

Allelopathic Effect of Meskit (*Prosopis juliflora* (Sw.) DC) Aqueous Extracts on Tropical Crops Tested under Laboratory Conditions

Getahun Asrat and Ali Seid*

Department of Biology, College of Sciences, P.O. Box 1817, Bahir Dar University, Bahir Dar, Ethiopia (*alinbiot@yahoo.com).

ABSTRACT

Phytoinhibitory effect of *Prosopis juliflora* aqueous extracts on tropical crops were tested under laboratory conditions. Maize, Cotton, and forage grasses (*Rodus* and *Panicum*) were used as test plants. Litter fall and under canopy soils were tested for checking allelopathic effects under natural conditions. All the extracts showed significantly negative effects on both germination and seedling growth of test crops. The effect of leaf extract was the highest, followed by litter fall, root extracts and soils respectively. However, at low concentration litter fall and root extracts showed unbalanced root growth stimulation on *Zea mays*, but hampered shoot growths. Since radicle growth alone cannot increase recruitment, unbalanced growth is eventually harmful to crops. Thus, we conclude that *P. juliflora* contains water-soluble allelochemicals capable of inhibiting tropical crops and not good for agroforestry.

Keywords: Agroforestry, Crops, Cotton, Grasses, *Prosopis*, Phytoinhibition, Ethiopia.

1. INTRODUCTION

Allelopathic compounds are metabolites which released from plants and can be beneficial or detrimental to the growth of receptor plants (Chang-Hung, 1999). Allelopathy ecology in natural and agricultural ecosystems has received increasing attention because of the significant reduction of important plants growth and yield reduction of crops. It is an ecological interaction primarily based on the ability of certain plant species to produce secondary chemical compounds, that exert some sort of biological effects on other organisms, many of which are still unknown (Waller, 2003).

Ecologically, allelopathic compounds might play an important role in structuring communities. The effects of allelochemicals on germination and growth of plants may occur through interference in cell division, energy metabolism, mineral uptake, and biosynthetic processes (Pasicznik, 1999). It would have important roles to play in determining plant diversity, dominance, succession and climax vegetation as well as usefulness in agro-ecosystems. It is also expected to be an important mechanism by which newly introduced alien plants could easily invade native plant communities (Hierro and Callaway, 2003). Thus, allelopathy could be a major factor for easy domination of invasive aliens up on introduction for agroforestry purposes.

The reason for such invasive easy establishment in areas once full of indigenous and endemic species often attributed to various reasons such as continuing anthropogenic related disturbances, such as land conversion, grazing, and habitat fragmentation, combined with international trade and climate change, indicate that these trends are likely to continue (Zainal et al., 1988).

P. juliflora, native of America, is widely cultivated in the tropics for shade, timber, forage; and its pods can be grounded into flour and used to make flat bread. The species also reported to have medicinal uses and edible lipids can be extracted from the seeds. Few decades ago, it was deliberately introduced into Eastern Ethiopia, for agroforestry purposes. Consequently, it has naturalized, salt-tolerant, growing near waterholes and along wadis at low altitude (Hedberg and Edwards, 1989).

It is now growing luxuriantly on sandy irrigated lands and dominating other plants (Hedberg and Edwards, 1989), perhaps due to its capacity to resist drought and salt stress tolerance. In 2002, a national stakeholder's workshop, *P. juliflora* was identified as one of the top three Invasive Alien Species (IAS) of Ethiopia. However, it took only few years to become not only a number one IAS, but also a controversial resource and a serious threat to biodiversity. It has significant impacts on lowlands ecosystems services and affecting livelihood. Different studies conducted in Ethiopia reveals that *P. juliflora* invasion showed both the seriousness of IAS's potential impacts on food security and rural livelihoods, and the need for a strong invasive control policy and strategy. Some authors indicated that as it has become one of the serious topics in the country, especially in eastern regions, where the majority of rural people depend on Semi-Pastoral resources (Sen and Chawan, 1970).

