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Original Article

Evaluation of bioherbicidal potential of *Carica papaya* leaves

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Abstract

Due to increased number of herbicide resistant weeds, it is needed to explore the allelopathic potential of plants as an alternative. The research was conducted to investigate allelopathic effects of *Carica papaya* L. leaf powder and aqueous extract on seeds as well as pre-germinated seeds of *Avena fatua* L., *Helianthus annuus* L., *Rumex dentatus* L., *Zea mays* L. and *Triticum aestivum* L. on filter paper and soil in Weed Management Program Laboratory, Department of Plant and Environmental Protection at PARC Institute of Advanced Studies in Agriculture, National Agriculture Research Centre, Islamabad, Pakistan. Germination percentage (%), radicle length (cm) and plumule length (cm) were parameters observed for 'Plant leaf powder bioassay' and 'Aqueous extract method'. Most significant growth inhibition was observed in *A. fatua* seedlings in filter paper method. *A. fatua* radicle length was reduced by *C. papaya* aqueous extract (80%) and leaf powder (89%) bioassays. Plumule length was reduced under the influence of aqueous extract (57-73%) and powdered material (59-77%). The inhibitory effects on other test species were in sequence of *H. annuus* followed by *Z. mays* and *R. dentatus*. The aqueous extract showed non-significant effect on wheat seed germination, radicle and plumule growth. It is suggested that *C. papaya* aqueous extract can be used as source of weed management in wheat crop.

Keywords: allelopathy, bioherbicide, *Rumex dentatus*, *Avena fatua*, weed suppression.

Avaliação do potencial de bioherbicida dase folhas de *Carica papaya*

Resumo

Devido ao aumento do número de ervas daninhas resistentes aos herbicidas, é necessário explorar o potencial alelopático das plantas como uma alternativa. A pesquisa foi conduzida com o objetivo de investigar os efeitos alelopáticos do pó foliar de *Carica papaya* e do extrato aquoso das sementes, bem como das sementes pré-germinadas de *Avena fatua*, *Helianthus annuus*, *Rumex dentatus*, *Zea mays* e *Triticum aestivum* em papel de filtro e solo no Laboratório do Programa de Manejo de Ervas Daninhas, Departamento de Plantas e Proteção Ambiental do Instituto PARC de Estudos Avançados em Agricultura, Centro Nacional de Pesquisa Agrícola, Islamabad, Paquistão. A porcentagem de germinação (%), o comprimento radicular e o comprimento da plúmula (cm) foram os parâmetros observados para o 'Bioensaio de Pó de Folha de Planta' e o 'Método de Extração Aquoso'. A maior inibição do crescimento foi observada em mudas de *A. fatua* no método de papel de filtro. O comprimento radicular de *A. fatua* foi reduzido com os extratos aquosos de *C. papaya* (80%) e pó de folhas (89%). O comprimento das plúmulas foi reduzido sob a influência do extrato aquoso

(57-73%) e material em pó (59-77%). Os efeitos inibitórios em outras espécies-teste foram na sequência de *H. annuus* seguido por *Z. mays* e *R. dentatus*. O extrato aquoso apresentou efeito não significativo na germinação das sementes de trigo, nos crescimentos radiculares e das plúmulas. Sugere-se que o extrato aquoso de *C. papaya* pode ser utilizado como fonte de manejo de plantas daninhas na cultura do trigo.

Palavras-chave: alelopatia, bioherbicida, *Rumex dentatus*, *Avena fatua,* supressão de plantas daninhas.

