufficient quantity of healthy seeds of three food crops viz. maize (BH540), peanut (local) and haricot bean (Hawasa Dume) were

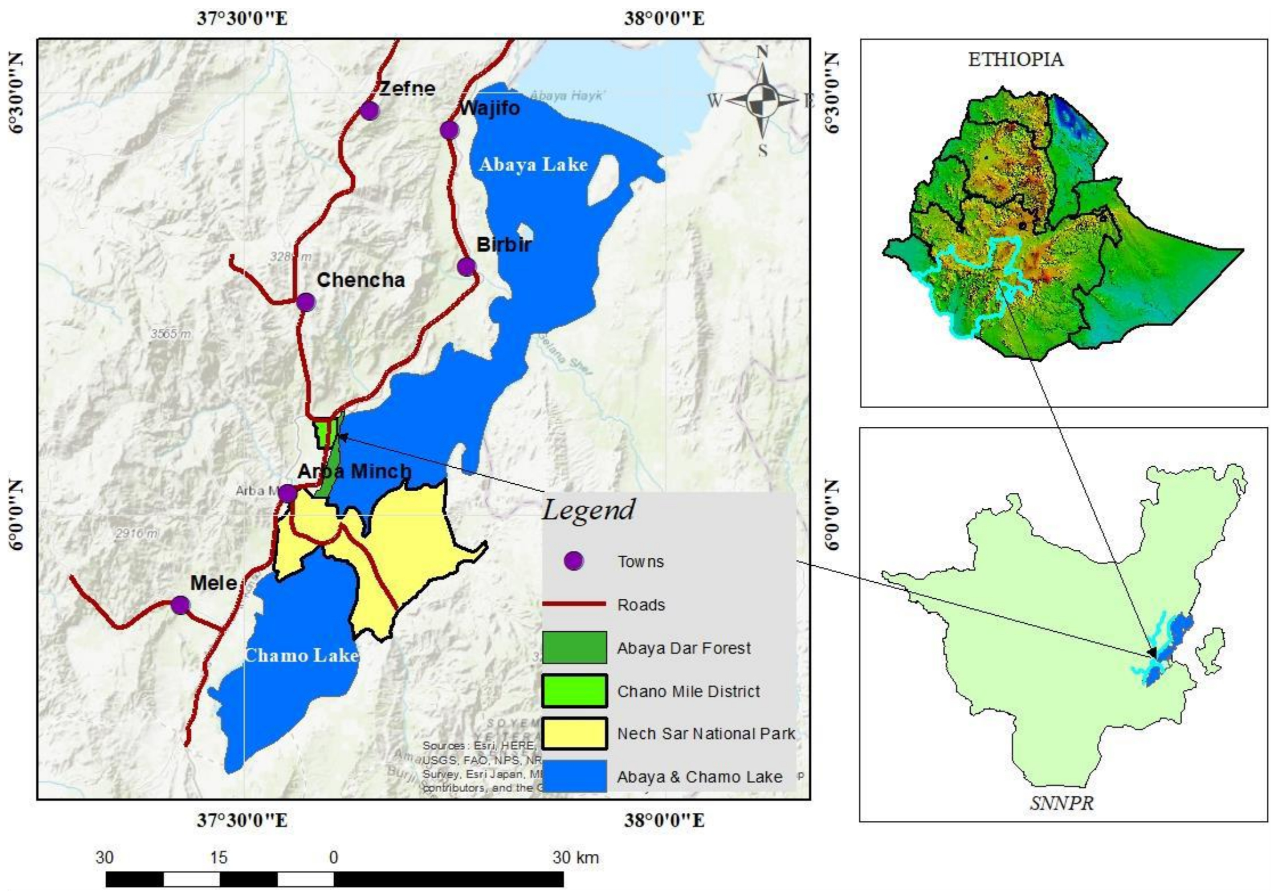

Figure 1. Map of the study area.
Source: Aman Abeje, 2019

tested for viability and healthy seeds of each food crops were surface sterilized in 15% sodium hypochlorite for 20 min and rinsed several times with distilled water (Tinnin and Kirkpatrick, 1985; Humaid and Warrag, 1998). The experiments were done in Petri dishes which were thoroughly washed, sterilized and autoclaved before Whatman No.1 filter paper being placed. 10 seeds of each food crops were evenly distributed in each Petri dish and were treated with different treatments (concentration) of 5 ml extract solution besides distilled water treatment as a control. These Petri dishes were kept moist by adding 2 ml of aqueous extracts or distilled water in every 2 days and were incubated at room temperature (21°C) for 10 days. Experiment was carried out using a Completely Randomized Design (CRD) with 4 treatments, that is, T_0 = Control (only distilled water); T1 = 10% leaf leachate concentration, T_2 = 15% leaf leachate concentration, T_3 = 20% leaf leachate concentration and each treatment was replicated 5 times. The number of seeds germinated was counted daily in each treatment and germination was recorded every day till 10 days and root and shoot lengths of seedlings were measured and recorded on the 10th day. The experimental data were subjected to analysis of variance (ANOVA). Percentage of inhibition/stimulation effect was calculated using the formula given by Surendra and Pot (1978):

$$I = 100 - (E2 \times 100/E1),$$

where I - % of inhibition/stimulation, E1- the response of control and E2- the response of treatment.

Pot culture

Plastic pots of 10 cm diameter were filled with 500 g soil mixture (soil: sand: peat in ratio of 3:1:1). Each pot was sown with 5 seeds of test crops and then irrigated with enough amounts of aqueous leaf extracts (10, 15 and 20%) of the *M. indica* and the control pots were irrigated with distilled water. The experiment was arranged with Completely Randomized Design (C.R.D.) with five replications. Fresh and dry weights of test crops were measured and recorded at 21 days after sowing.

Study on shading effect

The field experiment was laid out in randomized complete block design (RCBD) with four replications. The tree crown of mango was subdivided into three equal distances, that is, 1/3 of the tree crown (zone 1), 1/2 of the crown (zone 2), and periphery of the tree crown (zone 3) and each one treated as treatments while 4th treatment was control placed in open field. 1 m^2 size plot was constructed under these treatments in their respective positions. Medicinal and aromatic plants were sown on well prepared soil under these experimental distances and the open control for germination and growth performance evaluation. The experiment was replicated four times where similar trees of approximately similar age and canopy spread were considered for replication (Table 1).

