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RESEARCH ARTICLE

Potential of Suitable Companion Crops and Tree Species for Agroforestry in Jamu and Kashmir Himalaya, India

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ABSTRACT

Allelopathic effect of 3-agroforestry tree spp (*Salix alba* L., *Juglans regia* L., and *Populus ciliata* Wall. ex Royle) on germination and seedling growth of 4-crops (*Zea mays* L., *Phaseolus* radiata L. Hepper, *Cicer arietinum* L. and *Brassica nigra* (L) Koch) was evaluated The aqueous extracts < 5 % concentration of *Populus ciliata,* stimulated the germination and seedling growth of some crops (*Brassica nigra* and *Zea mays*), but > 5% concentration caused inhibition. *Salix alba* and *Juglans regia* aqueous extracts significantly inhibited the germination and seedling growth growth of only *Cicer arietinum*. All test crops were affected at high concentrations of aqueous extracts, while lower concentration of leaf and bark extracts/mulch (*Populus ciliata*) stimulated the growth of *Brassica nigra* and *Zea mays*. The suitability of trees for agroforestry based on laboratory and field trials followed the order: *Populus ciliata* > *Juglans regia* > *Salix alba* and the order of agriculture field crops preference is: *Brassica nigra* > *Zea mays* > *Phaseolus radiatus* > *Cicer arietinum*.

INTRODUCTION

Allelopathy refers to the beneficial or harmful effects of one plant on another plant (crop, weed, tree etc,) by release of chemical compounds (allelochemicals) from plant parts through leaching, root exudation, volatilization, residue decomposition and other processes in both natural and agricultural systems (Piyatida and Noguchi, 2010). The allelochemicals are released into the environment, where they affects the growth and development of neighbouring plants. The allelopathic interactions between the plants play crucial role in natural and manipulated ecosystems (Ferguson and Rathinasabapathi, 2003, Siddiqui, *et al*, 2009a). All types of plants (herbs, shrubs and trees), allelopathically affects the pattern of vegetation in their immediate vicinity (Nishimura *et al*, 1982, Rice, 1984). The farmers report crop yields losses due to adverse effects of some farm trees in agroforestry in crop fields (Ferguson and Rathinasabapathi, 2003, Singh *et al*, 2006, 2008, 2009a and 2009b, Willis, 2000, Yeni *et al*, 2010). In traditional agroforestry systems in Kashmir valley, several tree species are grown in and around the crop fields. These trees add organic matter through leaf litter, improve the physiochemical properties of soil and increases farm income but their allelopathic effects are not studied. Their leaf litter has variable contents of allelochemicals and exert diverse effects on soil. Some farm trees reduces or increases the crop yields (Siddiqui, *et al*, 2009a, Singh *et al* 2008, 2009a and 2009b, Todaria *et al,* 2010).

Juglans regia L. (Walnut, family Juglandaceae) is large tree in Himalayas (1375-3350 m above mean sea level). In Kashmir, it is planted near the crop fields and its wood is of good quality for furniture and musical instruments etc. The bark is used as dye for tanning, dyeing and for cleaning teeth (Luna, 1996).

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Salix alba L. (Willow, family Salicaceae) is moderate to large tree in Europe and western Asia. In India it is cultivated in Western Himalayas up to 2400 m above mean sea level in Kashmir and Kulu valley, Lahaul and Laddakh for fuelwood and fodder. Its wood is used for cricket and polo balls etc. (Luna, 1996).

Populus ciliata Wall ex, Royle, (Poplar, family Salicaceae) is an indigenous fast growing tree species of temperate Himalayas from Kashmir to Arunachal Pradesh between 1200-3000 m altitude (Beniwal and Haridashan, 1992). It is grown in crop fields and used for plywood, pulp etc. It is lopped for fodder in Kashmir and Himachal Pradesh and bark is used as a tonic, stimulant and blood purifier (Luna, 1996).

This study aimed to find the allelopathic potential of three agroforestry tree spp (*Populus ciliata, Juglans regia, Salix alba*) on germination and seedling growth of 4-crops (*Brassica nigra, Zea mays, Phaseolus radiatus, Cicer arietinum*) grown in agroforestry systems of Kashmir, Himalaya, to select ideal tree and crops combination to develop productive, and ecologically stable agroforestry systems.

MATERIALS AND METHODS

All studies were done at Dehradun, India [53'24" (N) latitude and 34'27" (E) longitude] from February to June 2011. The experimental treatments consisted of 2-aqueous extracts (leaf, bark), 2-mulches (leaf, bark), 3-agroforestry tree spp (*Salix alba* L., *Juglans regia* L. and *Populus ciliata* Wall. ex Royle**)** and 4-crops (*Zea mays* L., *Phaseolus radiatus* L. Hepper*, Cicer arietinum* L. and *Brassica nigra* (L) Koch).

Laboratory Bioassay

The fresh leaf and bark samples from 2-3 trees of each spp were collected from 15-20 years old trees in Kashmir region [34º 4' 6'' N latitude and 74º 48’ 5’’ E longitude, altitude 2000 m. above sea level]. The sun dried leaves and bark samples of each tree species were ground in mechanical grinder. The powdered leaf and bark at 2, 5, 10 g separately for each species was mixed/dissolved in 100 ml double distilled water in beaker and left for 24 h at room temperature (25 ± 2^0C). The resulting extract was filtered through Whatman # 1 filter paper and stored in conical flasks at 6-10^0C. Thereafter, 2, 3 and 5% extracts were prepared for each component with distilled water. The effects of extracts on seed germination, radical and plumule growth were determined at room temperature (25 ± 2^0C) by placing 100- seeds (5- replications of 20 seeds each) of each test crop in petri dishes (9 cm dia) containing 2- layers of Whatman # 1 filter paper saturated with test extract (Author, please specify how much extract was used on first day and subsequently-Few drops of respected extracts were used to make filter paper moisten enough for germination on first and subsequent days). In control double distilled water was used. The petri dishes were kept moist by adding 1ml extract or distilled water as required. The number of germinated seeds was counted daily till 10^{th} day. On 10^{th} day, final germination and radical and plumule length was recorded from 10 randomly selected seedlings per replicate.

Field trial

The field experiment was done in nearby agriculture field during February to May 2011. Ten seeds of each test crop were sown in each poly bag (23.75 x 13.5 cm) containing 2 kg soil using the following germination media: (i). Field soil (2 kg) alone (control), (ii). Field soil (2 kg) + dried leaf powder/mulch (2, 6, 10g/polybag i.e. 1, 3 and 5%), (iii). Field soil + dried bark powder/mulch (2, 6, 10g/polybag i.e. 1, 3 and 5%). Polybags were kept in open nursery conditions. Seeds of test crops were sown in polybags with mulches of different tree species in 3-replications. Polybags were irrigated with appropriate quantity of water as and when required. Care was taken to prevent the leaching of excess water from the polybags. Seeds germination was recorded at 15 days after sowing, shoot length, root length, shoot fresh weight, root fresh weight were recorded at 45 day after sowing by uprooting 15 plants (5 plants per replication) from each treatment. Dry matter of test crops was recorded after complete sun drying the roots and shoots of each plant. Statistical analysis was done to compare the mean values using least significant difference (LSD) test ($P<0.05$) (Sharma, 1998).

RESULTS

Laboratory Bioassay

Seed germination

Salix alba: Its leaf extracts reduced the germination of all test crops as compared to control. Maximum percent germination (98.3%) was found in *Brassica nigra* (1%), and minimum (73.3%) in *Zea mays* in which germination was found reduced greatly (25.2%) under 5% leaf extracts respectively, as compared to control. Maximum percent germination (100.0%) was found in *Brassica nigra* (1%), while the minimum (84.4%) percent germination with maximum reduction (13.87%) under bark extracts was found in *Zea mays* (5%), no stimulation was found in any test crop over control (Table 1).

Juglans regia: Percent germination was significantly reduced under all the leaf extracts in all test crops as compared to control. Maximum percent germination (100%) was found in *Cicer arietinum* (3%), and minimum (45%) in *Brassica nigra* in which germination was found reduced greatly (55%) under 5% leaf extracts respectively, as compared to control. Maximum percent germination (100.0%) was found in *Brassica nigra* (1%) and *Cicer arietinum* (3 and 5%), while the minimum (78.3%) percent germination with maximum reduction (21.7%) under bark extracts was found in *Brassica nigra* (5%). On the other hand percent germination was found stimulated (2.3%) in *Cicer arietinum* (3 and 5%) over control (Table 1).