1. Introduction

Weeds are non-economic plants that reduce crop yield (Mukhtar et al., 2012). Weeds along resource competition with crops exhibit allelopathy (Batish et al., 2007). Allelopathy is natural tool to increase crop yield by weed control reducing utilization of synthetic herbicides (Alagesaboopathi, 2010). Studies have suggested allelochemicals as alternatives to synthetic herbicides for weed control (Khanh et al., 2006; Jamil et al., 2009). In Pakistan, weeds are serious problem in crop production. Pesticides have been utilized for weed management but most of them are hazardous to the environment and human health. If weeds are properly controlled, grain production in Pakistan can be increased up to 37% (Khanh et al., 2008). Allopathy has been mentioned in many plants releasing chemicals in environment from aerial or underground parts. The allelochemicals released into environment act on neighboring weeds, plants, microbes both stimulatory and inhibitory. Allelopathic weeds have advantages from agronomic point of view and can be used in weed management practices (Anwar et al., 2016). Allelopathy is 'detrimental effect of one plant on another through release of chemicals'. The interaction is mediated by allelopathic compounds released from donor affecting acceptor organisms. Allelopathic interaction among individuals of same species is 'intraspecific toxicity' or 'auto-allelopathy'. Contrarily, term 'tele-toxicity' is used when suspect species is taxonomically different from donor species (Garima and Devi, 2017). Allelopathic compounds produced by higher plants are mostly secondary metabolites. Phenolics, quinones, cyanogenic glycosides, organic acids, lactones and terpenes belong to active compounds. Table 1 represents brief overview of allelochemicals isolated from different plants (Qureshi and Arshad, 2017). Phenolic acids and terpenoids are common types of allelochemicals (Shankar et al., 2009). Allelochemicals from donor plant disrupt physiological processes e.g., photosynthesis, respiration, water and hormonal balance of recipient plant by inhibition of enzyme activity (Soltys et al., 2013). Allelochemicals are useful for weed management in agriculture to reduce dependency on commercial herbicides. An allelopathic crop can potentially be used to control weeds through its allelochemicals. Scopolin and Scopoletin isolated from *Celtis laevigata* suppress *Amaranthus palmeri*. *Annona squamosa*, *Coffea arabica*, *C. papaya,* and *Tamarindus indica* inhibit germination of *Amaranthus spinosus*. *Eucalytus citriodora* showed allelopathic effect on the growth of *Digitaria pertenuis, Bidens pilosa, Setaria geniculate, Eragrostis cilianensis*. Similarly, *Eucalyptus citriodora* inhibited the germination of *P. hysterophorus* (Garima and Devi, 2017).

C. papaya belongs to family Caricaceae. Previously papaya seeds and fruits are reported to have powerful inhibitory compound benzyl isothiocyanate (BITC). This compound has fungicidal, bactericidal and insecticidal activity. Two closely related allelocompounds (allyl isothiocyanate, phenethyl isothiocyanate) are known to be germination inhibitors (Wolf et al., 1984). The specific objectives of current study were:

1. Assess herbicidal potential of *C. papaya* by 'plant leaf powder bioassay' against seeds and pre-germinated seeds of selected test species on filter paper and soil;
2. Assess herbicidal potential of *C. papaya* against seeds and pre-germinated seeds of selected test species through 'aqueous extract bioassay' on filter paper and soil.

2. Material and Methods

2.1. Collection of plant material and procurement of seeds of test species

Mature, healthy leaf material of *C. papaya* was collected from roadside of Rawalpindi District (73°02′ E longitude; 33°36′ N latitude), Pakistan. Collected leaves were thoroughly washed under running tap water to remove any dust particles and shade dried till complete drying (six days in our case). The dried leaf material was then ground to fine powder. Seeds of selected test species viz. *A. fatua, R. dentatus*, *T. aestivum* (Wafaq 2001), *H. annuus* (K.S.E 7777) and *Z. mays* (Islamabad Gold 2010) were procured from Department of Crop Science, National Agriculture Research Centre, Islamabad, Pakistan. 1% sodium hypochloride (NaClO) solution was used to surface sterilize seeds of test species.

2.2. Aqueous extract bioassay

Dried leaf powder (10g) of *C. papaya* was soaked in 200ml distilled water in round bottom flask and agitated on orbital shaker (150 rpm) for twenty four hours at room temperature (25°C). The extract was filtered through Whatman filter paper No. 1. Screening for seeds and pre-germinated seeds was carried out on filter paper and soil. For screening on filter paper, 5ml leaf extract was poured into petri dishes underlined with filter paper. Ten surface sterilized seeds of each test species were placed in petri dishes. The petri dishes were then sealed with parafilm, covered with aluminum foil and incubated

Table 1. Common allelopathic compounds and representing plants.

