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Allelopathic effect of *Celtis australis* on germination and growth parameters of some important food crops of the Garhwal Himalayas

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Abstract

Present study was conducted to assess the allelopathic effect of leaf and bark aqueous extracts of *Celtis australis* on *Triticum aestivum*, *Hordeum vulgare*, *Brassica rapa*, *Lens culinaris* and *Vigna umbellata* under *In-vitro* condition. Different leaf and bark aqueous extracts 5%, 10%, and 15% were used to irrigate the seeds of test crops. The results revealed that the concentration dependent significant ($p=0.05$) inhibitory effect of aqueous leaf and bark extracts on germination, root and shoot length of all the test crops. Among all the test crops *Triticum aestivum* was found most sensitive where the germination percentage was reduced down to 46.0% by the leaf extract (15%) as compared to control (82.3%), while the maximum inhibition in the root length of *Lens culinaris* (0.5 cm) by 10% leaf extract was observed as compare to control (8.2 cm). In shoot length maximum inhibitory effect was observed in *Hordeum vulgare* (3.5 cm) as compared to control (13.3 cm). Similarly, the bark extract showed the maximum inhibition in germination percentage of *Lens culinaris* (41.6%) at 15% concentration as compare to control (70.0%) while the maximum inhibition for the root length was recorded in *Triticum aestivum* (1.9 cm) at 15% concentration as compare to control (17.3 cm). In shoot length maximum inhibition was observed for *Triticum aestivum* (1.3 cm) at 10% extract level as compare to control (13.4 cm), while *Vigna umbellata* (5.5 cm) at 15% concentration showed stimulatory effect as compare to control (3.4 cm) exceptionally. Finally, it is concluded that *Vigna umbellata* exhibited the maximum tolerance against leaf and bark aqueous and might be a better option for intercropping with *C. australis*. However, the allelopathic effect on the other test crops can be minimized by removing the fallen leaves from the agricultural fields.

Keywords: Agricultural crops, Allelopathy, Bioassay, Leaf leachate, Tree crops.

INTRODUCTION

The term "Allelopathy" is derived from two Greek words 'Allelon' means each other and 'Pathos' means to suffer, thus, the injurious effect of one plant on other is known as allelopathy. It is the direct influence of various chemicals released from one plant on the growth and development of another plant (Mafeo and Mashela, 2010). Molish (1937) coined the term "allelopathy" which refers to all biochemical interactions either stimulatory or inhibitory among plants, including microorganisms. The higher plants (tree crops) are supposed to

release some phytotoxins into soil, which adversely affect the germination and yield of inter crops (Harborne, 1977). The effect of these phytotoxins called allelochemicals was observed more pronounced in early growth stages during germination, radical and plumule emergence (Rawat et al., 2017). The presence of these allelochemicals in the plant part extract inhibits the cell division and which further affect meristematic tissues in growing tip of roots adversely (Rietjens and Alink 2003). Similarly the inhibitory effect of the higher plants on various agricultural crops has been re-

ported by the leaf aqueous extract of *Tectona grandis* on stem and root of black gram and green gram (Manimegalai, 2012) and germination and seedling growth of *Raphanus sativus* by walnut leaf extract (Bahuguna et al., 2013). These allelochemicals can also persist in the soil for long time and can affect both neighboring plants as well as those planted in succession as an intercrop in next cropping season. Although the allelochemicals derived from plants may be more biodegradable than traditional herbicides but may also have undesirable effects on non-targeted species.

Celtis australis Linn. belongs to family Ulmaceae is an important multipurpose tree species which is usually grown in various traditional agroforestry systems in or around agricultural fields in rainfed agriculture of Kumaon and Garhwal region of Uttarakhand. It is commonly grown for fodder, fuel, timber and plays an important role to enhance socioeconomic structure of local people specially by supplying highly palatable, nutritious and tannin-free green fodder particularly during deficit period of green fodder (Yadav and Bisht, 2013). The timber quality of *Celtis australis* is excellent. It is used in making tools, handles, cups, spoons, oars, canoes, stick and agricultural implements (Bhatt and Verma, 2002). Besides having many advantages as a component in traditional agroforestry system, it is expected to release some chemicals (allelochemicals) either through stem flow or its litter decomposition and affect the intercrop adversely. So, our study is an attempt to evaluate the allelopathic potential of *Celtis australis* on various traditional field crops of Garhwal Hiamalays viz. *Triticum aestivum*, *Hordeum vulgare*, *Brassica rapa*, *Lens culinaris* and *Vigna umbellate*.