Populus ciliata: Maximum percent germination (100%) was found in *Cicer arietinum* (1 and 3%), and minimum (56.6%) in *Brassica nigra* in which germination was found reduced greatly (43.4%) under 5% leaf extracts respectively, as compared to control. Maximum percent germination (100.0%) was found in *Brassica nigra* (1%) and *Cicer arietinum* (3%) while the minimum (88.3%) percent germination with maximum reduction (11.7%) under bark extracts was found in *Brassica nigra* (5%). no stimulation was found in any test crop over control (Table 1).

Radical and plumule growth

Salix alba: Radical and plumule growth was significantly reduced under all the leaf extracts in all test crops as compared to control. Maximum radical (14.43cm) and plumule length (14.45cm) was found in *Zea mays* and *Phaseolus radiatus* respectively under 1% leaf extracts. Minimum radical (3.06cm) length in *Brassica nigra* (5%) and plumule length (2.02cm) was found in *Cicer arietinum* (5%), radical length (80.27%) and plumule length (77.58%) was severely reduced in *Cicer arietinum* (5%) as compared to control. Under different bark extracts, maximum radical length (18.70cm) was recorded in *Zea mays* (1%) and plumule length (14.89cm) was found in *Phaseolus radiatus* (1%), while the minimum radical (3.28cm) *Brassica nigra* (5%) and plumule length (3.24cm) was observed in *Cicer arietinum* (5%). Great reduction in radical (59.06%) and plumule growth (64.03%) was calculated in *Cicer arietinum* (5%) respectively, no stimulation was found in any test crop when compared to control (Table 2).

Juglans regia: Maximum radical (14.42cm) and plumule length (16.1cm) was found in *Zea mays* and *Phaseolus radiatus* respectively under 1% leaf extracts. Minimum radical (1.82cm) length in *Brassica nigra* (5%) and plumule length (2.26cm) was found in *Cicer arietinum* (5%), radical length (85.18%) and plumule length (74.91%) was severely reduced in *Cicer arietinum* (5%) as compared to control. Under different bark extracts, maximum radical length (17.66cm) was recorded in *Zea mays* (1%) and plumule length (16.76cm) was found in *Phaseolus radiatus* (1%), while the minimum radical (3.12cm) and plumule length (4.10cm) was observed in *Brassica nigra* (5%). Great reduction in radical (65.58%) and plumule growth (51.94%) was calculated in *Cicer arietinum* (5%) respectively, no stimulation was found in any test crop over control (Table 2).

Populus ciliata: Radical and plumule growth was significantly reduced under all the leaf extracts in all test crops as compared to control. Maximum radical (19.20cm) and plumule length (20.15cm) was found in *Zea mays* and *Phaseolus radiatus* respectively under 1% leaf extracts. Minimum radical (4.12cm) and plumule length (4.30cm) was found in *Brassica nigra* (5%), radical length (24.56%) and plumule length (42.45%) was severely reduced in *Brassica nigra* (5%), on the other hand radical (29.93%) and plumule growth (6.15%) was observed stimulated in *Phaseolus radiatus* under 1% leaf extract as compared to control. Under different bark extracts, maximum radical length (21.75cm) was recorded in *Zea mays* (1%) and plumule length (18.42cm) was found in *Phaseolus radiatus* (1%), while the minimum radical (3.4cm) and plumule length (3.4cm) was observed in *Brassica nigra* (5%). Maximum reduction in radical (40.35%) in *Brassica nigra* (5%) and plumule growth (34.91%) was calculated in *Zea mays* (5%) respectively, the maximum stimulation in radical (57.05%) and plumule length (25.1%) was calculated in *Cicer arietinum* (1%) when compared to control (Table 2).

Field Trial

Seed germination

Salix alba: Under leaf mulch, maximum (76.67%) germination was found in *Cicer arietinum* (1%) whereas minimum (43.00%) in *Zea mays* (5%). On the other hand maximum (93.33%) germination was found in *Brassica nigra* (1%) while the minimum (33.33%) in

Table 1. Effect of leaf/bark extract/ mulch of 3-trees on germination (%) of test crops in lab Bioassays at 10th days and at 15th days under field conditions

Extract	*Zea mays*		*Phaseolus radiatus*		*Cicer arietinum*		*Brassica nigra*	
	Lab	Field	Lab	Field	Lab	Field	Lab	Field
				Salix alba				
Control	98.00^{a}	70.00^{a}	100.00^{a}	83.33^{a}	97.70^{b}	90.00^{a}	100.00^{a}	60.00^{b}
Leaf 1%	95.00^{a}	70.00^{a}	91.60^{ab}	76.67^{ab}	88.80^{b}	73.33^{ab}	98.30^{a}	70.00^{a}
	(-3.06)	(0.00)	(-8.40)	(7.99)	(-9.01)	(18.52)	(-1.70	(-16.66)
3%	75.50^{b}	60.00^{b}	83.30^{bc}	60.00^{bc}	82.20^{b}	46.67^{b}	85.00^{b}	63.30^{ab}
	(-22.95)	(14.28)	(-16.70)	(27.99)	(-15.86)	(48.14)	(-15.00)	(-5.50)
5%	73.30^{b}	58.00^{b}	81.60^{c}	46.67^{bc}	91.10^{a}	43.00^{b}	80.00^{b}	53.30^{c}
	(-25.20)	(17.14)	(-18.40)	(43.99)	(-6.75)	(52.22)	(-20.00)	(11.16)
Bark 1%	88.80^{b}	66.67^{a}	86.60^{b}	66.67^{ab}	91.10^{b}	70.00^{ab}	100.00^{a}	93.33^{a}
	(-9.38)	(4.75)	(-13.40)	(19.99)	(-6.75)	(22.22)	(0.00)	(-55.55)
3%	86.60^{b}	60.00^{a}	86.60^{b}	50.00^{bc}	95.50^{ab}	60.00^{b}	95.00^{b}	70,00^{ab}
	(-11.63)	(14.28)	(-13.40)	(39.99)	(-2.25)	(33.33)	(-5.00)	(-16.66)
5%	84.40^{b}	33.33^{b}	88.30^{b}	40.00^{c}	93.30^{b}	50.00^{b}	93.00^{b}	46.67^{b}
	(-13.87)	(52.38)	(-16.70)	(51.99)	(-4.50)	(44.44)	(-7.00)	(22.21)
				Juglans regia				
Control	98.00^{a}	70.00	100.00^{a}	83.33^{a}	97.70^{b}	90.00^{a}	100.00^{a}	60.00^{b}
Leaf 1%	91.10^{ab}	76.67^{a}	91.60^{b}	76.67^{ab}	97.70^{a}	83.33^{ab}	98.30^{a}	93.33^{a}
	(-7.04)	(-9.52)	(-8.40)	(7.99)	(0.00)	(7.41)	(-1.70)	(-56.55)
3%	86.60^{b}	66.67^{a}	88.30^{bc}	60.00^{bc}	100.00^{a}	70.00^{bc}	85.00^{a}	80.00^{ab}
	(-11.63)	(4.75)	(-11.70)	(27.99)	(+2.30)	(22.22)	(-15.0)	(-33.33)
5%	91.10^{ab}	46.67^{b}	83.30^{c}	50.00^{c}	91.10^{b}	60.00^{c}	45.00^{b}	63.33^{b}
	(-7.04)	(33.32)	(-16.70)	(39.99)	(-6.75)	(33.33)	(-55.0)	(-5.55)
Bark 1%	93.30^{b}	60.00^{ab}	96.60^{b}	73.33^{a}	95.50^{b}	83.33^{ab}	100.00^{a}	86.67^{a}
	(-4.79)	(14.28)	(-3.40)	(12.00)	(-2.25)	(7.41)	(0.00)	(-44.45)
3%	93.30^{b}	50.00^{bc}	96.60^{b}	66.67^{a}	100.00^{a}	63.33^{bc}	88.30^{ab}	70.00^{ab}
	(-4.79)	(28.57)	(-3.40)	(19.99)	(+2.30)	(29.63)	(-11.70)	(-16.66)
5%	93.30^{b}	43.30^{c}	93.30^{c}	40.00^{b}	100.00^{a}	50.00^{c}	78.30^{b}	53.33^{b}
	(-4.79)	(38.14)	(-6.70)	(51.99)	(+2.30)	(44.44)	(-21.7)	(11.11)
				Populus ciliata				
Control	98.00^{a}	70.00^{a}	100.00^{a}	83.33^{a}	97.70^{b}	90.00^{a}	100.00^{a}	60.00^{b}
Leaf 1%	91.10^{b}	66.67^{a}	96.70^{a}	70,00^{b}	100.00^{a}	80.00^{a}	93.30^{a}	83.00^{a}
	(-7.40)	(4.75)	(-3.30)	(15.99)	(-1.11)	(11.11)	(-6.70)	(-38.33)
3%	84.70^{c}	60.00^{a}	88.30^{b}	60.00^{bc}	100.00^{a}	63.33^{ab}	73.30^{b}	70.00^{ab}
	(-13.57)	(14.28)	(-11.70)	(27.99)	(-1.11)	(29.63)	(-26.70)	(-16.66)
5%	91.10^{b}	40.00^{b}	86.60^{b}	50.00^{c}	97.70^{b}	36.70^{b}	56.6^{b}	50.00^{c}
	(-7.04)	(42.85)	(-13.40)	(39.99)	(0.00)	(59.22)	(-43.40)	(16.66)
Bark 1%	93.00^{b}	70.00^{a}	98.30^{a}	76.67^{a}	95.00b	73.33^{ab}	100.00^{a}	80.00^{a}
	(-4.79)	(0.00)	(-1.70)	(7.99)	(-2.76)	(18.52)	(0.00)	(-33.33)
3%	95.00^{b}	46.70^{b}	96.70^{a}	70.00^{a}	100.00^{a}	60.00^{bc}	98.30^{a}	63.33^{b}
	(-3.06)	(33.28)	(-3.30)	(15.99)	(+2.35)	(33.33)	(-1.70)	(-5.55)
5%	93.00^{b}	40.00^{b}	93.30^{b}	50.00^{b}	93.30^{b}	40.00^{c}	88.30^{b}	53.30^{b}
	(-5.10)	(42.85)	(-6.70)	(39.99)	(-4.50)	(55.55)	(-11.70)	(11.16)