The effect of *P. juliflora* on the associated flora depends significantly on the density and size of the canopy. Larger individuals and greater densities have significantly greater negative impact on the associated plants. The annuals were inhibited more than perennials. The number of annuals with significant reductions in density and/or frequency under *P. juliflora* canopies was significantly greater than the number of perennials. Thus, the density of more than 50% of the associated annuals was significantly inhibited under *P. juliflora* canopies. *P. juliflora* has little or no auto-inhibition because under field condition the density of *P. juliflora* seedlings was greater under the canopy of the same species than away from them (El-Keblawy and Al-Rawai, 2006).

While, some appreciate its drought hardiness and fast growing nature, others want to use it for agroforestry. Still others claimed that it has chemicals that inhibited growth of neighboring

plants. A study showed that the allelopathic compounds could be phenolic in nature (Hedberg and Edwards, 1989). Other researchers (Kahi, 2003; Humaid and Warrag, 1998) showed that *P. juliflora* foliage and pods contain autotoxin that can inhibit growth of other plants. However, the impact of the species on tropical food and feed crops in general and under Ethiopian condition in particular, was not studied before. Therefore, studying its allelopathic effects on major tropical food (maize), feed (*Panicum* and *Rodus* grasses) and commercial crops (cotton) intended to fill an important knowledge gap regarding *P. juliflora* impacts: evaluate its suitability for tropical agroforestry and draw useful management information.