The light transmission ratio of the canopy at the three distances was measured using lux meter and compared with the open control

Table 1. Characteristics of mango trees selected for the study.

Parameter	Tree age (year)	Height (m)	DBH (cm)	Crown size (m)
Mean±SE	13±0	12.16±0.44	25	11.3±0.35
Min	13	11.5	23	10.8
Max	13	13.0	28	12.0

Source: Aman Abeje, 2019

to express the difference in percentage. Treatment wise seed germination was recorded. Similarly, monthly growth performance from the sampling plots on five randomly selected plants such as plant height (cm), average number of branches per plant, average number of leaves per branch, average leaf area (cm^2) using leaf area meter and number of flowers per plant till seed set was recorded for each treatment. At the end of the experiment, fresh (g) as well as dry biomass (g) per 1 m^2 of each treatment were calculated. The experiment was analysed by using SAS version 9.1 software at probability level of 0.05 to determine statistical difference between the treatments, variance analysis and least significant difference (LSD) among the treatments.

RESULTS AND DISCUSSION

Allelopathic effects of aqueous leaf extracts of mango on seed germination

The dry leaf extract of *M. indica* showed inhibitory effect on seed germination (%) for maize and Haricot bean but stimulatory effect on Pea nut under both bioassay and pot study. The concentration showed greater potential at higher concentration (Tables 2 and 3) which can be attributed to the relative amount of allelochemicals released by the extract (El Rokiek et al., 2011). The variation in germination of different food crops might be due to the variation in tolerance of the species to different concentrations of the leaf leachate. The inhibitory effect of mango had also been reported earlier by Ashafa et al. (2012) in *Casia occidentalis.* Lower germination may be the result of water uptake inhibition (Tawaha and Turk, 2003), and the disturbance in the synthesis as well as the activity of gibberellic acid (GA3) (Olofsdotter, 2001). Reduction in germination percentage has also been reported by some other authors like Khan et al. (2009) in wheat treated with *Eucalyptus camaldulensis* leaf extract and Zoheir et al. (2008) in six plant species treated with *Azadiratcha indica* leaf extracts. The variation in germination of different food crops might be due to the variation of species.

