Pak. J. Bot., 49(SI): 139-144, 2017.

EVALUATION OF PHYTODIVERSITY FOR ALLELOPATHIC ACTIVITY AND APPLICATION TO MINIMIZE CLIMATE CHANGE IMPACT: JAPANESE MEDICINAL PLANTS

MUHAMMAD IBRAR SHINWARI[1*], OSAMU IIDA[2], MARYUM IBRAR SHINWARI[5] AND YOSHIHARU FUJII[3,4]

[1]*Department of Environmental Science, International Islamic University Islamabad, Pakistan*
[2]*Research Center for Medicinal Plant Resources, Tanegashima Station, Japan,*
[3]*International Agro-Biological Resources and Allelopathy, Tokyo University of Agriculture and Technology, Tokyo*
[4]*National Institute for Agro-Environmental Sciences, Tsukuba, Japan,*
[5]*Pakistan Scientific & Technological Information Centre, Islamabad, Pakistan*
**Corresponding author e-mail: m.ibrar@iiu.edu.pk*

Abstract

Climate change impact is ready to interfere in agro-ecosystems. Improvement of adaptations of crops to forthcoming climatic changes must be focused in research. In the present study, leaf liter of 160 medicinal plant samples (156 species) belonging to 134 genera and 74 families were collected from Research Center for Medicinal Plant Resources, Tanegashima, Japan and subjected to evaluation of their allelopathic effects using the Sandwich method. Lettuce (*Lactuca sativa* L.) was used as a test plant material in the bioassay because of its reliability for germination. Top ten medicinal plant species found with maximum inhibition activity were *Melia azedarach* (Meliaceae) followed by *Tylophora tanakae* (Ascepiadaceae), *Cinchona* sp. (Rubiaceae), *Flueggea virosa* (Phyllanthaceae), *Hibiscus acetosella* (Malvaceae), *Justicia procumbens* (Acanthaceae), *Terminalia chebula* (Combretaceae), *Hibiscus syriacus* (Malvaceae), *Lycium chinense* (Solanaceae) and *Elaeocarpus japonicas* (Elaeocarpaceae). Moreover, the presented results also showed minimum growth inhibition or maximum growth stimulation by *Ligustrum japonicum* (Oleaceae) followed by *Vitex rotundifolia* (Lamiaceae) and *Alpnia intermedia* (Zingiberaceae).These results may be utilized as benchmark information for further research on the elucidation of chemicals involved in the allelopathy in nature. The information obtained could also be helpful in the development of new and potent bioactive chemicals from natural products.

Key Words: Allelopathic activity, Medicinal Plants, Sandwich Method, Climate Change

Introduction

Diversity of medicinal plants is an important global wealth crucial for human health as well as pharmaceutical industry. Regeneration and propagation practices such an important resource has definitely been emphasized due to its value. But secondary metabolites (allelochemicals) released from plants and crops may have adverse effects in agricultural fields and managed forest ecosystems that are reduction of crop production etc. However, this property can also be utilized to combat future ecological threats. The potential of each species to release such phytochemicals is variable and unexplored. Therefore, it is worthwhile to determine the allelopathic potential of various plant species in general and medicinal plants specifically.

Globally studies have been made to know the living organism's interactions among themselves in ecological systems. The term Allelopathy has been applicable to those plants species that release chemicals into the environment either from their underground or aerial parts through root exudation, leaching by rains or dews, and volatilization or plant tissue decaying. The phyto-chemicals excreted into the environment affect other organisms, like plants, microorganisms and animals through inhibitory or excitatory means. These metabolites accumulate and persist for a reasonable time, thereby put significant impact on the growth and development of neighboring plants (Putnam & Duke, 1974, Rice, 1984).

In the past, many techniques were applied for assessment of allelopathic potential. For example, water extraction method applied on medicinal plants reflected relatively high allelopathic potential (Fujii, *et al.*, 1990). About 78 medicinal plants were evaluated for allelopathic activity through the solvent (methanol and water) extraction method (Fujii, *et al.*, 1991). In another research endeavor, 239 medicinal plant species were evaluated for allelopathic potential through Sandwich method. This method was used because it was reportedly took less time to evaluate allelopathic activity of leaf litter leacheate of a huge number of samples in the laboratory (Fujii, *et al.*, 2003). Allelopathic potential of 20 medicinal plants and weeds was determined through Sandwich method resulted maximum growth inhibition of radical occurred in *Pyrus pashia* followed by *Solanum surattense* and *Solanum villosum* (Shinwari, *et al.*, 2013a). Sandwich method has been applied as a latest technique by most of the researchers to evaluate allelopathy in medicinal plants against lettuce seeds (Shinwari, *et al.*, 2013a, Shinwari, *et al.*, 2013b, Anjum, *et al.*, 2010).