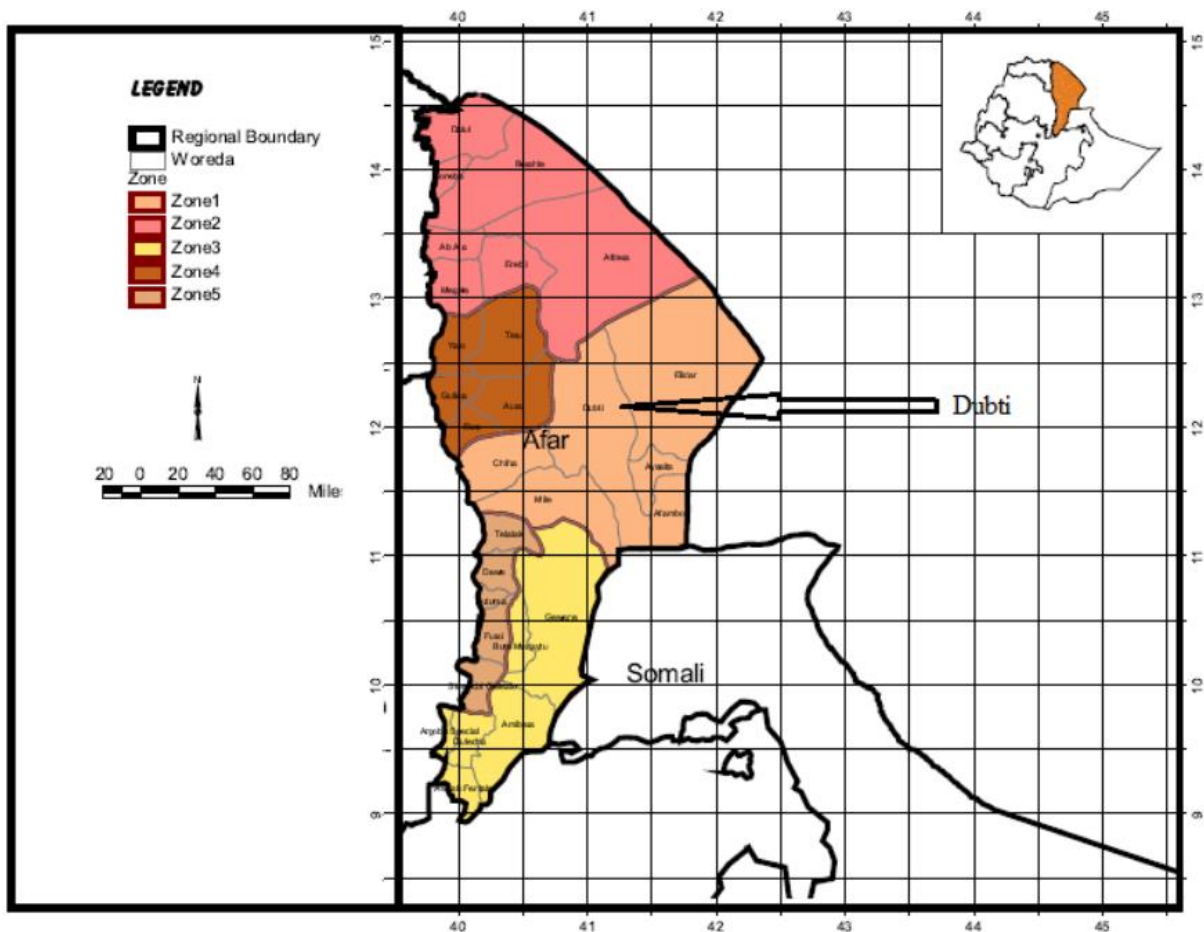


Figure 1. Location map of the study area in Afar Region, Ethiopia

2. MATERIALS AND METHODS

2.1. Description of the Study Area

The study was conducted in Dubti, East Ethiopia (Fig 1), where *P. juliflora* grow vigorously. The region is part of the lower awash area with elevation of about 503 meters above sea level.

The region has an annual mean rainfall of 564 mm and annual evapo-transpiration ranging between 1400 and 2200 mm (MOA, 2000). The region has semi-desert climatic conditions characterized by patches of scattered dry forests, *Acacia* woodlands, bush-land, savannah and scrubland (MOA, 2000).

2.2. Experimental Protocols and Data Analysis

Fresh and mature leaves and roots were collected from *P. juliflora* trees growing around Semera and Dubti area, North East Ethiopia. Topsoil, sub-soils and Litter fall samples were taken from *P. juliflora* shade and free area as control. Plant tissues have been washed several times by water and dried under natural light in open air. Leaf, litter fall and root samples were grounded and the powders were stored in plastic bottles at room temperature. The aqueous extracts of leaves, litter fall and roots were prepared by soaking in distilled water after mixing for 10 seconds and were kept at room temperature and dark conditions for 24 hours as Khan et al. (2011). Aqueous extracts were filtered with three layers of mash cloths and double layers of Whatman No.1 filter paper.

Test seeds were collected from Regional Research Center and agricultural offices. Seeds were surface sterilized in 15% sodium hypochlorite for 20 min and rinsed several times with distilled water (Humaid and Warrag, 1998; Tinnin and Kirkpatrick, 1985). Based on seed size, 20 seeds of *Z. mays*, 50 seeds of *P. maximum*, 50 seeds of *C. gayana*, and 30 seeds of *G. hirsutum* (four replicates each) were evenly distributed on Whatman No.1 filter paper in sterile glass Petri dishes (70 mm) and watered with 4 -7 ml extract solution of different concentrations. The control group was treated with proportional amount of distilled water based on seed sizes.

Germination percentage and growth rate data analyzed by descriptive statistics and comparisons made by Analyses of Variance (ANOVA) using statistical package for social sciences (SPSS-20) software. Significance levels among treatment means compared using Tukey's Honestly Significant Difference Test at 5% level of significance.

3. RESULTS AND DISCUSSION

3.1. Effects of Different Extracts on *Z. mays*

Results of analysis showed that all extract concentrations of leaves, roots and litter fall on shoot and root growth were significantly affected all the study species (Table 1). Radicle and plumule length of all the study species tended to decrease with increasing extract concentration except at

medium (10g/l) root extract and litter fall extracts on maize. Related results indicated the allelopathic influence of aqueous extracts of *Chrozophora obliqua* on *Z. mays* (Khan et al., 2011). Several previous studies also showed that *P. juliflora* reduced grass fodder availability (Pasicznik, 1999), density of native plants (Senait Regassa et al., 2007), decrease shoot and root elongation (Chang-Hung, 1999) and vegetation cover (Kahi, 2003).

Maize seeds treated with root extracts of 10 g/l and litter fall extracts of 5 g/l, 10 g/l and 15 g/l developed longer radicle than that of the control (Table 1). These results are also in accordance with the findings of aqueous extracts from *E. globulus* which increased *Olea europaea* subsp. *Cuspidata* germination rate and lengths of radicles and plumules (Amare Bitew, 2012).

Table 1. Mean of Radicle Elongation (cm) of the Study Species Treated With Different Concentrations of *P. Juliflora* Aqueous Extracts.