Plant species	Isolated Allelochemicals
Acroptilon repens (L.) DC.	Cnicin (Sesquiterpene lactone) and 7,8-benzoflavone (Flavone)
Alliaria petiolata (Bieb.) Cavara and Grande	Alliarinoside (Glucoside)
Artemisia tridentate ssp. *tridentata*	Methyl jasmonate (Volatile organic compound)
Berberis thunbergii DC.	Berberine (Alkaloid)
Carduus nutans L. and *C. acanthoides* L.	Aplotaxene (Essential oil)
Celastrus orbiculatus Thunb.	Celastrol (Terpenoid)
Centaurea biebersteinii DC.	(-)-Catechin (Flavonoid)
Centaurea diffusa Lam.	8-Hydroxyquinoline (Alkaloid), Caryophyllene oxide (Sesquiterpene), Linoleic acid (Fatty acid)
Centaurea maculosa Lam.	(±)- Catechin (Phenol)
Centrostachys aquatica (R.Br.) Moq.	Loliolide (Terpene)
Chenopodium ambrosioides (L.) Mosyakin & Clemants	α-terpinene (Terpene), limonene (Terpene), ascaridole(Terpene)
Cytisusscoparius (L.) Link	Sparteine (Alkaloid)
Elaeagnus angustifolia L.	Harman (Amine)
Euphorbia esula L.	Esulatin (Terpenoid)
Geranium carolinianum L.	Ethyl gallate (Phenol)
Hieracium pilosella L.	Umbelliferone (Coumarin)
Hypericum perforatum L.	Hypericin (Anthraquinone)
Hyptis suaveolens (L.) Poit.	Suaveolic Acid (Terpenoid)
Imperata cylindrica (L.) P.Beauv.	Tabanone, Hexadecahydro-1-azachrysen-8-yl ester (Alkaloid)
Linaria dalmatica (L.) P. Mill.	Linarioside (Glocoside)
Lythrum salicaria L.	Gallic acid (Phenolic acid)
Melaleuca quinquenervia (Cav.) Blake	Nerolidol (Sesquiterpene)
Mikania micrantha H.B.K.	Deoxymikanolide (Sesquiterpenoids), dihydromikanolide (Sesquiterpenes), 2,3-epoxy-1-hydroxy-4,9-germacradiene-12,8:15,6-diolide (Sesquiterpenoid)
Pastinaca sativa L.	Xanthotoxin (Coumarin)
Phragmites australis	Gallic acid (Phenolic acid)
Polygonum cuspidatum Sieb. And Zucc.	Piceid (Glucoside)
Pueraria montana (Lour.) Merr.	Biochanin-A (Isoflavone)
Rhamnus cathartica L.	Emodin (Resin)
Sapium sebiferum (L.) Roxb.	Xanthoxylin (Phenol)

in growth chamber at room temperature. Germination percentage (%), plumule and radicle length (cm) of test species were recorded after fifteen days with reference to control. For screening on soil, 15ml leaf extract was poured into petri dishes underlined with 25g soil.

2.3. Plant leaf powder bioassay

C. papaya leaf powder (0.25g) was added to filter paper in petri dish along with 5ml distilled water. In each petri dish, ten surface sterilized seeds of test species were placed. The petri dishes were sealed with parafilm, covered with aluminum foil and incubated in growth chamber at room temperature. Germination percentage (%), plumule and radicle length (cm) were recorded after fifteen days with reference to control. For screening on soil, *C. papaya* leaf powder (0.25g) was added to 25g soil along with 15ml distilled water in petri dish. 15ml distilled water was used in petri dishes as control without adding leaf powder on soil and parameters were studied for bioassay.

2.4. Statistical analysis

STATISTIX 9 was used for data interpretation and mean values of studied parameters were separated by Fisher‘s protected LSD test (Steel and Torrie, 1997).

3. Results

The data analysis indicated that application of plant aqueous extract and dry powdered material of *C. papaya* leaves (next mentioned as ‘screening material’) significantly reduced germination percentage (%) of all test species viz. *A. fatua*, *R. dentatus*, *H. annuus*, *Z. mays* and *T. aestivum* Although germination inhibition (%) was observed for all test species by dry powdered form and aqueous extract of screening material on filter paper and soil, most significant inhibition in germination percentage (%) was observed by its aqueous extract applied on filter paper. Among test species, germination of *A. fatua* seeds was most affected by *C. papaya* plant material in each form. For other test species, reduction in germination was observed in *R. dentatus*, followed by *Z. mays* and *H. annuus* with almost similar inhibitory effects. However, germination of *T. aestivum* was least affected with the application of both aqueous extract and dry powdered material (Table 2). Likewise, the effects of *C. papaya* on seed germination, most of the radicle growth inhibition was also observed in the seedlings of *A. fatua* on filter paper medium. The radicle length was significantly reduced by *C. papaya*, both in aqueous (80%) and dry powdered form (89%) (Table 3-4). On the other hand, plumule growth was also reduced under the influence of aqueous extract (57-73%) and powdered material (59-77%) (Table 5-6). The inhibitory effects on other test species were in the sequence of *H. annuus*, followed by *Z. mays*, *R. dentatus* and *T. aestivum* being the least affected test species among all. In a comparison between the effects on seed and pre-germinated seeds, more inhibition was found in pre-germinated seeds of different test species under the influence of aqueous extract and powdered plant material. *R. dentatus* was mostly affected by aqueous extract of *C. papaya* compared to the application of plant material in powdered form. The inhibitory effects were found in