It has been reported that allelopathic potential of medicinal plant species found at Research Center for Medicinal Plant Resources, Tanegashima Station, Japan had never been determined. Therefore, the allelopathic potential of 156 medicinal plant species (160 samples) was evaluated through newly developed sandwich method as a standard bioassay to utilize this unexplored important resource.

Materials and Methods

Plant materials: Leaves of 156 medicinal plant species (160 samples) has been collected from Research Center for Medicinal Plant Resources, Tanegashima, Japan and evaluated for their allelopathic potential through Sandwich method (Shinwari, *et al.*, 2013a, Shinwari, *et al.*, 2013b, Fujii, *et al.*, 2003, Shiraishi, *et al.*, 2002).

Method: Three replications each of 10 mg oven dried leaves were placed in each well of the six-well multi-dish plastic plate of each sample (Fujii, *et al.*, 2003, Fujii, *et al.*, 2004, Shinwari, *et al.*, 2013a, Shinwari, *et al.*, 2013b). Lettuce seedlings elongation percentage (radicles and hypocotyls) were calculated with reference to the control.

The "SDV" (standard deviation value) for allelopathy evaluation (Fujii, *et al.*, 2003, Fujii, *et al.*, 2004) and the mean/ standard deviation were calculated for the statistical analysis while criterion of SDV were evaluated.

Results

The percentages of elongation of the radicle and hypocotyl of the lettuce seedlings for all the tested species are given in Table 1. The mean and standard deviation of the percentages were calculated and the criteria of the standard deviation were evaluated. The criteria of *,**,***,**** in table 1 refer to radicle elongation that is lower than the mean value minus 1(σ),1.5(σ),2(σ) and 2.5(σ); that is SDV=40,35,and 25, respectively.

Results of all species have been evaluated statistically and compiled in a presentable form. Inhibition potential between 80 to 100 % against lettuce root growth has been found in 3 species viz., *Melia azedarach* (Meliaceae), *Tylophora tanakae* (Ascepiadaceae) and *Cinchona* sp. (Rubiaceae) between 60-79% in 10 species viz. *Flueggea virosa*, *Hibiscus acetosella* , *Justicia procumbens, Terminalia chebula, Lycium chinense, Hibiscus syriacus, Elaeocarpus japonicus, Murraya paniculata, Geranium thunbergii* and *Melastoma sanguineum*, between 40-59 in 27 species, between 20-39 in 67 species and the remaining 52 species showed level of inhibition below 19 %. For lettuce hypocotyl, ten species viz., *Melia azedarach, Tylophora tanakae, Cinchona* sp., *Hibiscus syriacus, Flueggea virosa, Hibiscus acetosella, Justicia procumbens, Murraya paniculata, Distylium racemosum* and *Peucedanum japonicum* indicted inhibition from 40 to 79% though remaining 55 plant species reflected inhibition below 39% while 95 species indicated stimulatory effect.

Discussion

About 40 species showed 40% or more inhibition for lettuce root. It has been described in literature that maximum allelopathic effect has been found on root growth rather than shoot growth, has been confirmed by the present results (Devi, *et al.*, 1997). Growth of hypocotyls and radicle of lettuce seedlings has been mentioned in the form of either inhibition or promotion. Negative values indicated promotion when compared to the corresponding controls (Table 1). In one of the latest study, 170 plant species (176 samples) from Peru have been subjected to screening for allelopathic activity by Sandwich method. The results reflected that *Aristeguieta ballii* (Asteraceae) with high allelopathic potential against lettuce, with a full inhibition of germination of seed of the tested plant. Moreover, there was a strong allelopathic effect that was noticed in the experimentation with the other 11 species from Peru, mostly from the families Asteraceae, Anacardiaceae, Fabaceae, and Solanaceae (Morikawa, *et al.*, 2012).