MATERIALS AND METHODS

Present study was conducted at the College of Forestry (V.C.S.G. Uttarakhand University of Horticulture and Forestry) Ranichauri, Tehri Garhwal, Uttarakhand, having geo-coordinates 30° 15' N latitude and 78° 30' E longitude at an altitude of about 2100 meter above mean sea level. The metrological data collected from the observatory of College of Forestry, Ranichauri Campus, showed the mean monthly maximum and minimum temperature during the study period (August, 2015 to March, 2016) ranges between 22.8°C to 2.0°C and annual rainfall between 1.2 to 197 mm. The fresh leaves and bark of *Celtis australis* were collected from ten trees at Forestry Nursery Block and the seeds of five agricultural crops were obtained from Department of Agriculture and Seed Science of College of Forestry Ranichauri. Then the healthy leaves and bark were dried at room temperature (25±2°C and grinded in mechanical grinder. To prepare leaf and bark aqueous extract 25g, 50g and 75g of dry

leaf and bark powder was soaked in 500 ml of distilled water for 24 hours at room temperature. The resultant solution was filtered with a three layers of Whatman filter paper no.1 and stored in a conical flask (Bhatt and Singh, 2009). The germination trial was conducted in laboratory condition, 25 seeds of each test crop were placed in a petri dish (9 cm diameter) and kept in a germinator at 25±2°C. Thus, there were four treatments of dry leaf extract of *C. australis* viz., (T₁ = 0% (Control), T₂= 5%, T₃= 10%, T₄= 15% concentration of leaf aqueous extract) and four treatments of the bark extract (T₁ 0% (Control) T₂=5%, T₂= 10% and T₃= 15% bark aqueous extract) replicated three times. To moistened the petri dishes 1ml of aqueous extract or distilled water was added in the respective treatment. The experiment extended over a period till last seed germination (8 days), the seed was considered as germinated when the radical emerged out. Finally, the shoot and root length of 10 randomly selected seedlings from each replication was measured at the end of experiment. Then mean germination time was calculated by following formula given by Ellis and Roberts (1981) as: Mean Germination Time (MGT) and Germination Index (GI) were calculated by the following formulae:

$$\text{MGT} = \frac{\sum Dn}{\sum n} \quad \dots \text{Eq. 1}$$

where n = no of seeds germinated on day D (D representing the no of days since the sowing of seeds)

Germination Index (GI) was calculated by following formula given by Kendrick and Frankland (1969), as:

$$\text{Germination Index (GI)} = \frac{\text{Total germination percent}}{\text{Time (hours) taken for 50\% germination}} \quad \dots \text{Eq. 2}$$

The experimental design adopted for present study was Complete Randomized Block Design and the data was analyzed by using software MS-Excel and STPR – 3.

RESULTS

Wheat (*Triticum aestivum*): The leaf and bark extract of *Celtis australis* showed concentration dependent inhibitory effect on germination of wheat. Maximum germination percentage was recorded in control (82.3%), while minimum in the seeds treated with 15% leaf extract (Table 1). Similarly, the germination percentage was also reduced significantly (50.3%) by the bark extract of 15% concentration as compared to control (Table 3). The significant inhibitory effect of leaf extract was observed on root and shoot length of wheat. Maximum root length (17.3 cm) and shoot length (13.4 cm) were recorded in control treatment while minimum root length (2.2 cm) and

Table 1. Bioassay effect of leaf extract of *Celtis australis* on germination and growth parameters of test crops.