Speed of germination

A significant decrease in speed of germination upon application of mango leaf leachate was observed under lab conditions and was more pronounced with increase in concentration of the leachate. The maximum reduction of speed of germination was observed for pea nut (44.77%) followed by Haricot bean (44.97) and lowest for maize (27.26) at 20% level of concentration.

Effect on plant growth

A significant reduction in shoot and root length of the seedling was recorded under both laboratory as well as pot conditions. The maximum reduction was observed at 20% concentration for both shoot and root length. The reduction in shoot length for maize, pea nut and Haricot bean was 60.52, 47.37 and 64.58% and for root length was 43.48, 44.09 and 63.38%, respectively under laboratory conditions and under pot conditions, the shoot length was 34.63, 36.71 and 21.81% and root length 37.75, 46.70 and 28.40%, respectively under same concentration for maize, pea nut and haricot bean, respectively. The inhibitory effect of mango leaves extract on shoot and root growth has also been reported earlier by Ashafa et al. (2012) for *C. occidentalis.* However, contrary to our results, Desalegn (2014) reported stimulation effect in case of *Lantana camara* for allelopathy through the release of natural plant chemicals (allelochemicals) in soil causing alteration in growth and physiological processes of the receiving plant. Allelochemicals often decreases cell elongation, expansion and division which are growth prerequisite (Olofsdotter, 2001).

There is massive reduction in shoot and root length when compared with control which can be attributed to the presence of allelochemicals in the leaf extracts of *Mangifera indica* which inhibit the synthesis of growth hormones which in turn prevented cell division and differentiation to increase the length of the shoot. Impaired metabolic activities caused by allelochemicals decreases root and shoot length (Saeid et al., 2010). 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). Similarly Chon et al. (2003), Singh et al. (2003) and Chon and Kim (2004) have also reported significant allelopathic potency of certain plant extracts owing to the presence of chemicals like phenolic acid which include coumarin, α-coumaric acid, p-coumaric acid, benzoic acid, phydroxybenzoic acid, ferullic acid and cinnamic acid in it. Phenolic acids have

Table 2. Allelopathic effects of *Mangifera indica* (L.) on the germination and growth under lab conditions.

Treatment	G (%)	Speed of germination	Shoot length (cm)	Root length (cm)
Maize				
T_0	96.25±2.50[a] (0.0)	23.55±0.31[a] (0.0)	1.90±0.08[a] (0.0)	3.68±0.09[a] (0.0)
T_1 (10%)	91.35±2.50[b] (-5.09)	20.10±0.57[b] (-14.65)	1.25±0.12[b] (-34.21)	3.08±0.09[b] (-6.30)
T_2 (15%)	90±4.08bc (-6.49)	19.98±0.52[b] (-15.16)	0.83±0.09[c] (-56.31)	2.25±0.12[c] (-38.86)
T_3 (20%)	85±4.08[d] (-11.69)	17.13±0.43[c] (-27.26)	0.75±0.12[c] (-60.52)	2.08±0.09[c] (-43.48)
$C_{D0.05}$	3.37	2.47	0.17	0.39
CV (%)	5.69	3.31	2.72	2.41
Peanut				
T_0	80±4.08[c] (0.00)	31.05±0.88[a] (0.00)	0.38±0.09[a] (0.0)	3.13±0.09[a] (0.0)
T_1 (10%)	83.75±2.50[b] (+4.69)	23.58±1.06[b] (-24.05)	0.37±0.00[a] (-2.63)	2.08±0.09[b] (-33.54)
T_2 (15%)	86.25±2.50[a] (+7.81)	21.78±0.67[c] (-29.86)	0.30±0.08[b] (-21.05)	1.73±0.09c (-44.72)
T_3 (20%)	88.75±2.50[a] (+10.94)	17.15±0.37[d] (-44.77)	0.20±0.08[c] (-47.37)	1.75±0.05[c] (-44.09)
$C_{D0.05}$	2.60	1.50	0.70	0.30
CV (%)	5.36	3.74	3.21	4.27
Haricot bean				
T_0	86.25±2.50[a] (0.0)	17.50±0.63[a] (0.00)	0.48±0.09[a] (0.0)	3.55±0.06[a] (0..0)
T_1 (10%)	85.35±2.50[a] (-1.05)	13.15±0.37[b] (-24.86)	0.35±0.06[bc] (-27.08)	2.85±0.06[b] (-19.72)
T_2 (15%)	80±4.08[b] (-7.25)	12.90±0.67[b] (-26.29)	0.25±0.06[cd] (-47.92)	1.88±0.10[c] (-47.04)
T_3 (20%)	71.25±2.50[c] (-17.39)	10.33±0.32[c] (-40.97)	0.17±0.05[d] (-64.58)	1.30±0.08[d] (-63.38)
$C_{D0.05}$	4.87	1.75	0.12	0.42
CV (%)	4.93	3.73	4.29	4.66