The present experimental results indicated maximum (more than 80%) inhibition by *Melia azedarach* (Meliaceae) followed by *Tylophora tanakae* (Asclepiadaceae) and *Cinchona* sp. (Rubiaceae) (Table 1). *Melia azedarach L.* (commonly called Chinaberry; known as 'Syringa' at South Africa), is a tree found in North and South America, Asia, North Australia and Africa. In one of the previous study, application of aqueous extracts from dried and fresh fruits and foliage of *Melia azedarach* for germination and growth stimulation of tomato resulted inhibitory activity on germination and radicle growth at all concentrations, and the inhibitory effect increased as the concentration of the extract increased. While the extracts from dried leaves of *M. azedarach* had the greatest effects (Tur, *et al.*, 2012). In another study, it has been observed that *M. azedarach* foliage possessed secondary metabolites that are water soluble cause inhibition in uptake of water and *Echinochloa crus-galli* α-amylase activity during the process of germination (Phuwiwat, *et al.*, 2012). Besides this, positive inhibitory effect of *M. azedarach* has also been reported against germination and growth of *Lactuca sativa* seeds while using classic reflux and ultrasonic techniques to get vegetable material extracts. It has been also been concluded that extraction in alcohol reflected better results as compare to water extraction technique for phytotoxics of *M. azedarach*. On the other hand, classic reflux method has proved to be better than ultrasounds extraction method (Lungu, *et al.*, 2011).

Various species of the genus *Tylophora* has been traditionally employed as herbal drugs due to their potent therapeutic potential. Phytotoxic and anti-cancer activity of derivatives of *Tylophora* genus has already been established (Bashir, *et al.*, 2009, Wenli & Wing, 2004) reflecting the growth inhibitory potential of this genus as confirmed by current results i.e., *Tylophora tanakae* that emerged as containing the second strongest inhibitory potential among 160 plant samples. Genus *Cinchona* emerged as the third strongest inhibitory potential containing plant in the present study (Table 1). However, in another investigation, inhibitory effect of quinoline from the genus *Cinchona* on seed germination was found very strong even by the alkaloids itself. When this finding has been evaluated for allelopathic significance, it has been observed that testing the soil contain two years growth of *Cinchona* plants, high concentrations of quinoline alkaloid found in the root zone while the soil has received very low concentrations and no toxicity has been observed on seeds germination near the plants. It has been concluded that although laboratory results showed seed germination inhibition by alkaloids *Cinchona*, but results obtained from field conditions reflects that the alkaloid was found ineffective in natural environment (Aerts, *et al.*, 1991).

Moreover, in the present study 71-80% inhibition have also been observed among 7 medicinal plant species; *Flueggea virosa* (Phyllanthaceae), *Hibiscus acetosella* (Malvaceae), *Justicia procumbens* (Acanthaceae), *Terminalia chebula* (Combretaceae), *Hibiscus syriacus* (Malvaceae), *Lycium chinense* (Solanaceae) and *Elaeocarpus japonicas* belongs to family Elaeocarpaceae (Graph 1). While 51-70% inhibition have been found among 23 medicinal plants. Results indicated that members of 3 families viz., Meliaceae, Ascepiadaceae and Rubiaceae caused maximum inhibition (>80%) radicle growth of lettuce. It has also been observed that 7 families viz., Phyllanthaceae, Malvaceae, Acanthaceae, Combretaceae, Combretaceae, Malvaceae, Solanaceae and Elaeocarpaceae resulted strong inhibition (70-79%) on growth of lettuce radicle (Table 1). The results obtained can be used as baseline data for futre research to focus phyto-chemicals that reflect allelopathy in nature. This may help to develop potent and novel bioactive chemicals.

The present results also showed minimum growth inhibition or maximum growth stimulation by *Ligustrum japonicum* (Oleaceae) followed by *Vitex rotundifolia* (Lamiaceae) and *Alpnia intermedia* (Zingiberaceae) (Table 1). It has been found in latest research that certain secondary metabolites that stimulate growth may be involved in inducing tolerance against several abiotic stresses like heat. Hence, these allelochemicals may be applied at different phonological stages to augment the stress tolerance. Such kind of biological measures may be used to minimize the impacts of future climatic changes.
Availability of sufficient food is necessary to ensure food security sustainability. Climate change has become a great threat that may decrease production by temperature increase and changed rainfall patterns that is expected to depress agricultural yields in most the ecological zones increasingly (Lobell *et.al.,* 2011). Loss of production may also happen because of weather extremes like maximized events of floods, dryness and heat. Discovery of growth stimulatory allelochemicals may help to at least minimize such losses in production in future.