Extract lev-els	Leaf														
	<i>Triticum aestivum</i>				<i>Lens culinaris</i>				<i>Hordeum vulgare</i>						
	Ger %	Root length (cm)	Shoot length (cm)	MGT (days)	GI (hrs.)	Ger %	Root length (cm)	Shoot length (cm)	MGT (days)	GI (hrs.)	Ger %	Root length (cm)	Shoot length (cm)	MGT (days)	GI (hrs.)
Control	82.3	17.3	13.4	3.26	0.93	70.0	8.2	7.1	4.60	0.76	77.0	14.7	13.3	4.90	0.83
5%	65.0	3.0	6.3	3.60	0.80	71.3	1.0	5.3	7.03	0.70	73.0	8.0	11.1	3.33	0.76
10%	59.0	2.2	3.9	3.13	0.83	62.6	0.5	3.4	5.06	0.63	58.0	5.3	8.6	2.43	0.66
15%	46.0	2.8	5.1	3.66	0.60	41.3	0.7	3.2	4.73	0.56	44.0	2.6	3.5	3.03	0.66
Mean	63.0	6.3	7.1	3.41	0.79	61.3	2.6	4.7	5.35	0.66	63.0	7.6	9.1	3.42	0.73
SE±	2.0	0.2	0.4	0.69	0.12	0.9	0.3	0.8	1.15	0.50	6.0	0.7	0.9	0.47	0.10
CD@ (5%)	6.6*	0.6*	1.5*	2.27 NS	0.39 NS	3.1*	0.2*	0.2*	3.77 NS	0.16 NS	6.0*	2.4*	3.1*	1.53*	0.33 NS

Table 2. Bioassay effect of leaf extract of *Celtis australis* on germination and growth parameters of test crops.

Extract levels	Leaf														
	<i>Brassica rapa</i>				<i>Vigna umbellate</i>										
	Ger %	Root length (cm)	Shoot length (cm)	MGT (days)	GI (hrs.)	Ger %	Root length (cm)	Shoot length (cm)	MGT (days)	GI (hrs.)	Ger %	Root length (cm)	Shoot length (cm)	MGT (days)	GI (hrs.)
Control	81.3	3.0	4.0	5.16	0.80	71.6	4.1	3.4	2.76	0.73	71.6	4.1	3.4	2.76	0.73
5%	76.3	1.8	3.9	5.70	0.83	59.3	4.2	3.3	3.06	0.60	59.3	4.2	3.3	3.06	0.60
10%	66.0	1.4	3.2	2.80	0.66	52.0	2.4	2.1	3.66	0.56	52.0	2.4	2.1	3.66	0.56
15%	52.6	0.7	2.4	1.83	0.63	44.0	1.4	2.2	2.86	0.53	44.0	1.4	2.2	2.86	0.53
Mean	69.0	1.7	3.4	3.87	0.73	56.7	3.0	2.7	3.09	0.60	56.7	3.0	2.7	3.09	0.60
SE±	2.2	0.3	0.3	0.68	0.70	2.2	0.1	0.3	0.39	0.40	2.2	0.1	0.3	0.39	0.40
CD@ (5%)	7.2*	1.0*	1.0*	2.23*	0.23 NS	7.4*	0.6*	1.1*	1.29 NS	0.13*	7.4*	0.6*	1.1*	1.29 NS	0.13*

Table 3. Bioassay effect of bark extract of *Celtis australis* on germination and growth parameters of test crops.

Extract levels	Bark														
	<i>Triticum aestivum</i>				<i>Lens culinaris</i>				<i>Hordeum vulgare</i>						
	Ger %	Root length (cm)	Shoot length (cm)	MGT (days)	GI (hrs.)	Ger %	Root length (cm)	Shoot length (cm)	MGT (days)	GI (hrs.)	Ger %	Root length (cm)	Shoot length (cm)	MGT (days)	GI (hrs.)
Control	82.3	17.3	13.4	3.26	0.93	70.0	8.2	7.1	4.60	0.76	77.0	14.7	13.3	4.90	0.83
5%	72.6	2.8	3.0	4.16	0.66	67.3	1.1	3.0	9.83	0.66	75.0	3.4	9.5	5.30	0.70
10%	62.6	2.3	1.3	3.73	0.63	51.0	1.4	1.3	5.93	0.63	64.0	4.0	8.6	4.00	0.70
15%	50.3	1.9	1.4	2.93	0.63	41.6	1.3	1.4	3.66	0.63	56.0	3.7	5.8	4.13	0.66
Mean	65.9	5.5	5.2	3.52	0.71	58.0	2.7	5.2	6.00	0.67	69.1	4.8	9.1	4.58	0.72
SE±	2.4	0.46	0.5	0.33	0.60	1.3	0.4	0.5	1.05	0.44	2.6	1.1	0.6	0.87	0.94
CD@ (5%)	7.9*	1.5*	1.8*	1.07 NS	0.19*	4.4*	1.6*	1.8*	3.44*	0.19 NS	8.7*	3.8 NS	2.2*	2.84 NS	0.30 NS

Table 4. Bioassay effect of bark extract of *Celtis australis* on germination and growth parameters of test crops.