Table 2. Germination percentage of seeds of test species in aqueous extract and leaf dry powder of *C. papaya* in filter papers and soil.

Treatments		Test Species				
		A. fatua	*H. annuus*	*R. dentatus*	*T. aestivum*	*Z. mays*
Aqueous extract	Filter Paper	20^{b}	59^{b}	26^{b}	95^{a}	48^{b}
	Control	86^{a}	100^{a}	80^{a}	99^{a}	92^{a}
	[1]LSD	14.197	17.604	14.541	17.902	19.778
	[2]F-value	42*	14.67*	43.98*	12.13*	13.52*
	Soil	29^{b}	50^{b}	21^{b}	91^{a}	56^{b}
	Control	90^{a}	96^{a}	89^{a}	94^{a}	93^{a}
	[1]LSD	17.510	14.744	16.580	13.554	14.08
	[2]F-value	22.36*	21.04*	51.38*	13.63*	38.81*
Dry powder	Filter Paper	36^{b}	56^{b}	55^{b}	96^{a}	40^{b}
	Control	95^{a}	97^{a}	86^{a}	98^{a}	82^{a}
	[1]LSD	17.66	16.974	17.529	14.722	16.974
	[2]F-value	26.08*	13.78*	21.73*	27.64*	13.29*
	Soil	49^{b}	37^{b}	32^{b}	93^{a}	29^{b}
	Control	99^{a}	99^{a}	89^{a}	96^{a}	84^{a}
	[1]LSD	18.890	18.60	17.67	18.608	17.435
	[2]F-value	17.19*	33.19*	32.71*	10.89*	21.97*

Note: [1]Means followed by different letters within one column differ significantly at ($P < 5\%$); [2]*=Significant at ($P < 1\%$).

Table 3. Radicle length (cm) of seeds and pre-germinated seeds of test species as suppressed by aqueous extract of *C. papaya* in filter papers and soil.

Treatments		Test species				
		A. fatua	*H. annuus*	*R. dentatus*	*T. aestivum*	*Z. mays*
Seeds	Filter Paper	4.32^{b}	5.11^{b}	6.21^{b}	12.6^{a}	4.12^{b}
	Control	11.2^{a}	9.48^{a}	8.03^{a}	13.15^{a}	10.3^{a}
	[1]LSD	1.0971	1.0360	1.0027	3.0879	0.6573
	[2]F-value	126.95*	128.48*	92.48*	18.78*	309.12*
	Soil	2.48^{b}	2.48^{b}	5.46^{b}	11.2^{a}	3.29^{b}
	Control	10.45^{a}	8.39^{a}	7.17^{a}	11.4^{a}	8.45^{a}
	[1]LSD	1.1918	1.0634	0.8063	1.8106	1.0912
	[2]F-value	98.97*	74.89*	126.70*	52.46*	83.01*
Pre-germinated seeds	Filter Paper	2.09^{b}	3.48^{b}	1.24^{b}	14.9^{a}	2.37^{b}
	Control	10.2^{a}	10.1^{a}	5.33^{a}	16.2^{a}	7.27^{a}
	[1]LSD	0.4135	2.0401	0.7263	3.4976	1.5567
	[2]F-value	740.81*	30.76*	64.28*	18.78*	22.96*
	Soil	2.28^{b}	2.17^{b}	3.07^{b}	12.1^{a}	2.12^{b}
	Control	9.11^{a}	8.49^{a}	4.11^{a}	13.4^{a}	6.42^{a}
	[1]LSD	0.8095	1.9073	0.9043	2.5542	1.2569
	[2]F-value	206.09*	27.90*	20.88*	23.58*	39.32*

Note: [1]Means followed by different letters within one column differ significantly at ($P < 5\%$); [2]*=Significant at ($P < 1\%$).