(Values in parenthesis indicate percent reduction/stimulation in germination as compared to control. Mean values followed by same letter within each column are not significantly different (p=0.05).

Table 2. Effects of leaf/bark extract of three agroforestry trees on radicle and plumule growth (mm) of traditional food crops.

	Zea mays		*Phaseolus radiatus*		*Cicer arietinum*		*Brassica nigra*	
Extract	Radical	Plumule	Radical	Plumule	Radical	Plumule	Radical	Plumule
				Salix alba				
Control	19.97^{a}	15.58^{a}	8.40^{a}	18.91^{a}	16.27^{a}	9.01^{a}	6.52^{a}	7.16^{a}
Leaf 1%	14.43^{b}	8.04^{b}	6.33^{b}	14.45^{b}	7.31^{b}	5.77^{ab}	4.66^{b}	5.82^{b}
	(-27.74)	(-43.39)	(-24.64)	(-23.58)	(-55.07)	(-35.96)	(-28.52)	(-18.71)
3%	13.72^{b}	7.78^{b}	6.15^{bc}	13.46^{b}	4.20^{b}	2.38^{b}	4.52^{b}	5.76^{b}
	(-31.29)	(-50.06)	(-26.78)	(-28.82)	(-74.18)	(-73.58	(-30.67)	(-19.55)
5%	11.95^{b}	6.86^{b}	4.20^{c}	10.94^{b}	3.21^{b}	2.02^{b}	3.06^{b}	4.36^{c}
	(-40.30)	(-55.96)	(-50.00)	(-42.14)	(-80.27)	(-77.58)	(-53.06)	(-39.10)
Bark 1%	18.70^{a}	10.97^{b}	8.19^{a}	14.89^{b}	13.42^{ab}	5.81^{b}	5.94^{a}	7.03^{a}
	(-6.35)	(-29.58)	(-2.50)	(-21.25)	(-17.51)	(-35.51)	(-8.89)	(-1.81)
3%	13.10^{b}	9.52^{b}	6.78^{b}	13.23^{b}	11.80^{b}	5.61^{b}	5.90^{a}	6.10^{a}
	(-34.40)	(-38.89)	(-19.28)	(-30.03)	(-27.47)	(-37.73)	(-9.50)	(-14.80)
5%	12.82^{b}	7.14^{b}	6.20^{b}	11.60^{b}	6.66^{c}	3.24^{b}	3.28^{b}	4.46^{b}
	(-35.80)	(-54.17)	(-26.19)	(-38.65)	(-59.06)	(-64.03)	(-49.69)	(-37.70
				Juglans regia				
Control	19.97^{a}	15.58^{a}	8.40^{a}	18.91^{a}	16.27^{a}	9.01^{a}	5.70^{a}	7.16^{a}
Leaf 1%	14.42^{a}	10.53^{b}	6.97^{a}	16.10^{b}	6.26^{b}	5.21^{b}	4.05^{a}	4.45^{bc}
	(-27.79)	(-32.41)	(-17.02)	(-14.85)	(-61.52)	(-42.17)	(-28.94)	(-37.84)
3%	14.41^{a}	8.83^{b}	5.42^{b}	15.99^{b}	3.47^{bc}	2.64^{b}	3.78^{a}	5.03^{ab}
	(-27.84)	(-43.32)	(-35.47)	(-15.44)	(-80.70)	(-70.69)	(-33.68)	(-29.74)
5%	8.06^{b}	7.68^{b}	3.93^{b}	13.84^{b}	2.41^{c}	2.26^{b}	1.88	2.64^{c}
	(-59.63)	(-50.70)	(-53.21)	(-26.81)	(-85.18)	(-74.91)	(-67.01	(-63.12)
Bark 1%	17.66^{a}	10.64^{b}	8.26^{ab}	16.76^{ab}	8.90^{b}	5.33^{a}	4.72^{a}	6.06^{ab}
	(-11.56)	(-31.70)	(-2.02)	(-11.36)	(-45.29)	(-40.84)	(-17.19)	(-15.36)
3%	12.46^{b}	9.65^{b}	6.40^{bc}	16.31^{bc}	7.72^{b}	4.66^{a}	4.60^{a}	5.58^{b}
	(-37.60)	(-38.06)	(-23.80)	(-13.74)	(-52.55)	(-48.27)	(-19.29)	(-22.06)
5%	12.73^{b}	8.02^{b}	4.46^{c}	13.67^{c}	5.60^{b}	4.33^{a}	3.12^{b}	4.10^{c}
	(-36.25)	(-48.52)	(-46.90)	(-27.71)	(-65.58)	(-51.94)	(-45.26)	(-42.73)

				Populus ciliata				
Control	19.97^{b}	15.58^{a}	8.40^{a}	18.91^{a}	6.27^{b}	9.01^{b}	5.70^{a}	7.16^{a}
Leaf 1%	19.20^{ab}	12.05^{ab}	9.74^{a}	20.15^{a}	16.31^{a}	8.90^{ab}	5.50^{a}	6.98^{a}
	(-3.85)	(-22.65)	(+15.95)	(+6.55)	(+0.24)	(-1.22)	(-3.50)	(-2.51)
3%	17.36^{b}	10.89^{b}	8.80^{ab}	15.49^{b}	14.05^{b}	8.19^{b}	4.65^{b}	6.39^{a}
	(-13.06)	(-30.10)	(+4.76)	(-18.08)	(-124.08)	(-9.10)	(-18.42)	(-10.75)
5%	15.16^{b}	8.23^{b}	6.73^{b}	15.13^{b}	13.55^{b}	7.48^{c}	4.30^{b}	4.12^{b}
	(-24.08)	(-47.17)	(-19.88)	(-19.98)	(-116.1)	(-12.98)	(-24.56)	(-42.45)
Bark 1%	21.75^{a}	14.98^{ab}	8.93^{a}	18.42^{a}	14.60^{a}	11.79^{a}	5.60^{a}	6.98^{a}
	(+8.91)	(-3.85)	(+6.3)	(-2.05)	(+132.85)	(+30.85)	(-1.75)	(-2.51)
3%	20.46^{a}	12.14^{b}	7.45^{b}	16.23^{b}	13.16^{a}	9.65^{b}	4.52^{a}	6.64^{a}
	(+2.39)	(-22.07)	(-11.30)	(-14.17)	(+109.88)	(+7.10)	(-20.70)	(-7.26)
5%	18.31^{b}	10.14^{b}	6.94^{b}	15.9^{b}	6.27^{b}	8.65^{b}	3.40^{b}	5.77^{b}
	(-8.31)	(-34.91)	(-17.38)	(-15.91)	(0.00)	(-3.99)	(-40.35)	(-19.41)

(Values in parenthesis indicate percent reduction/stimulation in germination as compared to control. Mean values followed by same letter within each column are not significantly different (p=0.05).