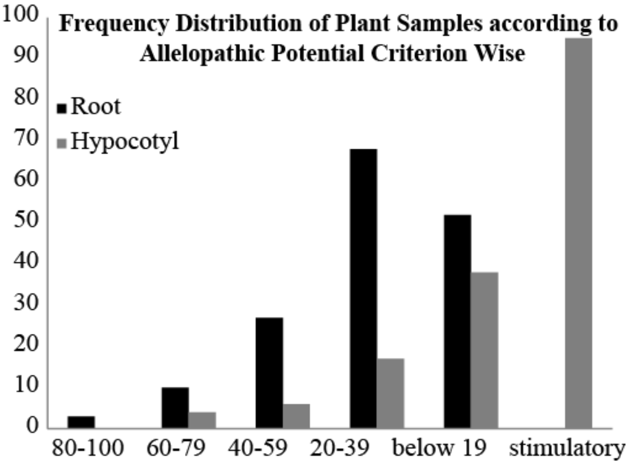

Table 1. Allelopathic potential determination of 156 medicinal plant species (160 Samples) from Japan

Family	Species Name (Scientific)	Extension (%) †		Criterion‡
		Radicle	Hypocotyl	
Meliaceae	*Melia azedarach* L.	14.1	23.5	****
Ascepiadaceae	*Tylophora tanakae* Maxim. ex Franch. & Sav	14.3	39.8	****
Rubiaceae	*Cinchona sp.*	15.7	28.0	****
Phyllanthaceae	*Flueggea virosa* (Willd.) Royle	20.8	55.7	***
Malvaceae	*Hibiscus acetosella* L.	23.4	55.1	***
Acanthaceae	*Justicia procumbens* L.	24.7	43.6	***
Combretaceae	*Terminalia chebula* Retz.	26.4	63.6	***
Malvaceae	*Hibiscus syriacus* L.	27.8	39.6	***
Solanaceae	*Lycium chinense* Mill.	27.8	78.2	***
Elaeocarpaceae	*Elaeocarpus japonicas* Siebold et Zucc.	28.6	61.9	***
Rutaceae	*Murraya paniculata* (L.) Jack	30.4	57.3	**
Geraniaceae	*Geranium thunbergii* Siebold et Zucc.	32.8	86.4	**
Melastomataceae	*Melastoma sanguineum* Sims.	33.0	88.3	**
Apocynaceae	*Allamanda neriifolia* Hook.	40.4	62.7	*
Rosaceae	*Spiraea nipponica* Maxim. *var. tosaensis* (Yatabe) Makino	41.3	68.6	*
Convolvulaceae	*Ipomoea pes-caprae* (L.) Sweet	42.4	98.5	*
Campanulaceae	*Adenophora triphylla* (Thunb.) A. DC.	43.4	73.4	*
Capparaceae	*Crataeva religiosa* G. Forst.	44.6	64.2	*
Acanthaceae	*Strobilanthes cusia* (Nees) Kuntze	46.2	132	*
Lauraceae	*Actinodaphne longifolia* (Blume) Nakai	46.5	87.3	*
Hamamelidaceae	*Distylium racemosum* Siebold et Zucc. (S1)	47.5	56.0	*
Apiaceae	*Peucedanum japonicum* Thunb. (S1)	47.7	43.4	*
Rubiaceae	*Uncaria rhynchophylla* (Miq.) Miq.	47.7	96.0	*
Verbenaceae	*Duranta plumieri* Tacq.	50.4	103	
Solanaceae	*Brunfelsia latifolia* (Pohl) Benth.	51.1	115	
Cornaceae	*Cornus brachypoda C. A. Mey.*	52.0	114	
Vitaceae	*Vitis thunbergii* Siebold et Zucc.	52.0	93.5	
Fabaceae	*Desmodium oxyphyllum* DC.	52.2	99.5	
Theaceae	*Eurya emarginata* (Thunb.) Makino	52.4	70.6	
Celastraceae	*Catha edulis* (Vahl) Endl.	53.4	119	
Moraceae	*Ficus virgate* Reinw. ex Blume	55.4	93.9	
Myrtaceae	*Myrtus communis* L.	56.0	101	
Celastraceae	*Microtropis japonica* (Franch. et Savat.) H. Hallier	56.3	95.4	
Myrtaceae	*Psidium cattleianum* Sabine var. lucidum hort.	56.5	100	
Rosaceae	*Rubus grayanus* Maxim.	58.2	107	
Fabaceae	*Lespedeza cuneata* (Du Mont. d. Cours.) G. Don	58.3	124	
Lycopodiaceae	*Lycopodium cernum* L.	58.3	82.3	