Mean ± SE values followed by same superscripts in the same column are not significantly different according to LSD at probability level of 0.05.0; T_0 = control. Value in bracket reflect the % deduction (-) or stimulation (+).
Source: Aman Abeje, 2019

been reported to inhibit the synthesis of GA3 which regulate *de novo* amylase production during seed germination and are abundantly found in leaf and litter leachates of many angiosperms (Abdul-Rahman and Habib, 1989). A number of phenolic acids and their derivatives have been reported to be present in *M. indica*'s leaf (El-Rokiek et al., 2010).

Shoot and root biomass

The leaf extract of mango also have inhibitory effect on fresh and dry biomass of all the three crops with maximum reduction of 44.35 and 48.94% recorded in Haricot bean followed by 37.97 and 30% reduction in pea nut and least 11.20 and 18.18% reduction for maize at 20% concentration of the mango leaf extract. The reason for decrease in biomass might be inhibitory effect of allelochemicals in uptake of water by seedling and reduction in other physiological processes of food crops.

Shading effect of mango tree

Mango canopy reduced light transmission ratio (LTR) in all distances from tree bole with maximum reduction being at zone1 (1/3 of the tree crown). This might be due to very dense leaves, and large canopy architecture that it is difficult or impossible to light interception. Yield reduction have also been reported for gram crop under *Acacia nilotica* (Bargali et al., 2004), rice crop under *A. nilotica* (Singh et al., 2008a; Bargali et al., 2009) and *Butea monosperma* (Singh et al., 2008b), wheat under *Populus deltoids* (Mishra et al., 2010) based traditional agroforestry systems. Results showed that mango canopy affected growth performance of Roselle varieties significantly ($P < 0.05$). The parameters like germination percent, plant height, number of branches/plant, number of leaves/plant, leaf area, fresh and dry weight of both the varieties showed significant increase with increase in distances from the tree canopy to periphery of the tree with maximum value for control (Table 4). However, the performance of WG-H. Jamaica variety of Hibiscus with regards to these parameters were better than WG-H. Sudan possibly due to high vegetative growth nature of variety WG-Hibiscus-Jamaica as compared to WG-Hibiscus-Sudan. Boffa et al. (2000) reported that plant height gradually increased from the middle of the transect to the vicinity of karite (*Vitellaria paradoxa*) canopies. Similarly, a significant increase in plant height, number of branches/plant, number of leaves/branch with increase in

Table 3. Allelopathic effects of *Mangifera indica* (L.) on the germination and growth under pot condition.