Phaseolus radiatus under 5% bark mulch. Considerable reduction was observed in all the test crops under all three concentrations, while the stimulation was observed in *Brassica nigra* under 1 and 3% leaf and bark mulch as compared to control (Table 3, Fig. 1).

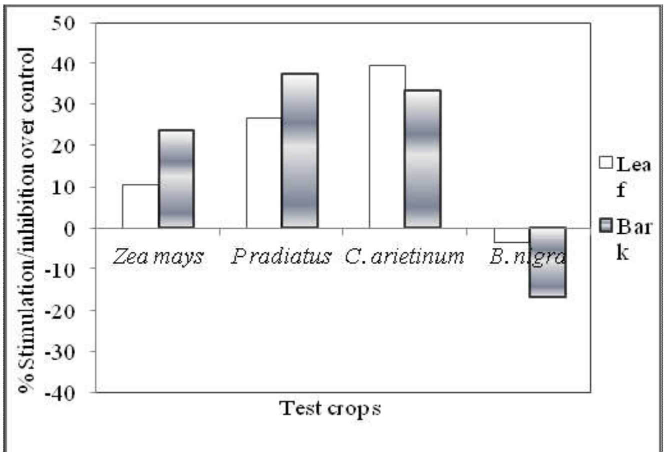

Figure 1. Effect of *Salix alba* leaf and bark extracts on germination of test crops under field trial

Juglans regia: Significant decrease in germination was noticed in all the test crops under both mulches when compared with control. Under leaf mulch, maximum (93.33%) germination was found in *Brassica nigra,* (1%) where as the minimum (33.32%) in *Phaseolus radiatus* (5%). Considerable reduction was observed in all the test crops under all three concentrations, while the stimulation was observed in *Brassica nigra* under 1 and 3% and *Phaseolus radiatus* (1%) leaf mulch as compared to control. On the other hand maximum (86.67%) germination in *Brassica nigra* (1%) and the minimum (40.00%) was found in *Cicer arietinum* under 5% bark mulch.

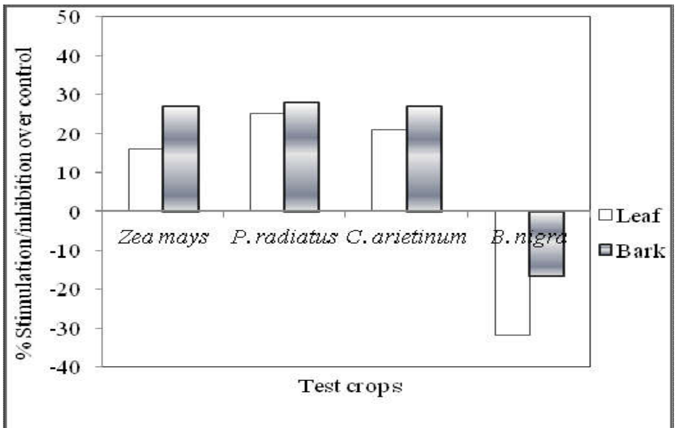

Figure 2. Effect of *Juglans regia* leaf and bark extracts on germination of test crops under field trial

The only stimulation was observed in *Brassica nigra* under 1 and 3% bark mulch as compared to control (Table 3, Fig. 2).

Populus ciliata: Maximum (83.00%) germination in *Brassica nigra* (1%) and the minimum (36.70%) was found in *Zea mays* under 5% leaf mulch., while the stimulation was observed in *Brassica nigra* under 1 and 3% leaf mulch as compared to control. Similarly, maximum (80.00%) germination in *Brassica nigra* (1%) where as the minimum (40.00) was found in *Phaseolus radiatus* and *Zea mays* under 5% bark mulch. Stimulation was observed in *Brassica nigra* under 1 and 3% bark mulch as compared to control (Table 3, Fig. 3).

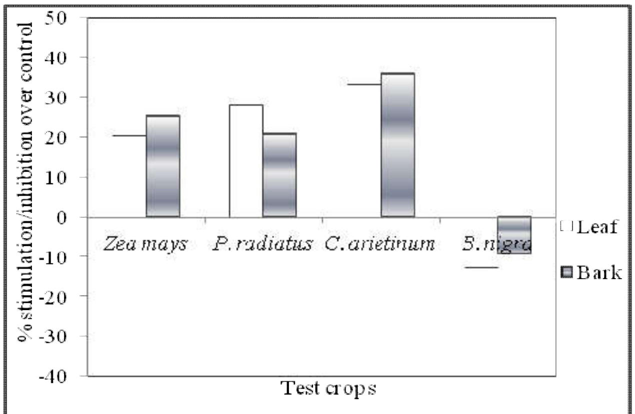

Figure 3. Effect of *Populus ciliata* leaf and bark extracts on germination of test crops under field trial

Root and Shoot Growth

Salix alba: Under leaf mulch, maximum shoot length (50.92cm) and root length (47.80cm) was found in *Zea mays* (3%), while the minimum (7.82cm) Shoot length at 5% and root length (5.78cm) was found in *Phaseolus radiatus* (1%). Maximum shoot fresh weight (4.43g) in *Brassica nigra* (3%) and root fresh weight (1.17g) was found in *Zea mays* at 3%, minimum shoot (0.09g) and root fresh weight (0.02g) was found in *Phaseolus radiatus* (5%). Maximum shoot dry weight (3.05g) in *Zea mays* at 1% and root dry weight (1.00g) was found in *Phaseolus radiatus* at 1%, minimum shoot dry weight (0.05g) and root dry weight (0.02g) was noticed in *Phaseolus radiatus* (5%). Maximum (2.37) root/shoot length ratio was found in *Zea mays* at (3%) and minimum (0.60) in *Phaseolus radiatus* (3%). Maximum R/S dry weight ratio (1.46) in *Cicer arietinum* (1%) and minimum (0.13) was found in *Brassica nigra* (5%). Significant reduction was calculated in almost all the test crops for most of the growth parameters, except for *Zea mays* in which considerable stimulation was found under 1 and 3% leaf mulch. Further R/S length and dry weight ratio were also stimulated in all the species except few cases, when compared to their respective controls. Under bark mulch, maximum shoot length (39.80cm) was found in *Brassica nigra* at (3%) and root length (19.40cm) was found in *Zea mays* at (1%), minimum (6.12cm) Shoot length (3%) and root length (3.14cm) was found in *Phaseolus radiatus* (1%). Maximum shoot fresh weight (5.60g) in *Brassica nigra* (3%) and root fresh weight (1.40g) was found in *Zea mays* (1%), minimum shoot (0.54g) and

Table 3. Effect of leaf/bark mulch of three agroforetsry tree species on various growth traits of traditional food crops at 15th day after sowing under field conditions. Values of parenthesis are percent reduction/stimulation in growth over control. Mean values followed by same later are not significantly different at P=0.05