Table 1.(cont'd)

Family	Species Name (Scientific)	Extension (%) †		Criterion‡
		Radicle	Hypocotyl	
Symplocaceae	*Symplocos lucida* Sieb. et Zucc.	58.4	88.2	
Apocynaceae	*Ervatamia coronaria* (Jacq.) Stapf	58.8	75.9	
Styracaceae	*Stryrax japonica* Siebold et Zucc.	59.9	80.9	
Staphyleaceae	*Euscaphis japonica* (Thunb.) Kanitz	60.4	80.1	
Asteraceae	*Cirsium spinosum* Kitam.	61.0	98.1	
Theaceae	*Camellia japonica* L.	61.8	107	
Adoxaceae	*Sambucus sieboldiana* (Miq.) Blume ex Graebn.	61.8	99.1	
Malpighiaceae	*Malpighia glabra* L.	61.9	85.0	
Sabiaceae	*Meliosma rigida* Siebold et Zucc.	62.4	91.2	
Rutaceae	*Zanthoxylum schinifolium* Siebold et Zucc.	63.4	96.9	
Rutaceae	*Evodia meliifolia* (Hance) Benth.	63.8	90.8	
Convolvulaceae	*Ipomoea batatus* (L.) Lam.	63.9	100	
Lamiaceae	*Ajuga pygnaea* A. Gray	64.2	96.5	
Menispermaceae	*Cocculus laurifolius* DC.	64.2	89.3	
Elaeagnaceae	*Elaeagnus umbellata* Thunb.	64.5	98.5	
Fabaceae	*Crotalaria sessiliflora* L.	64.9	118	
Magnoliaceae	*Michelia figo* (Lour.) Spreng.	65.3	84.7	
Myrtaceae	*Pimenta dioica* (L.) Merr.	65.5	91.6	
Urticaceae	*Debregeasia edulis* (Siebold et Zucc.) *Weddell*	65.7	134	
Burseraceae	*Canarium album* (Lour.) Raeusch.	66.9	80.2	
Lauraceae	*Neolitsea sericea* (Blume) Koidz.	67.1	100	
Ebenaceae	*Diospyros morrisiana* Hance	67.3	125	
Passifloraceae	*Passiflora edulis* Sims	67.9	98.1	
Symplocaceae	*Symplocos tanakae* Matsumura	68.2	95.6	
Aquifoliaceae	*Ilex liukiuensis* Loes.	68.8	113	
Moraceae	*Ficus religiosa* L.	69.0	125	
Boraginaceae	*Ehretia microphylla* Lam.	69.3	113	
Lauraceae	*Lindera citriodora* (Siebold et Zucc.) Hemsl.	69.4	124	
Ericaceae	*Vaccinium bracteatum* Thunb.	69.4	98.1	
Vitaceae	*Ampelopsis leeoides* (Maxim.) Planch.	69.5	124	
Lauraceae	*Litsea coreana* Léveillé	69.9	84.5	
Annonaceae	*Cananga odorata* (Lam.) Hook. fil. et Thoms.	70.4	102	
Sapotaceae	*Achras zapota* L.	70.9	114	
Malpiginiaceae	*Helicteris isora* L.	71.5	84.8	
Magnoliaceae	*Michelia compressa* (Maxim.) Sarg.	71.5	107	
Apocynaceae	*Ochrosia oppositifolia* (Lam.) K. Schum.	71.5	111	
Ebenaceae	*Diospyros japonica* Siebold et Zucc.	71.7	129	
Lamiaceae	*Premna microphylla* Turcz.	72.0	121	
Phyllanthaceae	*Breynia officinalis* Hemsl.	72.3	107	
Poaceae	*Arundinaria yakushimensis* S. Hatusima et Muroi	72.4	97.7	
Myrtaceae	*Psidium gaujava* L.	72.4	127	
Malvaceae	*Hibiscus tiliaceus* L.	72.6	111	
Goodeniaceae	*Scaevola sericea* Vahl	72.8	118	
Adoxaceae	*Viburnum suspensum*	72.9	115	
Rubiaceae	*Psychotria serpens* Lindl.	73.7	149	
Gleicheniaceae	*Dicranopteris linearis* (Burm. fil.) Underw.	74.0	100	
Cycadaceae	*Cycas revoluta* Thunb.	74.5	108	
Lamiaceae	*Vitex cannibifolia* Sieb. et Zucc.	75.0	107	
Stachyuraceae	*Stachyurus praecox* Siebold et Zucc. var. lancifolius (Koidz.) Hara	75.1	133	
Lauraceae	*Litsea japonica* (Thunb.) Juss.	75.4	105	
Myrtaceae	*Rhodomyrtus tomentosa* Wight	75.4	92.8	
Hamamelidaceae	*Distylium racemosum* Siebold et Zucc.	76.1	112	
Ulmaceae	*Celtis bonienensis* Koidz.	76.6	87.9	
Lauraceae	*Lindera strychnifolia* (Siebold et Zucc.) F. Vill.	76.6	76.9	
Lamiaceae	*Callicarpa takakumensis* Hatusima	76.9	76.6	
Caesalpiniaceae	*Cassia fistula* L.	77.3	120	
Malvaceae	*Hibiscus hamabo* Siebold et Zucc.	77.9	141	
Verbenaceae	*Lantana camara* L.	78.0	150	