<i>Extract</i>	<i>Extract</i>	<i>Panicum</i>	<i>Rodus</i>	<i>Maize</i>	<i>Cotton</i>
Leaves	Control	2.88	2.17	4.27	1.80
	5	1.44 ^{*a}	1.23 ^{*a}	4.03	1.41 ^{*a}
	10	1.27 ^{*a}	1.18 ^{*a}	3.72 ^{*a}	1.12 ^{*a}
	15	0.53 ^{*b}	0.78 ^{*b}	2.54 ^{*b}	1.02 ^{*a}
	25	0.36 ^{*c}	0.33 ^{*c}	1.87 ^{*c}	0.17 ^{*c}
	50	0.33 ^{*c}	0.20 ^{*c}	1.38 ^{*c}	0.10 ^{*c}
	75	0.12 ^{*d}	0.10 ^{*c}	1.33 ^{*c}	0.00 ^{*c}
Litter	5	1.82 ^{*a}	1.34 ^{*a}	4.66	0.85 ^{*a}
	10	1.63 ^{*a}	1.10 ^{*b}	4.79	0.65 ^{*a}
	15	1.56 ^{*b}	1.05 ^{*bc}	5.54	0.48 ^{*b}
	25	1.19 ^{*b}	0.81 ^{*c}	2.14 ^{*a}	0.20 ^{*c}
	50	0.58 ^{*c}	0.43 ^{*c}	2.03 ^{*a}	0.15 ^{*c}
Root	5	0.33 ^{*c}	0.27 ^{*c}	1.94 ^{*c}	0.10 ^{*c}
	5	1.96 ^{*a}	1.94 ^{*a}	3.92	1.58 ^{*a}
	10	1.81 ^{*a}	1.25 ^{*b}	5.13 ^{*a}	1.40 ^{*a}
	15	1.59 ^{*b}	1.08 ^{*b}	4.08	0.74 ^{*b}
	25	1.49 ^{*b}	0.72 ^{*bc}	3.33 ^{*b}	0.30 ^{*c}
	50	0.33 ^{*c}	0.40 ^{*c}	3.15 ^{*b}	0.12 ^{*c}
	75	0.36 ^{*c}	0.16 ^{*c}	2.05 ^{*c}	0.10 ^{*c}

Note: Level of significance is $P < 0.05$, Column with same letters in each treatment are the same groups.

The effects of leaf extracts on *G. herisutum* were found different. There was no elongation of radicle when treated with 75 gm/l of leaf extract and no plumule growth in 50 gm/l and 75 g/l of

other extracts (Tables 1 & 2). This is in line with aqueous extracts of *P. juliflora* leaves on *Cynodon dactylon* (Waller, 2003; Humaid and Warrag, 1998). Some researchers also reported that aqueous extract of *P. juliflora* inhibit wheat seeds germination and seedling growth with proportional inhibitory effect extracts concentration (Siddiqui et al., 2009).

Table 2. Mean of Plumule elongations (cm) of study species in response to different concentrations of aqueous extracts of *P. juliflora* leaf, root and litter fall.

<i>Extracts</i>	<i>Conc.(g/l)</i>	<i>Panicum</i>	<i>Rodus</i>	<i>Maize</i>	<i>Cotton</i>
	0.00	3.50	3.18	5.21	1.91
Leaves	5	2.19* ^b	2.10* ^b	3.80* ^a	1.53
	10	2.10* ^b	1.80* ^{bc}	3.36* ^{ab}	1.34* ^a
	15	1.97* ^a	1.65* ^c	2.05* ^c	1.25* ^a
	25	1.88* ^b	1.57* ^c	1.83* ^c	0.20* ^c
	50	0.87* ^b	0.96* ^c	1.71* ^{cd}	0.00* ^c
	75	0.22* ^c	0.10* ^d	1.53* ^d	0.00* ^c
Litter	5	2.86	2.48* ^a	4.50* ^a	0.99* ^b
	10	2.50* ^a	1.73* ^c	3.61* ^{ab}	0.86* ^b
	15	2.34* ^a	1.63* ^c	3.52* ^b	0.53* ^{bc}
	25	2.22* ^b	1.55* ^c	2.49* ^c	0.20* ^c
	50	1.54* ^b	1.52* ^c	1.30* ^d	0.00* ^c
	75	0.99* ^b	1.45* ^c	1.67* ^c	0.00* ^c
Root	5	2.38* ^b	2.33* ^b	4.48* ^a	1.67
	10	2.11* ^b	2.04* ^b	4.35* ^a	1.43* ^a
	15	1.89* ^{bc}	1.98* ^b	3.83* ^{ab}	1.07* ^b
	25	1.77* ^{bc}	1.81* ^{bc}	3.56* ^b	0.60* ^c
	50	0.98* ^c	1.49* ^c	3.43* ^b	0.00* ^c
	75	0.52* ^c	1.38* ^c	2.28* ^c	0.00* ^c