Mulch	*Salix alba*						*Juglans regia*						*Populus ciliata*					
									Zea mays									
	Sl	Rl	Sdw	Rdw	R/S l	R/S dw	Sl	Rl	Sdw	Rdw	R/S l	R/S dw	Sl	Rl	Sdw	Rdw	R/S l	R/S dw
Control	20.30^{b}	5.12^{b}	0.78^{b}	0.21^{b}	0.25^{b}	0.44^{c}	20.30^{b}	5.12^{b}	0.78^{b}	0.21^{b}	0.25^{b}	0.44^{a}	20.30^{b}	5.12^{b}	0.78^{c}	0.21^{b}	0.25^{b}	0.44^{a}
Leaf 1%	21.52^{b}	12.9^{b}	3.05^{a}	0.58^{a}	0.65^{b}	0.24^{c}	28.22^{b}	21.78^{a}	3.09^{b}	0.65^{b}	0.86^{a}	0.22^{b}	42.10^{ab}	25.80^{a}	5.10^{bc}	0.80^{b}	0.60^{a}	0.20^{b}
	(6.0)	(155)	(291.0)	(176.2)	(160.0)	(-45.5)	(39.0)	(325.4)	(296.2)	(209.5)	(244.0)	(-50.0)	(107.4)	(403.9)	(553.8)	(280.9)	(140.0)	(-54.5)
3%	50.92^{a}	47.80^{a}	1.61^{ab}	0.88^{ab}	2.37^{a}	1.27^{a}	37.36^{ab}	28.96^{a}	4.76^{b}	1.09^{b}	0.78^{a}	0.22^{b}	59.86^{a}	28.76^{a}	11.97^{a}	1.79^{b}	0.48^{a}	0.15^{b}
	(151)	(834)	(106.4)	(319.0)	(848.0)	(188.6)	(84.0)	(465.6)	(510.3)	(419.0)	(-2120)	(-50.0)	(194.9)	(461.7)	(1434.6)	(752.4)	(92.00	(-65.9)
5%	29.60^{b}	26.3^{ab}	0.46^{b}	0.08^{b}	0.93^{b}	1.05^{ab}	53.70 ^{a}	28.32^{a}	12.40^{a}	1.36^{a}	0.54^{ab}	0.11^{b}	49.76^{a}	26.72^{a}	7.22^{ab}	0.60^{a}	0.54^{a}	0.11^{b}
	(46)	(414)	(-41.0)	(-61.9)	(272.0)	(138.6)	(164.5)	(453.2)	(1489.7)	(547.6)	(116.0)	(-75.0)	(145.2)	(421.9)	(825.7)	(+214.3)	(116.0)	(-75.00)
Bark 1%	21.5^{b}	12.9^{b}	3.1^{a}	0.50^{a}	0.60^{a}	0.40^{a}	29.40^{b}	27.70^{a}	4.80^{a}	1.10^{a}	2.20^{a}	0.20^{b}	46.24^{a}	28.3^{a}	9.15^{a}	1.10^{a}	0.61^{a}	0.12^{b}
	(6.0)	(154)	(291.0)	(138.0)	(140.0)	(-9.1)	(44.8)	(441.0)	(515.4)	(423.8)	(780.0)	(-54.5)	(127.8)	(425.7)	(1073.1)	(423.8)	(144.0)	(-72.7)
3%	50.9^{a}	47.8^{a}	1.6^{ab}	0.13^{b}	0.60^{a}	0.43^{a}	28.90^{b}	21.50^{a}	3.20^{ab}	0.40^{b}	0.70^{b}	0.10^{b}	37.24^{a}	28.02^{a}	5.77^{ab}	0.91^{a}	0.79^{a}	0.17^{b}
	(151)	(8346)	(106.4)	(-38.1)	(140.0)	(-2.3)	(42.4)	(319.9)	(310.3)	(90.47)	(180.0)	(-77.3)	(83.4)	(447.3)	(639.7)	(333.3)	(216.0)	(-61.4)
5%	29.60^{b}	26.3^{ab}	0.5^{b}	0.47^{a}	0.64^{a}	0.24^{b}	42.80^{a}	28.84^{a}	5.85^{a}	1.20^{a}	0.67^{b}	0.20^{b}	32.24^{ab}	27.78^{a}	3.28^{bc}	0.62^{ab}	0.86^{ab}	0.19^{b}
	(46)	(414)	(-41)	(123.8)	(156.0)	(45.45)	(110.8)	(463..3)	(650.00)	(471.4)	(168.0)	(-54.5)	(58.81)	(442.6)	(320.51)	(195.23)	(244.0)	(-56.81)
									Phaseolus radiatus									
Control	33.94^{a}	7.22^{a}	1.65^{a}	0.13^{b}	0.23^{b}	0.08^{c}	33.94^{a}	7.22^{bc}	1.65^{a}	0.13^{b}	0.23^{b}	0.08^{b}	33.94^{a}	33.94^{a}	1.65^{a}	0.13^{a}	0.23^{c}	0.08^{b}
Leaf 1%	8.10^{b}	5.78^{b}	1.78^{a}	1.00^{a}	0.79^{a}	0.60^{a}	9.78^{b}	5.50^{c}	1.08^{a}	0.30^{ab}	0.59^{ab}	0.24^{ab}	11.82^{b}	11.82^{b}	1.08^{a}	0.15^{a}	0.57^{ab}	0.23^{a}
	(-76.1)	(-19.9)	(+7.9)	(669.2)	(243.5)	(650.0)	(-71.2)	(-23.8)	(-34.5)	(130.8)	(156.5)	(200.0)	(-65.2)	(-65.2)	(-34.5)	(15.4)	(147.8)	(187.5)
3%	12.08^{b}	7.10^{a}	0.28^{b} (-	0.02^{b}	0.60^{ab}	0.16^{bc}	10.62^{b}	10.02^{a}	1.21^{a}	0.53^{a}	0.98^{a}	0.44^{a}	14.93^{b}	14.93^{b}	1.21^{a}	0.03^{b}	0.83^{a}	0.14^{b}
	(-64.4)	(-1.66)	83.0)	(-84.6)	(160.9)	(100.0)	(-68.7)	(38.8)	(-26.7)	(307.7)	(326.1)	(450.0)	(-56.0)	(-56.0)	(-26.7)	(-76.9)	(260.9)	(75.0)
5%	7.82^{b}	7.54^{a}	0.05^{b} (-	0.02^{b}	0.97^{a}	0.43^{ab}	13.98^{b}	8.48^{ab}	0.33^{b}	0.04^{b}	0.63^{ab}	0.15^{b}	15.98^{b}	15.98^{b}	0.33^{b}	0.05^{b}	0.47^{bc}	0.11^{b}
	(-76.9)	(+4.4)	96.9)	(-84.6)	(321.7)	(437.5)	(-58.8)	(17.45)	(-80.00)	(-69.2)	(173.9)	(87.50)	(-52.9)	(-52.9)	(-80.0)	(-61.5)	(104.3)	(37.5)
Bark 1%	6.36^{c}	3.14^{bc}	0.52^{b}	0.34^{a}	0.50^{bc}	0.34^{a}	6.36^{b}	6.12^{ab}	0.87^{b}	0.19^{a}	0.99^{a}	0.19^{b}	14.60^{b}	14.60^{b}	4.19^{a}	0.50^{a}	0.83^{a}	0.30^{a}
	(-81.3)	(-56.5)	(-68.5)	(161.5)	(117.3)	(325.0)	(-81.3)	(-15.2)	(-47.3)	(46.2)	(330.4)	(137.5)	(-52.9)	(-52.9)	(153.9)	(284.6)	(260.9)	(275.0)
3%	6.12^{c}	4.90^{ab}	0.35^{b}	0.20^{bc}	0.84^{ab}	0.44^{a}	7.72 ^{b}	4.48^{b}	0.07^{b}	0.06^{b}	0.62^{ab}	0.84^{a}	10.32^{b}	10.32^{b}	0.24^{b}	0.02^{a}	0.69^{a}	0.14^{b}
	(-81.9)	(-32.1)	(-78.8)	(53.8)	(265.2)	(450.0)	(-77.5)	(-37.9)	(-95.8)	(-53.8)	(169.6)	(950.0)	(-69.6)	(-69.6)	(-85.5)	(-84.6)	(200.0)	(75.0)
5%	7.20^{bc}	7.20^{a}	0.60^{b}	0.26^{ab}	1.02^{a}	0.37^{a}	8.5^{b}	8.30^{a}	0.10^{b}	0.00^{b}	0.80^{a}	0.20^{b}	12.34^{b}	12.34^{b}	0.59^{b}	0.05^{b}	0.81^{a}	0.09^{b}
	(-78.8)	(-0.3)	(-63.6)	(100.0)	(343.5)	(362.5)	(-74.9)	(14.9)	(-93.9)	(-100)	(247.8)	(150.0)	(-63.6)	(-63.6)	(-64.2)	(-61.5)	(252.2)	(12.5)