Table 1.(cont'd)

Family	Species Name (Scientific)	Extension （%） †		Criterion‡
		Radicle	Hypocotyl	
Juglandaceae	*Juglans ailanthifolia* Carr.	78.4	113	
Myrtaceae	*Syzygium jambos* Alston	78.4	91.4	
Ranunculaceae	*Clematis terniflora* DC.	78.9	109	
Myrtaceae	*Melaleuca leucadendron* L.	79.0	113	
Lardizabalaceae	*Stauntonia hexaphylla* (Thunb.) Decne.	79.3	122	
Boraginaceae	*Messerschmidia argentea* (L. fil.) Johnston	79.5	111	
Lamiaceae	*Callicarpa japonica* Thunb. var. *luxurians* Rehd.	79.8	114	
Menispermaceae	*Tinospora crispa* (L.) Miers	79.8	82.2	
Calycanthaceae	*Calycanthus fertilis* Walt.	79.9	100	
Orobanchaceae	*Aeginetia indica* L. var. *gracilis* Nakai	80.2	85.6	
Papaveraceae	*Macleaya cordata* (Willd.) R. Br.	80.6	112	
Myrtaceae	*Syzigium aromaticum* Merr. et Perry	80.6	81.3	
Menispermaceae	*Cocculus orbiculatus* (L.) Forman	80.8	146	
Ochnaceae	*Ochna serrulata* (Hochst.) Walp.	81.1	135	
Urticaceae	*Oreocnide pedunculata (Shirai) Masamune*	81.1	126	
Theaceae	*Camellia lutchuensis* T. Ito et Matsumura	81.3	107	
Menispermiaceae	*Stephania japonica* (Thunb.) Miers	81.6	124	
Berberidaceae	*Mahonia japonica* (Thunb.)	82.3	71.5	
Lamiaceae	*Salvia japonica* Thunb.	82.8	154	
Apocynaceae	*Rauvolfia verticillata* Baill.	83.5	115	
Zingiberaceae	*Alpinia katsumadai* Hayata	83.7	98.4	
Pittosporaceae	*Pittosporum tobira* (Thunb.) Aiton	84.0	104	
Lamiaceae	*Vitex trifolia* L.	84.4	93.7	
Fagaceae	*Quercus glauca* Thunb.	84.6	118	
Myrtaceae	*Eucalyptus citriodora* Hook.	84.8	112	
Cupressaceae	*Thujopsis dolabrata* (L. fil.) Siebold et Zucc.	84.9	144	
Theaceae	*Camellia sasanqua* Thunb.	85.1	118	
Dioscoraceae	*Dioscorea alata* L.	85.3	128	
Sapindaceae	*Euphoria longana* Lam.	85.7	122	
Fagaceae	*Pasania edulis* Makino	86.4	207	
Fagaceae	*Quercus acuta* Thunb. ex Murray	86.8	91.5	
Theaceae	*Ternstroemia gymnanthera* (Wight et Arn.) Bedd.	87.0	145	
Vitaceae	*Ampelopsis brevipedunculata* (Maxim.) Trautv. var. *heterophylla* (Thunb.) Hara	87.6	141	
Ulmaceae	*Aphananthe aspera* (Thunb.) Planch.	88.7	126	
Rubiaceae	*Paederia scandens* (Lour.) Merrill	88.9	123	
Rubiaceae	*Gardenia jasminoides* Ellis forma *grandiflora* (Lour.) Makino	89.0	120	
Phyllanthaceae	*Glochidion obovatum* Siebold et Zucc.	89.4	119	
Lauraceae	*Cinnamomum sieboldii* Siebold et Zucc.	90.2	116	
Araliaceae	*Schefflera octophylla* (Lour.) Harms	90.5	94.6	
Lamiaceae	*Vitex trifolia* L. var. bicolor (Willd.) Moldenke	90.6	75.7	
Cupressaceae	*Chamaecyparis obtusa* (Siebold et Zucc.) Siebold et Zucc. ex Endl.	91.2	128	
Zingiberaceae	*Alpinia formosana* K. Schum.	92.3	112	
Verbenaceae	*Clerodendrum trichotomum* Thunb. var. *yakusimense* (Nakai) Ohwi	92.3	127	
Zingiberaceae	*Alpinia speciosa* (Wendl.) K. Schum.	93.1	112	
Anacardiaceae	*Mangifera indica* L.	93.3	106	
Moraceae	*Ficus sarmentosa* Roxb. var. *nipponica* (Franch. et Savat.) Corner	94.2	110	
Myoporaceae	*Myoporum bontioides* (Siebold et Zucc) A. Gray	95.8	107	
Lauraceae	*Cinnamomum daphnoides* Siebold et Zucc.	96.1	111	
Apiaceae	*Peucedanum japonicum* Thunb.(S2)	97.3	127	
Magnoliaceae	*Magnolia stellata* (Siebold et Zucc.) Maxim.	97.5	139	
Podocarpaceae	*Podocarpus nagi* (Thunb.) Zoll. et Moritzi	97.7	107	
Euphorbiaceae	*Ricinus communis* L. f. *sanguineus* hort.	97.8	76.8	
Asteraceae	*Farfugium japonicum* (L.) Kitamura	97.9	108	
Lamiaceae	*Vitex rotundifolia* L. fil.	98.1	117	