Note: Level of significance is $P < 0.05$, Column with same letters in each treatment are the same groups.

3.2. Effects of Under Canopy the Test Species

Top and subsoil (0-10 and 10-20 cm depth) collected from *P. juliflora* under canopy showed differences in allelopathic effects (Fig 2). The topsoil showed significant inhibitory effects ($P < 0.05$) on radicle growth of all the test species except cotton. This could be due to accumulation

of responsible compounds in the upper part of the soil after being released from the plant (Pasicznik, 1999).

On the contrary, the subsoil has shown some stimulating effect on seedling growth of test grasses. This could be due to that either decomposition or transformation of the inhibiting compounds and not reaching the subsoil. This finding did not agree with Zainal et al. (1988), who reported that *P. juliflora* litter receiving soils always result in low fertility. However, it supports the idea that *P. juliflora* improves soil fertility for its N-fixation (Aggrawal, 1998).

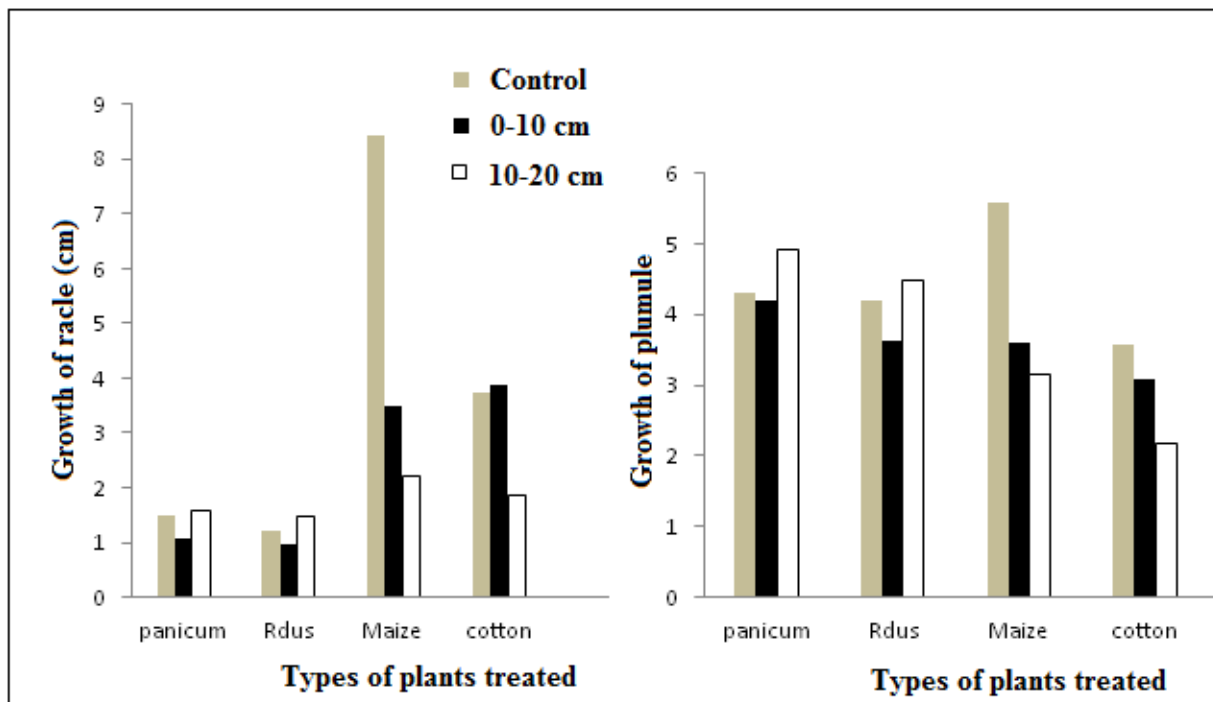


Figure 2. Effects *P. juliflora* under the canopy soils (0-10 & 10-20 cm depth) on growth of the Radicle (left) and Plumule (right) of the study species