									Cicer arietinum									
Control	23.40^{a}	23.16^{a}	1.56^{a}	0.21^{a}	0.99^{a}	0.14^{b}	23.40^{a}	23.16^{a}	1.56^{a}	0.21^{ab}	0.99^{ac}	0.14^{b}	23.40^{a}	23.16^{a}	1.56^{a}	0.21^{a}	0.99^{a}	0.14^{b}
Leaf 1%	11.90^{b}	9.20^{b}-	0.17^{b} (-	0.14^{ab}	0.79^{b}	1.46^{a}	13.22^{b}	11.88^{b}	0.20^{b}	0.08^{c}	0.91^{ab}	0.50^{ab}	10.48^{b}	6.06^{b}	0.17^{b}	0.06^{b}	0.58^{b}	0.39^{a}
	(-49.1)	(60.3)	89.1)	(-33.3)	(-20.2)	(942.9)	(-43.5)	(-48.7)	(-87.2)	(61.9)	(-8.1)	(257.1)	(-55.2)	(-73.8)	(-89.1)	(-71.4)	(-41.4)	(178.6)
3%	14.58^{b}	12.78^{b}	0.27^{b} (-	0.09^{b}	0.88^{ab}	0.43^{b}	15.08^{b}	10.90^{b}	0.24^{b}	0.15^{bc}	0.72^{c}	0.84^{a}	17.24^{ab}	14.74^{ab}	0.39^{b}	0.10^{b}	0.85^{a}	0.27^{ab}
	(-37.7)	(-44.7)	82.7)	(-57.1)	(-11.1)	(207.1)	(-35.6)	(-52.9)	(-84.6)	(28.6)	(-27.3)	(500.0)	(-26.3)	(-36.4)	(-75.0)	(-52.4)	(-14.1)	(92.9)
5%	13.40^{b}	12.80^{b}	0.32^{b} (-	0.07^{b}	0.96^{a}	0.59^{b}	18.68^{b}	13.64^{b}	0.53^{b}	0.28^{a}	0.73^{b}	0.61^{a}	19.84^{a}	18.00^{a}	0.74^{ab}	0.14^{ab}	0.85^{a}	0.20^{b}
	(-42.7)	(-44.8)	79.5)	(-66.7)	(-3.0)	(321.4)	(-20.2)	(-41.1)	(-66.0)	(33.3)	(-26.3)	(335.7)	(-15.2)	(-22.3)	(-52.6)	(-33.3)	(-14.1)	(42.9)
Bark 1%	11.90^{b}	5.14^{b}	0.10^{b}	0.05^{b}	0.43^{b}	0.43^{a}	13.22^{b}	11.88^{b}	0.20^{b}	0.08^{c}	0.91^{b}	0.50^{ab}	15.32^{b}	1.34^{b}	0.41^{b}	0.15^{b}	0.86^{ab}	0.38^{a}
	(-49.1)	(-77.8)	(-93.6)	(-76.2)	(-56.6)	(207.1)	(-43.5)	(-48.7)	(-87.2)	(61.9)	(-8.1)	(257.1)	(-34.5)	(-94.2)	(-73.7)	(-28.6)	(-13.1)	(171.4)
3%	11.46^{b}	7.08^{b}	0.15^{b}	0.07^{b}	0.81^{a}	0.67^{a}	15.08^{b}	10.90^{b}	0.24^{b}	0.15^{bc}	0.72^{c}	0.84^{a}	11.58^{b}	9.04^{b}	0.31^{b}	0.09^{b}	0.77^{bc}	0.33^{a}(1
	(-51.0)	(-69.4)	(-90.4)	(-66.7)	(-18.2)	(378.5)	(-35.6)	(-52.9)	(-84.6)	(28.6)	(-27.3)	(500.0)	(-50.5)	(-60.79)	(-80.1)	(-57.1)	(-22.2)	35.71)
5%	9.50^{b}	7.50^{b}	0.10^{b}	0.10^{b}	0.70^{ab}	0.60^{a}	18.68^{b}	13.64^{b}	0.53^{b}	0.28^{a}	0.73^{b}	0.61^{a}	15.16^{b}	9.50^{b}	0.36^{b}	0.13^{b}	0.63^{c}	0.35^{a}
	(-59.4)	(-67.6)	(-93.6)	(-52.4)	(-29.3)	(328.6)	(-20.2)	(-41.1)	(-66.2)	(33.3)	(-26.3)	(335.7)	(-35.2)	(-58.9)	(-76.9)	(-38.1)	(-36.4)	(150.0)
									Brassica nigra									
Control	47.05^{a}	20.78^{a}	1.98^{a}	0.31^{a}	0.46^{b}	0.18^{b}	47.05^{a}	20.78^{b}	1.98^{a}	0.31^{a}	0.46^{b}	0.18^{b}	47.05^{a}	20.78^{a}	1.98^{a}	0.31^{b}	0.46^{b}	0.18^{b}
Leaf 1%	27.54^{b}	18.5^{c}	0.81^{c} (-	0.11^{bc}	0.68^{a}	0.15^{ab}	30.54^{ab}	16.02^{b}	1.27^{ab}	0.12^{b}	0.67^{ab}	0.16^{b}	27.20^{b}	21.44^{a}	0.99^{b}	0.14^{b}	0.71^{a}	0.19^{a}
	(-41.5)	(-10.9)	59.1)	(-64.5)	(47.8)	(-16.7)	(-35.1)	(-22.9)	(-35.9)	(-61.2)	(45.7)	(-11.1)	(-42.2)	(3.2)	(-50.0)	(-54.8)	(54.3)	(5.6)
3%	30.76^{b}	20.44^{ab}	2.31^{a}	0.27^{a}	0.65^{ab}	0.11^{bc}	20.02^{b}	74.56^{a}	0.61^{b}	0.10^{b}	0.95^{a}	0.18^{b}	29.26 ^{b}	15.06^{b}	0.86^{b}	0.14^{b}	0.55^{b}	0.17^{b}
	(-34.6)	(-1.63)	(16.7)	(-12.9)	(41.3)	(-38.9)	(-57.4)	(-258.8)	(-69.2)	(-67.7)	(106.5)	(0.00)	(-37.8)	(-27.5)	(-56.6)	(-54.8)	(19.6)	(-5.6)
5%	23.46^{b}	18.98^{bc}	1.34^{bc} (-	0.15^{b}	0.81^{a}	0.13^{bc}	23.48^{b}	14.58^{b}	0.69^{b}	0.25^{ab}	0.61^{b}	0.48^{a}	38.38 ^{b}	18.58^{a}	1.35^{b}	0.15^{a}	0.52^{b}	0.19^{a}
	(-50.1)	(-8.7)	32.3)	(-51.6)	(76.1)	(-27.8)	(-50.1)	(-29.8)	(-65.2)	(-19.4)	(32.6)	(166.6)	(-18.4)	(-10.6)	(-31.81)	(-516.1)	(13.04)	(5.6)
Bark 1%	22.40^{c}	15.10	0.40^{b}	0.10^{c}	0.80^{a}	0.30^{a}	31.72^{a}	18.10^{c}	1.27^{ab}	0.20^{ab}	0.20^{b}	0.67^{a}	27.54^{b}	18.5^{c}	0.81^{c}	0.11^{c}	0.68^{a}	0.15^{ab}
	(-52.4)	(-27.3)	(-79.8)	(-67.7)	(73.9)	(66.7)	(-32.6)	(-12.9)	(-35.9)	(-35.5)	(-56.5)	(272.2)	(-41.5)	(-10.9)	(-59.1)	(-64.5)	(47.8)	(-16.7)
3%	39.80^{ab}	18.90^{ab}	1.40^{ab}	0.30^{ab}	0.50^{b}	0.30^{a}	31.46^{ab}	19.78^{ab}	0.61^{b}	0.16^{b}	0.13^{b}	0.70^{a}	30.76^{b}	20.44^{ab}	2.31^{a}	0.27^{ab}	0.65^{ab}	0.11^{b}
	(-15.4)	(-9.0)	(-29.3)	(-3.22)	(8.7)	(66.7)	(-33.1)	(-4.8)	(-69.2)	(-48.4)	(-71.7)	(288.9)	(-34.6)	(-1.6)	(16.66)	(-12.90)	(41.30)	(-38.9)
5%	26.30^{bc}	15.26^{b}	0.51^{b}	0.16^{bc}	0.60^{ab}	0.35^{a}	18.48^{b}	18.56^{bc}	0.69^{b}	0.07^{b}	0.07^{b}	1.04^{a}	23.46^{b}	18.98^{bc}	1.34^{bc}	0.15^{bc}	0.81^{a}	0.13^{b}
	(-44.1)	(-26.6)	(-74.2)	(-48.4)	(30.4)	(94.4)	(-60.7)	(-10.7)	(-65.2)	(-77.4)	(-84.8)	(477.8)	(-50.1)	(-8.7)	(-32.3)	(-51.6)	(76.1)	(-27.8)