Table 1.(cont'd)

Family	Species Name (Scientific)	Extension (%) †		Criterion‡
		Radicle	Hypocotyl	
Valerianaceae	*Patrinia villosa* (Thunb.) Juss.	98.3	105	
Schisandraceae	*Illicium verum* Hook. fil.	99.3	142	
Rutaceae	*Zanthoxylum ailanthoides* Siebold et Zucc.	99.6	130	
Aquifoliaceae	*Ilex integra* Thunb.	99.8	108	
Myrtaceae	*Feijoa sellowiana* O. Berg	102	129	
Verbenaceae	*Stachytarpheta dichotoma* Vahl	103	115	
Myrtaceae	*Callistemon rigidus* R. Br.	104	121	
Aquifoliaceae	*Ilex rotunda* Thunb.	104	161	
Zingiberaceae	*Alpnia intermedia* Gagnep.	109	126	
Lamiaceae	*Vitex rotundifolia* L. fil. forma *albescens* Hiyama	110	128	
Oleaceae	*Ligustrum japonicum* Thunb.	111	110	
	Mean (M)	71.0	104	
	Standard Deviation (σ)	20.7	26.2	
	Mean -1 (σ)	50.3	77.4	
	Mean -1.5 (σ)	40.0	64.3	
	Mean -2 (σ)	29.7	51.3	
	Mean -2.5 (σ)	19.3	38.2	

† Table 1: Percentage growth rate, compared to that of the control; ‡stronger inhibitory activity in the radicle: *M–1(σ),** M – 1.5(σ),***M–2(σ), and **** M – 2.5(σ)

Acknowledgements

Financial support for this research study by Ministry of Agriculture, Forestry and Fisheries of Japan, National Institute for Agro-Environmental Sciences, Tsukuba, Japan, Higher Education Commission of Pakistan and Pakistan Museum of Natural History Islamabad has been highly appreciated.