Treatment	Maize				
	G%	**Shoot length (cm)**	**Root length (cm)**	**Fresh biomass (g)**	**Dry biomass t (g)**
T_0	95 ± 4.08^{a} (0.0)	28.50 ± 1.29^{a} (0.0)	13.50 ± 0.41^{a} (0.0)	2.59 ± 0.17^{a} (-0.0)	0.33 ± 0.03^{a} (0.0)
T_1 (10%)	90 ± 0.00^{b} (-5.26)	21.75 ± 0.65^{b} (-23.68)	12.38 ± 0.48^{b} (-8.29)	2.55 ± 0.10^{a} (-1.5)	0.31 ± 0.03^{a} (-6.06)
T_2 (15%)	88.75 ± 2.50^{b} (-6.58)	19.63 ± 0.48^{c} (-31.12)	10.63 ± 0.48^{c} (-21.26)	2.47 ± 0.05^{a} (-4.63)	0.28±0.04ab (-15.15)
T_3 (20%)	83.75 ± 2.50^{c} (-11.25)	18.63 ± 0.48^{c} (-34.63)	8.43 ± 0.48^{d} (-37.55)	2.30 ± 0.08^{b} (-11.20)	0.25 ± 0.03^{b} (-18.18)
$C_{D0.05}$	3.21	1.61	1.01	0.14	0.40
CV (%)	4.59	6.51	5.23	3.28	3.28
Peanut					
Tr.	G%	Shoot length (cm)	Root length (cm)	Fresh weight (g)	Dry weight (g)
T_0	78.75 ± 2.50^{c} (0.0)	8.50 ± 0.58^{a} (0.0)	9.38±0.48a (0.0)	1.58 ± 0.10^{a} (0.0)	0.40 ± 0.03^{a} (0.0)
T_1 (10%)	82 ± 0.00^{b} (+4.13)	7.63 ± 0.48^{ab} (-10.24)	7.00 ± 0.41^{b} (-25.37)	1.56 ± 0.10^{a} (-1.27)	0.39 ± 0.02^{a} (-2.50)
T_2 (15%)	85 ± 0.00^{a} (+7.94)	7.13 ± 0.85^{b} (-16.12)	5.63 ± 0.48^{c} (-39.98)	1.23 ± 0.05^{b} (-22.15)	30 ± 0.02^{b} (-25%)
T_3 (20%)	87.5 ± 2.89^{a} (+11.11)	5.38 ± 0.48^{c} (-36.71)	5.00 ± 0.82^{c} (-46.70)	0.98 ± 0.10^{c} (-37.97)	0.28 ± 0.01^{b} (-30)
$C_{D0.05}$	2.71	0.90	0.87	0.21	0.05
CV (%)	3.81	2.92	4.71	3.77	3.77
Haricot bean					
Tr.	G%	Shoot length	Root length (cm)	Fresh weight (g)	Dry weight (g)
T_0	85.00±0.00a (0.0)	31.50 ± 1.29^{a} (0.0)	8.38 ± 0.48^{a} (0.0)	2.30 ± 0.08^{a} (0.0)	0.47±0.12a (0.0)
T_1 (10%)	83.27 ± 0.00^{a} (-2.03)	31.35 ± 0.29^{a} (0.48)	8.29 ± 0.25^{a} (-1.07)	1.78 ± 0.05^{b} (-22.61)	0.37 ± 0.02^{b} (-21.27)
T_2 (15%)	78.75 ± 2.50^{b} (-7.94)	26.00 ± 0.41^{b} (-17.46)	7.63 ± 0.48^{b} (-8.95)	1.40 ± 0.08^{cd} (-39.13)	0.27 ± 0.02^{bc} (-42.55)
T_3 (20%)	70 ± 0.00^{c} (-17.64)	24.63 ± 0.48^{c} (-21.81)	6.00 ± 0.41^{c} (-28.40)	1.28 ± 0.08^{cd} (-44.35)	0.24 ± 0.04^{cd} (-48.94)
$C_{D0.05}$	3.29	1.91	0.47	0.27	0.60
CV (%)	3.97	4.51	3.61	4.33	4.35

Mean ± SE values followed by same superscripts in the same column are not significantly different according to LSD at probability level of 0.05.0. Value in bracket reflect the % deduction (-) or stimulation (+).
Source: Aman Abeje, 2019

light intensity Hibiscus-Sudan should not be planted in association with Hibiscus-Sudan should not be planted in Dejene et al. (2019) for Roselle variety. Similarly, Sanou et al. (2011) reported a positive correlation with light availability under tree and yield of millet in Burkina Faso. Ziblim et al. (2015) reported that plant height was noted to have a positive linear relationship with the number of leaves of the plant.