3.3. Effects *P. juliflora* Extracts on Germination of Test Plants

While *C. gayana* germination significantly inhibited by all types (of) extracts, but *P. maximum* was inhibited significantly only by leaf extracts. Leaves had the most allelopathic effect followed by litter fall and roots extracts (Fig 3). Earlier reports also indicated that fresh leaf extracts were found to have greater inhibitory impact on germination than extracts from stems, litter fall and fruit (Sen and Chawan, 1970).

However, there were germination percentage reduction, *Z. mays* and *G. herisutum* seeds in all types of extracts, but not significantly different compared to control. This means that some species seeds germination processes may not be affected by external compounds. This also found to support investigation results of *P. juliflora* allelopathic effect on wheat and *Chromolaena odorata* extracts on cowpea (Okwulehie and Amazu, 2004).

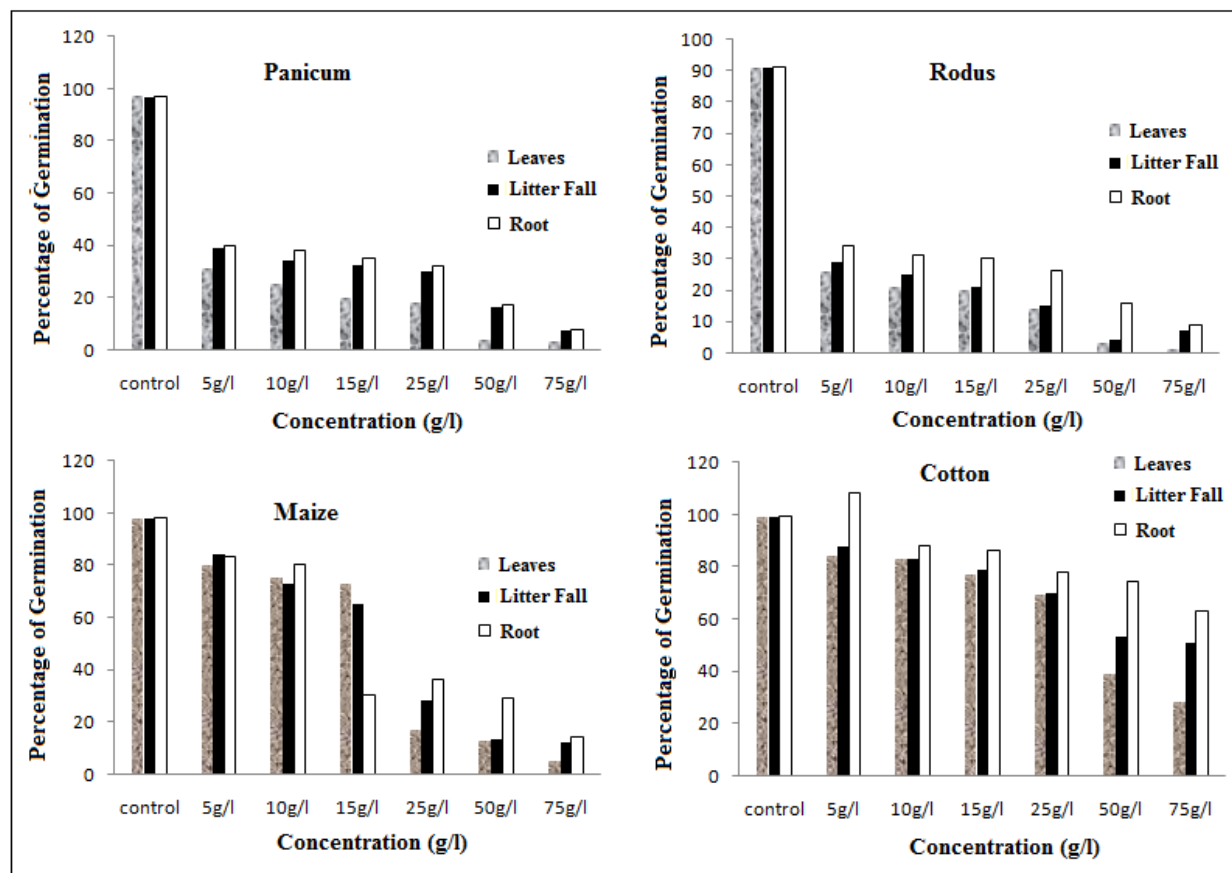


Figure 3. Germination percentage of the study species treated with of aqueous extracts of leaves, roots and litter of *P. juliflora*