Table 4. Radicle length (cm) of seeds and pre-germinated seeds of test species as suppressed by leaf dry powder of *C. papaya* in filter papers and soil.

Treatments		Test species				
		A. fatua	***H. annuus***	***R. dentatus***	***T. aestivum***	***Z. mays***
Seeds	Filter Paper	1.01^{b}	4.25^{b}	5.49^{b}	13.1^{a}	3.23^{b}
	Control	9.34^{a}	8.49^{a}	7.07^{a}	14.3^{a}	9.01^{a}
	[1]LSD	0.5692	1.4388	1.203	3.2679	0.6136
	[2]F-value	485.76*	56.00*	56.71*	22.22*	279.70*
	Soil	2.47^{b}	6.06^{b}	6.45^{b}	10.3^{a}	4.31^{b}
	Control	8.05^{a}	9.30^{a}	8.46^{a}	9.49^{a}	11.1^{a}
	[1]LSD	0.999	1.0662	1.320	1.540	1.1125
	[2]F-value	66.33*	95.32*	56.72*	45.47*	111.84*
Pre-germinated seeds	Filter Paper	2.07^{b}	2.08^{b}	2.10^{b}	1.9^{a}	3.30^{b}
	Control	12.3^{a}	9.45^{a}	6.07^{a}	13.4^{a}	8.07^{a}
	[1]LSD	0.9870	1.1352	0.9713	2.4770	1.4150
	[2]F-value	209.06*	110.25*	49.22*	18.01*	41.84*
	Soil	3.38^{b}	1.17^{b}	2.17^{b}	11.8^{a}	1.49^{b}
	Control	10.05^{a}	8.00^{a}	5.21^{a}	13.4^{a}	8.14^{a}
	[1]LSD	0.8763	1.2929	0.8953	3.1490	1.7841
	[2]F-value	129.81*	66.06*	50.17*	22.59*	34.17*

Note: [1]Means followed by different letters within one column differ significantly at ($P < 5\%$); [2]*=Significant at ($P < 1\%$).

Table 5. Plumule length (cm) of seeds and pre-germinated seeds of test species as suppressed by aqueous extract of *C. papaya* in filter papers and soil.

Treatments		Test species				
		A. fatua	***H. annuus***	***R. dentatus***	***T. aestivum***	***Z. mays***
Seeds	Filter Paper	4.34^{b}	2.22^{b}	2.12^{b}	7.05^{a}	4.22^{b}
	Control	10.15^{a}	6.39^{a}	8.06^{a}	8.16^{a}	8.45^{a}
	[1]LSD	0.6647	0.9468	0.6294	1.3210	1.0678
	[2]F-value	238.96*	37.04*	197.36*	45.63*	97.24*
	Soil	2.34^{b}	2.00^{b}	1.69^{b}	7.32^{a}	3.09^{b}
	Control	7.40^{a}	8.37^{a}	7.45^{a}	8.49^{a}	7.00^{a}
	[1]LSD	0.8978	1.0434	1.0019	2.3502	0.7620
	[2]F-value	71.85*	73.9*	87.41*	9.64*	101.44*
Pre-germinated seeds	Filter Paper	3.01^{b}	4.49^{b}	2.12^{b}	10.1^{a}	4.01^{b}
	Control	9.08^{a}	10.05^{a}	9.20^{a}	11.8^{a}	11.45^{a}
	[1]LSD	0.3036	1.5861	0.8317	2.5454	1.7866
	[2]F-value	825.69*	47.89*	152.73*	14.38*	80.15*
	Soil	2.30^{b}	4.16^{b}	2.01^{b}	8.96^{a}	7.13^{b}
	Control	8.48^{a}	9.08^{a}	7.44^{a}	10.1^{a}	13.2^{a}
	[1]LSD	1.2227	1.2301	0.9318	2.3413	1.2891
	[2]F-value	54.40*	56.75*	69.05*	20.36*	88.02*

Note: [1]Means followed by different letters within one column differ significantly at ($P < 5\%$); [2]*=Significant at ($P < 1\%$).