Extract levels	Bark														
	<i>Brassica rapa</i>				<i>Vigna umbellate</i>				<i>Vigna umbellate</i>						
	Ger %	Root length (cm)	Shoot length (cm)	MGT (days)	GI (hrs.)	Ger %	Root length (cm)	Shoot length (cm)	MGT (days)	GI (hrs.)	Ger %	Root length (cm)	Shoot length (cm)	MGT (days)	GI (hrs.)
Control	81.3	3.0	4.0	5.16	0.80	71.6	4.1	3.4	2.76	0.73	71.6	4.1	3.4	2.76	0.73
5%	76.3	5.3	6.8	4.90	0.80	66.3	2.8	4.5	2.83	0.73	66.3	2.8	4.5	2.83	0.73
10%	64.3	4.7	6.4	4.96	0.73	57.3	3.1	3.9	2.63	0.70	57.3	3.1	3.9	2.63	0.70
15%	51.6	3.4	4.9	2.86	0.70	45.0	3.5	5.5	2.23	0.66	45.0	3.5	5.5	2.23	0.66
Mean	68.0	5.5	6.7	4.47	0.75	60.2	5.4	6.9	2.61	0.70	60.2	5.4	6.9	2.61	0.70
SE±	2.4	0.4	0.4	0.65	0.97	2.1	0.7	0.3	0.30	0.57	2.1	0.7	0.3	0.30	0.57
CD@ (5%)	8.0*	1.4*	1.4*	2.13NS	0.31NS	6.9*	2.5*	1.0*	0.99 NS	0.18 NS	6.9*	2.5*	1.0*	0.99 NS	0.18 NS

shoot length (3.9 cm) were found in the treatment of 10% leaf extract (Table 1). Similarly, in bark extract significant inhibitory effect was recorded. Maximum root length (17.3 cm) and shoot length (13.4 cm) were recorded in control while minimum root length (1.9 cm) in the treatment of 10% bark extract and shoot length (1.3 cm) recorded in 15% bark extract (Table 3). The effect of all the concentration of aqueous extract had no significant effect on MGT and GI. In leaf extract maximum value of MGT (3.66 days) was recorded in 15% leaf extract whereas minimum value of MGT (3.13 days) noted in 10% leaf extract. Similarly in GI maximum value (0.93 hours) was recorded in control while minimum value (0.60 hours) showed in 15% bark extract (Table 1). In bark extract lower concentration 5% and 10% had stimulatory effect on MGT 4.16 days and 3.73 days compared to control 3.26 days. However the results were non-significant. In case of GI as concentration increased the significant inhibitory effect was recorded. Maximum value of GI (0.93 hours) was recorded in control while minimum value (0.66 hours) was noted in 5% concentration level (Table 3).

Lentil (*Lens culinaris*): In crop lentil, results show significant stimulation at lower concentration in germination percentage. Maximum germination was observed (71.3%) at 5% leaf extract while minimum (41.3%) in 15% leaf extract (Table 1). In case of bark extract significant inhibitory effect was observed as the concentration level was increased. Maximum germination (70.0%) was found in control treatment, whereas, minimum germination percentage (41.6%) in 15% concentration level (Table 3). The root and shoot length of lentil were significantly reduced towards negative impact of leaf extract. Maximum root length (8.2 cm) and shoot length (7.1 cm) were recorded in control treatment, while, minimum shoot length (3.2 cm) in 15% leaf extract. The root length (0.5 cm) was found minimum in 10% leaf extract (Table 1). The results revealed significant inhibitory effect in root length and shoot length. In bark extract maximum root length (8.2 cm) and shoot length (7.1 cm) length were found in control treatment, whereas, minimum root length (1.1 cm) in 5% bark extract and shoot length (1.3 cm) in 10% bark extract (Table 3). In leaf extract non-significant results were obtained in case of MGT and GI. Maximum value of MGT (7.03 days) was noted in 5% extract level while minimum value of MGT (4.60 days) in control. In GI maximum value (0.76 hours) was noted in control whereas minimum value of GI (0.56 hours) was noted in 15% leaf extract (Table 1). In bark extract maximum value of MGT (9.83 days) was recorded in 5% concentration while minimum value of MGT (3.66 days) was observed in 15% extract level, However results was significant. No significant results

were obtained in GI. Maximum value (0.76 hours) was recorded in control while minimum value (0.63 hours) was noted in 10% and 15% extract level respectively (Table 3).