The number of flowers/plant also increases with increase in canopy distances from the bole but increase in case of Sudan variety was non-significant. Under the present study both fresh and dry weights increase significantly with increase in the canopy distances. The result was contrary to Boffa et al. (2000) who demonstrated that average grain ($P < 0.1$) and biomass ($P < 0.05$) yields of sorghum under karite (*V. paradoxa)* in the zone surrounding canopies were slightly higher than at mid-distance between trees.

The performance of Hibiscus variety WG-H. Jamaica showed superiority over WG-H. Sudan for most of this parameter studies and looks more resistant to light availability and thus result in lesser reduction in growth parameters.

Conclusion

Evaluating allelopathic and shading effects of multipurpose tree species with associated crops may be crucial to determine the success of an agroforestry practice or system. *M. indica* claimed allelopathic and has shading effect on germination and growth of associated crops growing in its vicinity. The bioassay and pot-culture study both witnessed the inhibitory effect of *M. indica* on growth of maize, peanut and haricot bean for majority of the parameters except stimulatory effect of leaf extract on germination % of peanut. The inhibition of growth for majority of parameters may be due to the presence of phenolic acids in the *M. indica* leaf residues and the effect was found increasing with increase in its concentration which may not be optimum and still required to be tested for higher concentration in future studies. The shading effect of the species also results in inhibitory effect on growth parameters of the crops grown

Table 4. Growth performance of Roselle varieties of Hibiscus at different canopy distances from mango tree.

Parameter	WG-H. Jamaica				WG-H. Sudan			
	Zone1	Zone2	Zone3	Control	Zone1	Zone2	Zone3	Control
Germination (%)	70±0.00^{d}	78.75±2.50^{c}	87.5±2.89^{b}	96.25±2.50^{a}	61.25±2.50^{d}	70±0.00^{c}	78.75±2.50^{b}	87.5±2.89^{a}
Plant height (cm)	52.75±0.9^{d}	58.00±0.8^{c}	72.75±2.5^{b}	82.75±1.5^{a}	46.75±1.4^{d}	52.75±0.9^{c}	62.75±2.4^{b}	73.00±1.3^{a}
Branches/Plant	9.5±0.57^{d}	10.75±0.50^{c}	12.75±0.50^{b}	15.75±0.50^{a}	7.25±0.50^{d}	8±0.00^{c}	9.25±0.50^{b}	11.25±0.50^{a}
Leaves/branches	85.75±1.41^{d}	98.25±1.82^{c}	118.25±2.44^{b}	121.75±3.30^{a}	61.5±1.41^{d}	82±1.25^{c}	83.75±1.73^{bc}	98±1.50^{a}
Flowers per plant	7.25±0.50^{c}	8.00±0.50^{c}	10.25±0.50^{b}	17.25±0.50^{a}	6.25±0.50^{c}	7.25±0.50^{b}	7.25±0.50^{b}	12.75±0.50^{a}
Leaf area (cm^2)	1444±20.19^{d}	1887.5±25.31^{c}	2325.75±20.62^{b}	2975.25±17.98^{a}	507.5±20.15^{d}	653±19.62^{c}	811.5±23.57^{b}	1053.75±16.45^{a}
Fresh weight (g)	2661.25±19.31^{c}	2708.25±17.25^{b}	2729.75±19.85^{b}	2848.75±19.97^{a}	2216.5±11.70^{d}	2246.5±13.98^{c}	2337.5±13.98^{b}	2537.25±14.99^{a}
Dry weight (g)	12.12±0.32^{c}	12.15±0.10^{c}	13.45±0.39^{b}	16.41±0.17^{a}	11.26±0.07^{c}	11.47±0.18^{c}	12.33±0.43^{b}	13.57±0.11^{a}

Mean ± SE values followed by same superscripts in the same rows are not significantly different according to LSD at probability level of 0.05. WG-H. Jamaica=Wondogenet hibiscus Jamaica; WG-H. Sudan= Wondogenet hibiscus Sudan.
Source: Aman Abeje, 2019

beneath it and this effect gets decreased with increase in distance from the bole to canopy may be due to better light transmission ratio at the periphery and effect may also vary from species to species. Thus, it is recommended that maize, haricot bean, peanut and WG-

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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