Shoot length (cm), RL= Root length (cm), Sdw=Shoot dry weight (gm), Rdw=Root dery weight (gm), R/Sl=Root/Shoot length ratio, R/S dw=R/S dry weight ratio root fresh weight (0.09g) was found in *Cicer arietinum* (1%). Maximum shoot (2.08g) at 5% and root dry weight (0.50g) was noticed in *Zea mays* (1%), minimum shoot (0.10g) and root dry weight (0.05) was found in *Cicer arietinum* (1%). Maximum (1.02) R/S length ratio in *Phaseolus radiatus* (5%) and minimum (0.43) was observed in *Cicer arietinum* at (1%). Maximum (0.67) R/S dry weight in *Cicer arietinum* at (3%) and minimum (0.24) in *Zea mays* (5%). Significant suppression was recorded in almost all the test crops for most of the growth parameters, except for *Zea mays* in which considerable stimulation was found under 1 and 3% bark mulch. R/S length and dry weight ratio were also increased in all the species except few cases, when compared to their respective controls (Table 3).

Juglans regia: Under leaf mulch, maximum shoot length (53.70cm) in *Zea mays* (5%) and root length (74.56cm) was found in *Brassica nigra* at (3%), minimum (9.78cm) Shoot and root length (5.50cm) was found in *Phaseolus radiatus* (1%). Maximum shoot (16.77g) and root fresh weight (2.64g) was found in *Zea mays* (5%), minimum shoot fresh weight (0.63g) was found in *Cicer arietinum* (1%) and root fresh weight (0.05g) was found in *Phaseolus radiatus* (5%). Maximum shoot (12.40g) and root dry weight (1.36g) was observed in *Zea mays* (5%), minimum shoot dry weight (0.20g) was found in *Cicer arietinum* (1%) and root dry weight (0.04g) was found in *Phaseolus radiatus* (5%). Maximum (0.98) R/S length ratio in *Phaseolus radiatus* (3%) and minimum (0.54) was found in *Zea mays* (5%). Maximum (0.84) R/S dry weight ratio in *Cicer arietinum* (3%). and minimum (0.11) was found in *Zea mays* at (5%). Significant reduction was recorded in almost all the test crops for most of the growth parameters, except for *Zea mays* in which considerable stimulation was found under 1, 3 and 5% leaf mulch. Further R/S length and dry weight ratio were also enhanced in all the species except few cases, when compared to their respective controls. On the other hand, maximum (42.80cm) shoot length under bark mulch in *Zea mays* and root length (28.84cm) was found in *Zea mays* at (5%), minimum (6.36cm) shoot length (1%) and root length (4.48cm) was found in *Phaseolus radiatus* (3%). Maximum shoot (8.64g) and root fresh weight (2.27g) was found in *Zea mays* at (5%), minimum (0.50g) shoot and root fresh weight (0.00g) was found in *Phaseolus radiatus* (5%). Maximum shoot (5.85g) and root dry weight (1.20g) was noticed in *Zea mays* (5%), minimum (0.07g) shoot at 3% and root dry weight (0.00g) was found in *Phaseolus radiatus* (5%). Maximum R/S length ratio (2.20) was found in *Zea mays* (1%) and R/S dry weight ratio (1.04) was found in *Brassica nigra* (5%), minimum (0.07) R/S length in *Brassica nigra* (5%) and R/S dry weight (0.10) was found in *Zea mays* at (3%). Significant suppression was recorded in almost all the test crops for most of the growth parameters, except for *Zea mays* in which considerable increase was recorded under 1, 3 and 5% bark mulch. Further R/S length and dry weight ratio were also stimulated in all the species except few cases, when compared to their respective controls (Table 3).

Populus ciliata: Under leaf mulch, maximum shoot length (59.86cm) and root length (28.76cm) was found in *Zea mays* (3%), minimum (10.48cm) Shoot length and root length (6.06cm) was found in *Cicer arietinum* (1%). Maximum (14.45g) shoot and root fresh weight (2.68g) was found in *Zea mays* (3%), minimum shoot fresh weight (0.35g) in *Cicer arietinum* (1%) and root fresh weight (0.06g) was found in *Phaseolus radiatus* at (3%). Maximum (11.97g) shoot (3%) and root dry weight (1.79g) was recorded in *Zea mays* (5%), minimum shoot dry weight (0.179g) was found in *Cicer arietinum* (3%) and root dry weight (0.03g) was found in *Phaseolus radiatus* (3%). Maximum (0.85) R/S length ratio (at 3 and 5%) and R/S dry weight ratio (0.39) was found in *Cicer arietinum* (1%). Minimum (0.47) R/S length and dry weight ratio (0.11) was found in *Phaseolus radiatus* (5%) and *Zea mays* (5%). Significant reduction was observed in all the test crops for most of the growth parameters, except for *Zea mays* in which considerable enhancement was found under 1, 3 and 5% leaf mulch. R/S length and dry weight ratio were also stimulated in all the species except few cases, when compared to their respective controls. Under bark mulch, maximum shoot (46.24cm) and root length (28.30cm) was found in *Zea mays* (1%), minimum (10.32cm) shoot and root length (6.8cm) was found in *Phaseolus radiatus* (3%). Maximum (19.31g) shoot (3%) and root fresh weight (2.37g) was found in *Zea mays* (1%), minimum (0.74g) shoot and root fresh weight (0.03g) was found in *Phaseolus radiatus* (3%). Maximum shoot (9.15g) and root dry weight (1.10g) was observed in *Zea mays* (1%), minimum shoot dry weight (0.24g) and root dry weight (0.02g) was found in *Phaseolus radiatus* (3%). Maximum (0.86) R/S length ratio in *Zea mays* (5%) and R/S dry weight ratio (0.38) was found in *Cicer arietinum* (1%), minimum (0.61) R/S length in *Zea mays* (1%) and R/S dry weight ratio (0.09) was found in *Phaseolus radiatus* (5%). Significant reduction was recorded in almost all the test crops for most of the growth parameters, except for *Zea mays* in which considerable increase was found under 1, 3 and 5% bark mulch. Further R/S length and dry weight ratio were also stimulated in all the species except few cases, when compared to their respective controls (Table 3).

In the face of the utmost significant allelopathic effect, it will be worthy to utilize the data on allelopathic investigation as a substantial factor in the competitive ability of the tree species and field crops. Phytotoxic responses of leaf and bark extracts of various agroforestry tree crops on germination and radical and plumule extension of field crops have also been reported earlier (Ferguson and Rathinasabapathi, 2003; Todaria and Dhanai, 2010; Obongoy, *et al*, 2010; Wu *et al*, 2009l Yeni *et al*, 2010). Singh *et al.* (2006) found *Ficus auriculata* Lour, the most toxic for germination while *Ficus palmate* Forsk inhibit the radical and plumule growth of all the tested crops. Similarly, our findings has clearly reveled that leaf and bark extracts of *Juglans regia* and *Salix alba* were found most toxic for germination as well as radical-plumule growth, irrespective of different concentrations, radical and plumule growth was also significantly reduced as compared to control. Leaf extracts of *Juglans regia* and *Salix alba* significantly inhibited the percent germination in all the test crops, irrespective of different concentrations. Similarly, radical and plumule growth was severely affected under all the concentrations of bark extracts as compared to control. Leaf and bark extracts of *Populus ciliata* were found less effective in germination and radical-plumule for all the test crops except for, *Brassica nigra*, irrespective of all concentrations. The bark aqueous extract was almost found stimulatory in radical and plumule growth of all test crops except *Brassica nigra* as compared to control (Table 2).