Barley (*Hordeum vulgare*): In barley, similarly increase in concentration significantly influence germination percentage. Maximum germination percentage (77%) was recorded in control treatment while minimum germination (44%) in 15% concentration level (Table 1). Considering in bark extract germination percent was significantly reduced. Maximum germination (77.0%) exhibit in control treatment while minimum germination percentage (56%) was recorded in 15% bark extract (Table 3). In leaf extract there is a significant reduction observed in both root and shoot length. Maximum root length (14.7 cm) and shoot length (13.3 cm) were recorded in control treatment while minimum root length (2.6 cm) and shoot length (3.5 cm) were recorded in 15% extract level (Table 1). In bark extract non-significant results was obtained in case of root length whereas significant inhibitory results was noted in shoot length. Maximum root length (14.7 cm) and shoot length (13.3 cm) were noted in control treatment and minimum root length (3.4 cm) in 5% concentration level while shoot length (5.8 cm) was recorded in 15% extract level respectively (Table 3). Maximum value of MGT (4.90 days) was observed in control while minimum value of MGT (2.43 days) was recorded in 10% leaf extract. However the result was significant. Non-significant results were noted in case of GI. Maximum value of GI (0.83 hours) was recorded in control whereas minimum value of GI (0.66 hours) obtained in 10% and 15% concentration respectively (Table 1). In bark extract no significant outcomes were recorded towards negative influence of increased extract level in respect of MGT and GI. Maximum value of MGT (5.30 days) was noted in 5% concentration while minimum (4.00 days) in 10% concentration whereas the maximum value of GI (0.83 hours) was recorded in control and GI (0.66 hours) were noted in 15% concentration (Table 3).

Toria (*Brassica rapa*): The effect of leaf extract on germination percent of *Brassica rapa* revealed that as increasing in the concentration of aqueous leaf extract contains decreasing effect on germination percentage. The germination percentage was observed maximum in control (81.3%) and minimum (52.6%) in 15% concentration. However significant results was observed (Table 2). In bark extract results indicated significant reduction towards increasing concentration. Maximum germination percent was recorded in control treatment (81.3), while minimum germination percent (51.6%) was recorded in 15% concentration (Table 4). The increased concentration shows significant inhibitory effect on root and shoot length in leaf extract. Maximum root length (3.0

cm) and shoot length (4.0) were recorded in control treatment while minimum root length (0.7 cm) and shoot length (2.4 cm) were recorded in 15% concentration (Table 2). The stimulatory effect were observed in bark when the concentration was increased and the results exhibit significant stimulation. Maximum root length (5.3 cm) and shoot length (6.8 cm) were observed in 5% concentration while minimum root length (3.0 cm) and shoot length (4.0 cm) were recorded in control (Table 4). Maximum value of MGT (5.70 days) was observed in 5% concentration while minimum value of MGT (1.83 days) in 15% concentration and GI (0.83 hours) in 5% concentration and GI (0.63 hours) was noted in 15% concentration. Significant results were obtained in case of MGT whereas GI shows non-significant results (Table 2). In bark extract, the effect of all concentration had no significant effect on MGT and GI. Maximum value of MGT (5.16 days) was observed in control while minimum value of MGT (2.86 days) was recorded in 15% concentration and maximum value of GI (0.80 hours) was recorded in control and 5% concentration respectively while minimum value of GI (0.70 hours) was noted in 15% concentration (Table 4).

Ricebean (*Vigna umbellate*): In case of ricebean proportionate significantly inhibitory effect observed on germination as increased concentration of leaf aqueous extract. Maximum germination (71.6%), was found in control treatment while the reduction in germination percentage (44.0%) was analyzed in 15% concentration (Table 2). Similarly in bark extract significant reduction in germination percentage was observed. Maximum germination percent (71.6%) was recorded in control whereas minimum germination percent (45.0%) was recorded in 15% concentration (Table 4).