the range of 73-77% plumule and 23-77% radicle, both in seeds and pre-germinated seeds (Table 2-5). The inhibitory effects of *C. papaya* on *Z. mays* and *H. annuus* were somehow like each other. 82% radicle growth inhibition was found in soil experiment of *Z. mays* with powdered plant material while in case of *H. annuus*, these effects were up to 85% (Table 2-3). On the other hand, there was up to 67% radicle growth inhibition in *Z. mays* with plant aqueous extract while 76% plumule growth inhibition in *H. annuus* with the same extract. Apart from the effects on above mentioned four test species, *T. aestivum* was found to be the least affected test species. Aqueous extract of *C. papaya* inhibited 2-10% radicle and 11-14% plumule growth in both seed and seedling stages with soil and filter paper experiments (Table 2 & 4). *C. papaya* in dry powdered form variably affected the growth of this test species. Maximum inhibition (86%) was found in radicle growth of pre-germinated seedlings while 9% stimulation was also observed in radicle growth of seeds of this plant species (Table 4 and 6).

Table 6. Plumule length (cm) of seeds and pre-germinated seeds of test species as suppressed by leaf dry powder of *C. papaya* in filter papers and soil.

Treatments		Test species				
		A. fatua	*H. annuus*	*R. dentatus*	*T. aestivum*	*Z. mays*
Seeds	Filter Paper	2.47^{b}	2.23^{b}	0.02^{b}	7.65^{a}	4.09^{b}
	Control	8.49^{a}	5.42^{a}	7.96^{a}	9.48^{a}	7.46^{a}
	^{1}LSD	1.2971	0.8718	0.0182	2.7846	0.9640
	^{2}F-value	46.74*	55.81*	14.11*	6.44*	57.31*
	Soil	3.00^{b}	2.12^{b}	2.12^{b}	11.25^{a}	5.45^{b}
	Control	7.44^{a}	6.40^{a}	9.07^{a}	12.15^{a}	8.07^{a}
	^{1}LSD	1.4091	1.1428	0.7297	2.2332	0.9679
	^{2}F-value	26.83*	29.95*	221.41*	28.95*	83.03*
Pre-germinated seeds	Filter Paper	2.13b	4.09^{b}	2.00^{b}	9.35^{a}	5.30^{b}
	Control	9.45^{a}	9.45^{a}	8.12^{a}	9.35^{a}	11.4^{a}
	^{1}LSD	0.9834	1.2510	0.6111	1.8694	2.1870
	^{2}F-value	124.1*	57.71*	216.40*	17.04*	37.65*
	Soil	3.31^{b}	3.25^{b}	2.13^{b}	7.01^{a}	2.14^{b}
	Control	8.07^{a}	8.06^{a}	7.10^{a}	8.45^{a}	10.05^{a}
	^{1}LSD	1.0523	1.1964	0.9823	2.1252	0.8164
	^{2}F-value	48.12*	66.81*	66.95*	70.87*	280.93*

Note: ^{1}Means followed by different letters within one column differ significantly at ($P < 5\%$); ^{2}*=Significant at ($P < 1\%$).

4. Discussion

C. papaya belongs to a small family *Caricaceae*. It is succulent plant growing in tropical countries and sub-tropical regions of the world. Allelochemicals are released by different parts of the plant and leaves are most active in this respect (Rehman et al., 2014). The plant is reported to possess organic acids, alkaloids, tannins and flavonoids which hamper growth of adjacent plants (Canini et al., 2007). *C. papaya* is known to influence the growth of plants in its vicinity by the release of the allelochemicals during the decomposition of its litter (Christobel et al., 2017). Allelopathic potential of *C. papaya* leaves for pest management is reported earlier. Crude aqueous leaf extracts of *C. papaya* on susceptibility of fourth instar larvae of *Spodoptera litura* showed a significant total percent mortality (Deshmukhe et al., 2009). Therefore, allelopathic effect of leaves of *C. papaya* was evaluated for its aqueous extract as well as dry powder against five test species i.e., *T. aestivum*, *A. fatua*, *H. annuus*, *Z. mays* and *R. dentatus*. For each test species, screening plant material was applied on filter paper and soil separately in both aqueous extract and powdered form that variably reduced the germination and growth of test plants.