DISCUSSION

Laboratory trial

Among all the test crops, *Cicer arietinum* was found more sensitive but *Phaseolus radiatus* was found least effective under different leaf and bark extracts of *Juglans regia* and *Salix alba* with respect to germination and radical-plumule growth, leaf extracts were found stimulatory in terms of germination and radical-plumule growth as compared to bark extracts (Figures 1, 2 and 3). Our experience with Poplars with respect to germination and growth of all the test crops are in line with the earlier findings (Chon *et al,* 2000; Thapliyal *et al*, 2008). Almost all the test crops were found sensitive in terms of germination and radicle -plumule growth, irrespective of different concentrations of extracts of all three tree species except for *Populus ciliata,* which is at par with the findings of Thakur and Bhardwaj (1992). Our findings on *Salix alba* and *Juglans regia* with respect to germination and growth of all test crops are in line with the earlier findings of Appleton *et al.* (2000), they also found that the juglone and leaf extract had an inhibitory effect on plant growth of several plant species. Kocakaliskan and Terzi (2001) and Terzi (2008) also demonstrated that both juglone and other walnut leaf extracts inhibit the germination and seedling growth of several plant species. On an average the only stimulation was observed in *Brassica nigra* (1 and 3%), percent germination in other test crops was significantly suppressed under both lab and field conditions with leaf/bark extracts and mulches of all there agroforestry tree species. Juglans extracts slightly stimulated the germination of *Cicer arietinum* under laboratory condition. As far as seedling growth is concerned, leaf/bark extracts of *Salix alba* and *Juglans regia* significantly inhibit the radical-plumule growth, however, leaf/bark extracts of *Populus ciliata* had remarkable stimulation in radical-plumule growth of *Cicer arietinum* and slightly in radical growth of *Phaseolus radiatus* (Table 1 and 2).

Field trial

Percent germination was considerably reduced in all the test crops under different leaf and bark mulch of all three agroforestry tree species, however, stimulation was noticed in *Brassica nigra* under 1 and 3% leaf and bark mulch respectively as compared to control. Our findings clearly reveal that *Populus ciliata* was found least effective among all three agroforestry tree species (Table 1). As far as effect of different leaf and bark mulch of all three agroforestry tree species on various growth parameter of test crops is concerned, significant reduction was calculated in almost all the test crops for most of the growth parameters, except for *Zea mays* in which considerable stimulation was found under 1 and 3% leaf mulch. Further, R/S length and dry weight ratio were also stimulated in all the species except few cases, when compared to their respective controls (Table 3). Further, among all three agroforestry tree species, *Populus ciliata* was found least harmful to growth performance of all the tested crops. Mulch of all there agroforestry trees stimulated the seedlings growth (Root, shoot length and their dry weight) of *Zea mays*. *Populus ciliata* stimulated the root growth of *Phaseolus radiatus*. Its root dry weight was stimulated by both leaf and bark mulch (at 1 % Conc) of all tree spp. However, all concentrations of *Salix alba* bark extract stimulated the root dry weight. Root-shoot growth of *Cicer arietinum* and *Brassica nigra* were considerably reduced under leaf/bark mulch of these three agroforestry tree species (Table 3).

The above summary indicates that variable concentrations of leaf/bark mulch had great significant differences with respect to germination and root-shoot growth of all the test crops except *Populus ciliata* where it was found moderately or less effective but stimulatory in some cases. In earlier studies on agroforestry systems, the agricultural losses experienced by farmers, have been ascribed to adverse effect of farm trees on cultivated land (Todaria and Dhanai, 2010; Csizar, 2009; Siddiqui *et al*, 2009a; Singh *et al*, 2009a; Singh *et al*, 2009b; Singh *et al*, 2008; Nakafeero *et al*, 2007; Nazir *et al*, 2007; Uniyal and Chhetri, 2010; Willis, 2000). These findings revealed that almost all test crops were found sensitive in terms of germination and growth of seedlings irrespective of different concentrations of mulch of tree species except *Populus ciliata*, where it was found stimulatory in some cases which is at par with the earlier studies on agroforestry tree species of Garhwal hills for their allelopathic effects on field crops (Obongoy *et al*, 2010; Todaria and Dhanai, 2010; Siddiqui *et al*, 2009a; Singh *et al*, 2009a; Singh *et al*, 2009b; Singh *et al*, 2008). Therefore, it may be suggest that the *Salix alba* and *Juglans regia* have strong allelopathic effect and should avoid in the agriculture fields while *Populus ciliata* has least or no allelopathic effect and it may be grown mixed with the agriculture crops.

The phytotoxic influences of agroforestry tree crops might be due to the presence of tannins, phenolics and other secondary metabolites found in various plant parts (Mohammad *et al*, 2009). The chemical responsible for Walnut allelopathy is juglone (5-hydroxy-1,4 naphthoquinone) (Ferguson *et al*, 2003; Jose, 2002; Yeni *et al*, 2010). Previous reports indicate that foliage leachates are sources of toxic metabolites and the toxic effects are species specific (May and Julian, 1990). In this study, we also found that leaf extracts were very effective in suppressing germination as compared to bark but both leaf and bark extracts were equally effective in suppressing radicle and plumule extension, which is at par with the findings of various scientists (Thapliyal *et al*, 2008; Ahmed *et al*, 2008; Mohammad *et al*, 2009; Siddiqui *et al*, 2009a; Siddiqui *et al*, 2009b; Singh *et al*, 2008, Singh *et al*, 2006; Umer *et al*, 2010; Obongoy *et al*, 2010; Uniyal and Chhetri, 2010; Wu *et al*, 2009). Similar study (Chon *et al*, 2000) reported root length as best indicator of allelopathic effect of plant extracts because root growth has been reported to be more sensitive to toxic compounds than hypocotyls growth. Furthermore, the permeability of allelochemicals to root tissues was reported to be greater than that to shoot tissues (Nishida *et al*, 2005). Certain allelochemicals may reduce cell division, resulting in reduction of shoot -root systems. In addition, an indirect association between lower germination and allelopathic inhibition may be the consequence of the inhibition of water uptake (El-Khatib, 1997). All the investigated tree crops are used extensively as multipurpose farm trees in Kashmir Himalaya. The allelopathic influence of these agroforestry tree species might be due to high alkaloid contents. Different inhibitory effects of various parts of the same plants are likely due to variability in the amount of phytotoxic compounds in different plant tissues (Nishimura *et al*, 1982).

Conclusions

Present study revealed the considerable effect of agroforestry tree species on germination and radical-plumule/root-shoot growth of all test crops. Among these tree species, *Populus ciliata* was found least effective but stimulatory with respect to germination and radical-plumule/ root-shoot growth in some test crops at low concentration but inhibitory under high (5%) concentration. *Salix alba* and *Juglans regia* significantly inhibited germination and radical/plumule/ root-shoot growth of all test crops except *Brassica nigra*, *Zea mays* and *Phaseolus radiatus* were found resistant under lower concentration, while *Cicer arietinum* was found most sensitive test crop. The study revealed that the agriculture crops may be cultivated under *Populus ciliata* as it shows least/no effect. The preference order of agroforestry tree species on the basis of both laboratory and field trials is suggested as: *Populus ciliata* > *Juglans regia* > *Salix alba* and the order of agriculture field crops preference is: *Brassica nigra* > *Zea mays* > *Phaseolus radiatus* > *Cicer arietinum*. Therefore, it is concluded that the results obtained within the scope of our study yielded sufficient evidence for considerable allelopathic effects from *Juglans regia* and *Salix alba*. Our data support allelopathy as a substantial factor in the competitive ability of the tree species and field crops. We therefore, should focus on the further study for population dynamical aspects to unravel the key traits underlying the establishment of sustained agriculture in Kashmir Himalaya.

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