In case leaf extract significant stimulatory effect found in root length whereas significant inhibitory effect recorded in shoot length. Maximum root length (4.2 cm) and shoot length (3.4 cm) was found in 5% concentration and control treatment while minimum root length (1.4 cm) and shoot length (2.1 cm) were analyzed in 15% concentration and 10% concentration respectively (Table 2). Similarly, in bark extract significantly inhibition was found in root length and stimulation in shoot length respectively. Maximum root length (4.1 cm) found in control and shoot length (5.5 cm) in 15% concentration. Whereas minimum root length (2.8 cm) recorded in 5% concentration and shoot length (3.4 cm) in control (Table 4). The results depicted no significant effect was found towards different concentration level. Maximum value of MGT (3.66 days) was observed in 10% concentration and while minimum value of MGT (2.76 days) noted in control and maximum value of GI (0.73 hours) recorded in control while minimum value of GI (0.53 hours) in 15% concentration. However

the results was non-significant. (Table 3). The MGT and GI were not significantly affected by different concentration of bark extract maximum value of MGT (2.83 days) was observed in 5% concentration while minimum value of MGT (2.23 days) found in 15% concentration and maximum value of GI (0.73 hours) were recorded in control and 5% respectively while minimum value of GI (0.66 hours) was noted in 15% concentration (Table 4).

DISCUSSION

In present findings in general the leaf and bark extract of *Celtis australis* showed a concentration dependent inhibitory effect on germination percentage as compared to control treatment except in *Lens culinaris*, where stimulatory effect was observed in leaf extract. The results observed attributed to the presence of various allelochemicals in leaf as well as bark aqueous extract.

The effect of these allelochemicals of leaf and bark extract varied with concentration of leaf as well as bark extract and the tolerance level of various test crops. The tolerance level of these test crops towards the allelopathic effect of aqueous leaf extract on germination was in following order: *Triticum aestivum* > *Hordeum vulgare* > *Lens culinaris* > *Vigna umbellate* > *Brassica rapa*, whereas in case of bark extract *Lens culinaris* > *Triticum aestivum* > *Vigna umbellate* > *Brassica rapa* > *Hordeum vulgare*. Present findings are in line with Bhatt and Todaria (1990) they had also reported the inhibitory effect of leaf extract of *Adina cardifolia*, *Alnus nepalensis* and *Celtis australis* on germination percentage of *Hordeum vulgare* and *Eleusine coracana*. (Kaushal et al. 2011) also found the inhibitory effect of leaf extract of *Morus alba*, *Grewia optiva*, *Toona ciliata* and *Populus deltoids* on germination of chickpea, wheat, maize, bean and soyabean. Similarly, the concentration dependent inhibitory effect of *Dendrocalamus stocksii* leaf leachates on germination of finger millet has been reported (Rawat et al. 2017). The aqueous leaf extract of *Aquilaria malaccensis*, *Michelia champaca*, *Tectona grandis*, *Trema orientalis* was also reduced down the germination percentage of *Oryza sativa*, *Zea mays*, *Vigna radiata*, *Vigna umbellata*, and *Archis hypogea*. In general, the concentration dependent significant ($p=0.05$) reduction was observed in root length of *Triticum aestivum*, *Hordeum vulgare*, *Lens culinaris* by both leaf and bark extract however, the significant stimulatory effect was observed in the root of *Vigna umbellata* and *Brassica rapa*. The inhibition in root and shoot length of test crops might be due to the presence of various allelochemicals in the aqueous leaf and bark extract of *C. australis*. However, its effect was concentration dependent and acted differently on root and shoot length of various test crops. These allelo-