In our experiments, *C. papaya* affected germination of all test species. Similar to our results, inhibition of seed germination was observed in *Sinapis arvensis* by *Glaucium* species (Ghorbanli et al., 2011), in sorghum, sesame, sunflower and corn by mungbean (Lertmongkol et al., 2011), in chive and soybean by ginger (Han et al., 2008). Reigosa et al. (1999) proposed that allelochemicals affect physiological functions during germination thus hindering the process. It was reported that, seed characteristics such as seed coat permeability and seed size influence effects of allelochemicals in seeds and interference of the allelochemical compounds vary accordingly (Marianne et al., 2000). Similar results were proposed by Gherardi and Valio (1976) and Chow and Lin (1991) in bioassays with lettuce seeds and by Reyes et al. (1980) with cucumber seeds. Chow and Lin (1991) used extracts of sarcotesta and seeds of papaya, which showed presence of germination and growth inhibitors in the sarcotesta, halting the germination of lettuce seeds, which had also observed earlier by Gherardi and Valio (1976). They state that such inhibitors are phenolic in nature. In our study, most significant inhibition effects were found on *A. fatua* as compared to other test species. Similar results were reported by Turk and Tawaha (2003) showing negative germination effects of aqueous extract of *Brassica nigra* on *A. fatua*. *A. fatua* was also found to be a susceptible species against *P. hysterophorus* (Batish et al., 2002; Marwat et al., 2008; Anwar et al., 2019). These observations have indicated that this test plant species is susceptible to number of allelopathic plants (Anwar et al., 2017a, 2018c).

Radicle and plumule length inhibition was obsered in test species. Kato-Noguchi (2011) also observed epicotyl and hypocotyl inhibition by the allelopathic extracts of different plants. Similar results were reported by Oudhi (2001), Anwar et al. (2018d) and Maharjan et al. (2007). Allelopathic assessment of *C. papaya* leaves, in our study, indicated that radicle length was more affected than plumule length. These findings support root sensitivity to allelochemicals compared to shoot. Relative greater root sensitivity may be explained by the fact, that after the seed germination, roots are first to be in contact with toxic compounds (Qureshi et al., 2014). Similar results were proposed by Fujii and Aziz (2005) while examining allelopathic effect of fourteen different plant species extracts on growth of lettuce seeds. The inhibitory actions under influence of allelochemicals are possibly due to reduction in cell division and cell size (Einhellig, 1996). The aqueous extract of *C. papaya* leaves, however, showed non-significant effect on wheat seeds germination, radicle and plumule growth. Similar results were reported by Tanveer et al. (2007) and Anwar et al. (2017b), where *E. helioscopia* was found to be non-toxic against wheat growth. Researches have suggested that a specific dose of these chemicals may cause growth stimulation (Pelinganga and Mashela, 2012). Abu El-Soud (2001) demonstrated growth stimulation in pea crop by *Acacia nilotica* leaf residue. Christobel et al. (2017) stated that *C. papaya* aqueous leaf extract can be applied for growth improvement of *Phaseolus aureus*. Stimulation is suggested usually due to presence of growth promoting substances along with inhibitory substances (Yamada et al., 2010; Anwar et al., 2018a, b).

The results of the present work clearly indicate that *C. papaya* is a candidate of consideration for weed management in wheat crop. It was reported elsewhere that *C. The papaya leaf extract* is source of phenolic substances, acknowledged as the basis of allopathic properties of the plant species (Golisz et al., 2007). Understanding the mechanisms may contribute to the use of plant compounds as natural herbicide, which will help to limit use of synthetic herbicides.

5. Conclusions

Biochemical evaluation of plants plays an important role in the sustainability and improvement of agro-ecosystems. Results of this study indicated that *A. fatua* was more susceptible towards the allelopathic effects of *C. papaya*. Donor plant in both extract and powdered form greatly reduced the germination and growth of *A. fatua*. Moreover, these inhibitory effects were greater for extract than powdered form due to the presence of water soluble allelochemicals. The growth of *R. dentatus* was less inhibited as compared to *A. fatua*. While the inhibitory effects on *Z. mays* and *H. annuus* were somehow like other test species. Wheat was observed to be least affected test species against *C. papaya*. The aqueous extract of *C. papaya* leaves is locally available in sufficient quantities; biodegradable, economic to the farmer hence can be effectively utilized for weed management in wheat crop. It might be suggested that to exploit this plant as natural herbicide, its allelochemicals and their effects must be studied in detail with more advanced techniques. On the other hand, it might be suggested that *C. papaya* should not be introduced in intercropping system due to its negative effects on food crops.

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