3.4. Effects of *P. juliflora* Under-Canopy Soil on Germination

The present study showed that *P. juliflora* under canopy soil has allelopathic effects on germination of useful plants in the study area. The topsoil found to have more deleterious effects than subsoil on percent of seed germination (Fig 4). This is may be because of high accumulation of allelochemicals released from *P. juliflora* litter fall or from root exudates on the surface. In addition, some chemicals found in *P. juliflora* like alkaloids and flavonoids are known to be

rapidly degraded following senescence. While other chemicals may accumulate under tree canopy for longer time (Sola et al., 1992), its transformation is characteristics of soil microbes that may also affect the quantitative and qualitative availability of photochemical or the expression of allelopathic property (Pasicznik, 1999).

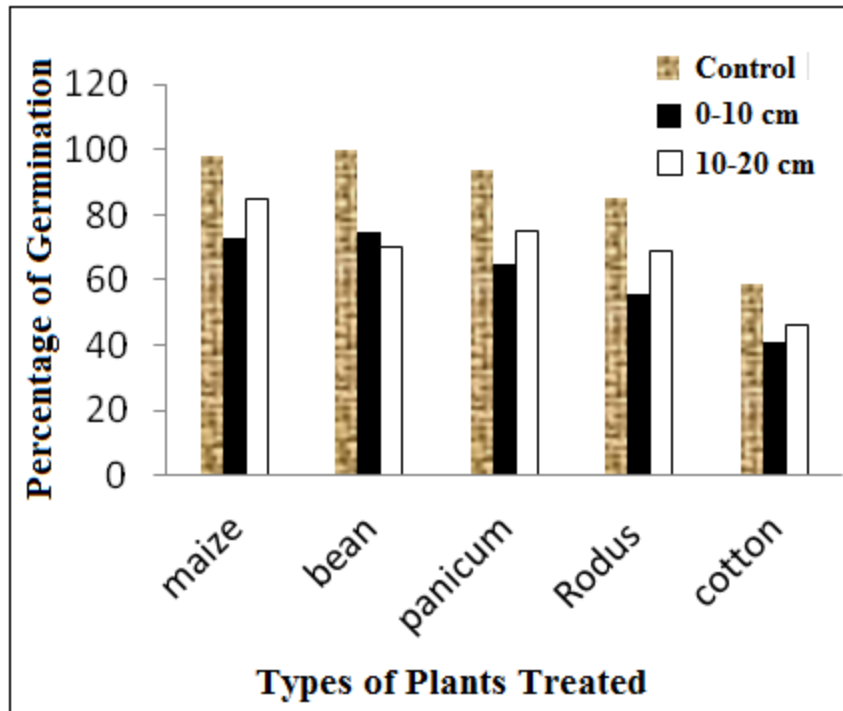


Figure 4. Effects of *P. juliflora* under canopy soils (depth of 0-10 & 10-20 cm) on germination percentage of study species

4. CONCLUSION

The present study indicates that presence of water soluble and biodegradable phytotoxic substances of *P. juliflora* are capable of inhibiting germination and growth of tropical crops. The substance found in leaves, litter and root extracts as well as the under canopy topsoil have enough concentration of phototoxic compounds to affect nearby plants. Hence, it is capable of reducing germination, and significantly inhibiting seedlings growth of crops. For the open canopy of *P. juliflora* light prevention cannot explain why grasses eliminated after the introduction of the species. Allopathic exudates could be the reason why eastern Ethiopian grasslands invaded by the species. Thus, prevention of *P. juliflora* encroachment in to cultivation areas and reclamation of cleared area before cultivation is highly recommended.

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