chemicals damage the cell membrane of receptor plant (Rice 1984) which further might reduce down the root and shoot length of receptor plant. In present study it was found that the roots of *Lens culinaris* are more sensitive to allelopathic extracts instead of other parts of plants because they are the first to come in contact with allelochemicals. Similar findings were also reported by Kulkarni et al. 2014, where they found root growth of paddy and ragi crops was significantly affected by the leaf extract of *Mangifera indica*. In case of shoot length significant inhibitory effect was recorded in leaf and bark extract of *C. australis* on all the test crops except in *Brassica rapa* and *Vigna umbellata* where, the stimulatory effect of all the concentration of bark extract showed the stimulatory effect. The inhibitory effect of leaf extract on shoot length was observed maximum in *Hordeum vulgare* while minimum on *Vigna umbellata*. The results observed are attributed to the various allelochemicals presence in leaf aqueous extract of *C. australis* and plant response to these allelochemicals. Similarly, Bhat et al. (2011) also reported that the leaf and bark aqueous extract of *Anogeissus latifolia* reduced down the shoot growth of *V. unguiculata* with increasing concentration of extract. Jayakumar and Manikandan (2005) also found the inhibitory effect of *Acacia leucopholea* on shoot length of viz., *Arachis hypogaea* (groundnut) and *Sorghum vulgare* (sorghum) in proportionate manner with increasing concentration. In case of bark aqueous extract these allelochemicals showed the stimulatory effect on shoot length of *Brassica rapa* and *Vigna umbellata* (Table 4). These results were also in line with the findings of Thapliyal et al., (2008) where they had found that the bark extract was less toxic to germination and radicle growth of *Amaranthus caudatus*, *Echinochloa frumentaceae*, *Lens culinaris* as compared to leaf extract. (Kaushal et al., (2011) had also reported that the stimulatory effect of aqueous leachates of *Morus alba* at lower concentrations on growth of maize and soybean. Singh et al., (2009), recorded that the leaf and bark leachate of *Toona hexandra*, *Ficus subinsica*, and *Bauhinia purpurea* on radicle and plumule growth of *Hordeum vulgare*, *Triticum aestivum* and *B. campestris*. Among the test crops *Brassica campestris* was the most resistant to toxic effects of aqueous extract. Similar findings were also reported by Shruthi et al. 2014 where they observed the stimulatory and inhibitory effect of aqueous leaf extract of *Azadirachta indica* on shoot length of *Vigna radiate*. According to Thapliyal et al. 2008, the MGT directly showed the quickness of germination if the lower value of Mean Germination Time (MGT) express faster rate of germination while, the Germination Index (GI) is directly correlated with germination percent. Thus, the greater the value of GI, the greater

will be the germination percent. In general the non-significant ($p=0.05$) effect of both the leaf and bark extract of *C. australis* were observed on MGT and GI of all the test crops. However, in *H. vulgare* and *B. rapa* the significant reduction ($p=0.05$) in MGT and GI of *V. umbellata* by the aqueous leaf extract of *C. australis* was observed. In 5 % concentration of aqueous leaf extract increased the MGT of *Brassica rapa* exceptionally (Table 2). In case of bark the GI in *Triticum aestivum* and in *Lens culinaris* was decreased by the bark extract in significant manner (Table 3) maximum value of GI was noted in control which means the increasing concentration level inhibit the rate of germination with increasing the concentration from 5% to 15% slower the germination were observed in test crops which showed the lower the germination. In case of GI, maximum value noted on control it means that the increasing concentration level inhibit the rate of germination. However, MGT and GI express as lower value in the increasing leaf and bark concentration it means that the germination were affected negatively by the leaf and bark extract of *C. australis* in concentration dependent manner. Similar results was also reported by Bahuguna et al. (2013) where they found the inhibitory effect of walnut on radish in respect to GI. Similarly, Thapliyal et al. 2008 also reported that the GI of *Echinochloa frumentaceae* has been reduced down by the leaf and bark extract of *Sapindus mukorossi* in an concentration dependent manner. Prasad et al. 2010 also observed that the GI of *Brassica rapa* has been decreased towards the leaf extract of *Juglans regia* at higher concentration level.

Conclusion

The present study on the allelopathic effect of leaf and bark aqueous extract of *Celtis australis* on germination and growth of some important food crops of the Garhwal Himalayas showed that among these, *T. aestivum* was the most sensitive crop while *V. umbellata* was found the most tolerant against the leaf and bark aqueous extract. The other crops viz., *H. vulgare*, *B. rapa* and *L. culinaris* was found moderately resistant. Though, our study is preliminary in nature and showed concentration dependent inhibitory effect on germination and growth parameters of all the test crops. In general, *V. umbellata* exhibited the maximum tolerance against leaf and bark aqueous and might be a better option for intercropping with *C. australis*. However, the allelopathic effect on the other test crops can be minimized by removing the fallen leaves from the agricultural fields.

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