References

Aerts, R.J., W. Snoeijer, E. van der Meijden and R. Verpoorte. 1991. Allelopathic inhibition of seed germination by Cinchona alkaloids? *Phytochem.,* 30(9): 2947-2951.

Anjum, A., U. Hussain, Z. Yousaf, F. Khan and A. Umer. 2010. Evaluation of allelopathic action of some selected medicinal plants on lettuce seeds by using sandwich method. *J. Med. Plant Res.,* 4: 536-541.

Bashir, A., N. Ali, S. Bashir and M.I. Choudhary. 2009. Biological activities of aerial parts of *Tylophora hirsuta* Wall *Afr. J. Biotechnol.,* 8(18): 4627-4631.

Devi, S.R., F. Pellissier and M.N.V. Prasad 1997. Allelochemicals. In: *Plant Ecophysiology*. (Ed.): M.N.V. Prasad, John Wiley & Sons, Inc., New York.

Fujii, Y., M. Furukawa, Y. Hayakawa, K. Sugawara and T. Shibuya. 1991. Survey of Japanese medicinal plants for the detection of allelopathic properties *Weed Res. Japan.,* 36: 36-42.

Fujii, Y., S. Parvez, M.M. Parvez, Y. Ohmae and O. Iida. 2003. Screening of 239 Medicinal plant species for allelopathic activity using the sandwich method. *Weed Biol. Manag.,* 3(4): 233-241.

Fujii, Y., T. Shibuya, K. Nakatani, T. Itani, S. Hiradate and M.M. Parvez. 2004. Assessment method for allelopathic affect from leaf litter leachates. *Weed Biol. Manag.,* 4: 19-23.

Fujii, Y., T. Shibuya and T. Yasuda. 1990. Survey of Japanese weed and crops for the detection of water-extractable allelopathic chemicals using Richard's function fitted to lettuce germination test. *Weed Res. Japan.,* 35: 362-370.

Lobell, D.B., W. Schlenker and J.C. Roberts. 2011. Climate trends and global crop production since 1980. Report published in *Science*, May 2011. www.sciencexpress.org / 5 May 2011 / Page 1 / 10.1126/science.1204531

Lungu, L., C.V. Popa, J. Morris and M. Savoiu. 2011. Evaluation of phytotoxic activity of Melia azedarach extracts on Lactuca sativa. *Romanian Biotechnological Letters.,* 16 (2):6089- 6095

Morikawa, C.I.O., R. Miyaura, M.D.L.T. Figueroa, E.L.R. Salgado and Y. Fujii. 2012. Screening of 170 Peruvian plant species for allelopathic activity by using the Sandwich Method. *Weed Biol. Manag.,* 12:1-11

Phuwiwat, W., W. Wichittrakarn, C. Laosinwattana and M. Teerarak. 2012. Inhibitory effects of Melia azedarach leaf extracts on seed germination and seedling growth of two weed species. *Pak. J. Weed Sci. Res.,* 18: 485-492.

Putnam, A.R. and W.B. Duke. 1974. Biological suppression of weeds evidence for allelopathy in accessions of cucumber *Sci.,* 185:370-71

Rice, E.L. 1984. *Allelopathy*. (2nd edition) Academic Press

Shinwari, M.I., M.I. Shinwari and Y. Fujii. 2013a. Allelopathic activity of medicinal plants and weeds from Pakistan. *Allelopathy J.,* 32 (2):223-232

Shinwari, M.I., M.I. Shinwari and Y. Fujii. 2013b. Allelopethic evaluation of shared invasive plants and weeds of Pakistan and Japan for environmental risk assessment. *Pak. J. Bot.,* 45(S1): 467-474.

Shiraishi, S., I. Watanabe, K. Kuno and Y. Fujii. 2002. Allelopathic activity of leaching from dry leaves and exudates from roots of ground cover plants assayed on agar. *Weed Biol. Manag.,* 2: 133-142.

Tur, C.M., J. Borella and L.H. Pastorini. 2012. Alelopatia de extratos aquosos de cinamomo (Melia azedarach L.- Meliaceae) sobre a germinação e crescimento inicial do tomate (*Lycopersicon esculentum* Mill. - Solanaceae). *Biotemas,* 25(3): 49-56.

Wenli, G. and L. Wing. 2004. Novel mode of action of tylophorine analogs as antitumor compounds. *Cancer Res.,* 64: 678-688.

(Received for publication 15 January 2016)