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SCREENING OF 196 MEDICINAL PLANT SPECIES LEAF LITTER FOR ALLELOPATHIC POTENTIAL

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Abstract

The taxonomic richness of medicinal plants in Pakistan can foster reasonable economic contributions through medicinal, industrial and environmental applications. The current study aims to explore allelopathic effect of medicinal plants on the germination and seedling growth of lettuce using sandwich method. In total 196 plant species had been tested using sandwich method to assess allelopathic effect of leaves leachates of different plants on *Lactuca sativa* L. (lettuce) seeds. The results of this study identified 4 plants having strong inhibitory effect, 14 plants with medium inhibitory and 13 plants of low inhibitory effect on the lettuce seeds. *Boerhavia procumbens* exhibited the strongest inhibitory allelopathic effect and *Viburnum grandiflorum* showed strong stimulatory effect on the growth of lettuce seeds. The diversified allelopathic effects of plants have the potential to improve weed management, sustainable agriculture, food production as well as medicinal, industrial and environmental applications.

Key words: Allelopathy, Medicinal Plants, Sandwich, Lettuce, Pakistan

Introduction

The services to human beings provided by medicinal plants are acknowledged and well documented since antiquity. The chemical interaction mechanisms of plants with the environment known as allelopathy (Aslani *et al.,* 2014) which may have damaging or beneficial effects. These interactions occur due to the release of secondary metabolites which are wonderful natural complex molecules and difficult task to prepare them synthetically (Kumar *et al*., 2011). Besides harmful effects, natural complex compounds have a potential for beneficial utilization in the industry as a raw material, medicines and agriculture (Morris, 1999). The researchers are more interested, exploring and wisely using such bioactive compounds or allelochemicals for bio-friendly products or eco-friendly products. Several research studies are reflecting effective applications of allelochemicals in managing agricultural productivity, health and environmental sustainability (Bibi *et al*., 2011; Khanh *et al*., 2005; Albuquerque *et al*., 2011; Farooq *et al*., 2013).

The exploration of allelochemicals and their effective utilizations require substantial prior investigations of allelopathic effects of medicinal plants. The sandwich method is recognized as an effective technique, developed by Fujii (1994) to investigate the allelopathic effects of leachates (dry leaves of plants). The objective of this study was to investigate the allelopathic effects of medicinal plants on *Lactuca sativa* L. (lettuce) using sandwich method. The study had attempted the identification of allelopathic effects of 197 plant species collected from different regions of Pakistan. This article particularly focused on collection, screening, identification, and allelopathic investigations of medicinal plants. The allelopathic effects of some medicinal plants investigated in this study were less or seldom reported previously. Hence, this study will share the more knowledge and contribute to effective utilization of medicinal plants in agriculture and industry in addition with medicinal use.

Material and Methods

Sample collection and preparation: A total of **196** medicinal plants were collected randomly from various locations enriched with plant species. The study focused on collection of medicinal plants from Islamabad and its vicinity (Baragali, Margalla Hills, Murree, and Barahkoh), Rawalpindi, Azad Jammu and Kashmir (AJK) (Rawalakot and Bagh). Fresh samples were collected, separately placed in paper bags and labelled. These samples were transported to Ecology and Biodiversity Laboratory, Department of Environmental Science, International Islamic University, Islamabad for further experimentation. A herbarium sheet of each plant sample was made for the identification and then oven dried at 60°C for 48 hours. The samples were stored in air tight box to avoid contamination and ensure chain of custody. An analysis of allelopathic potential of collected plant species was performed through leaf litter analysis using Sandwich method (Fuji, 2004; Shinwari *et al*., 2013; Appiah *et al*., 2015).

Sandwich Method: The agar medium was prepared in a beaker by adding 7.5 g agar powder in 1000 ml of distilled water. The beaker was placed in autoclave at temperature of 120°C, 115 pa pressure for 20 minutes as well as cooled down to 40°C (Appiah *et al*., 2015). The dried plant samples (10 or 50 mg) were added in 5 mL plus 5 mL agar two layers in each well of multi-well plastic plates (six wells). Furthermore, 5 seeds of Lettuce (*Lactuca sativa* L.) were vertically placed in each well. The plates were concealed with plastic tape, labelled, and wrapped with aluminum foil for incubation in dark condition (Fujii *et al*., 2004) (Fig. 1). The sandwich method is known as productive, established and reported technique to evaluate the allelopathic effect under laboratory condition. This study screened 196 medicinal plants and determined allelopathic activity of leachates from collected donor plant's leaves and a control (only Lettuce in agar). The experiments were replicated three times to ensure accuracy and statistical validity of data. The results were reported as an average value of data. An incubator (BGPX/Summer) containing multi-well plastic dishes was used at 25°C for 72 hours for incubation followed by the measurement of hypocotyl and radicle length (Fujii *et al*., 2003; Fujii *et al*., 2004; Morikawa *et al*., 2012; Shinwari *et al*., 2017; Appiah *et al*., 2015).

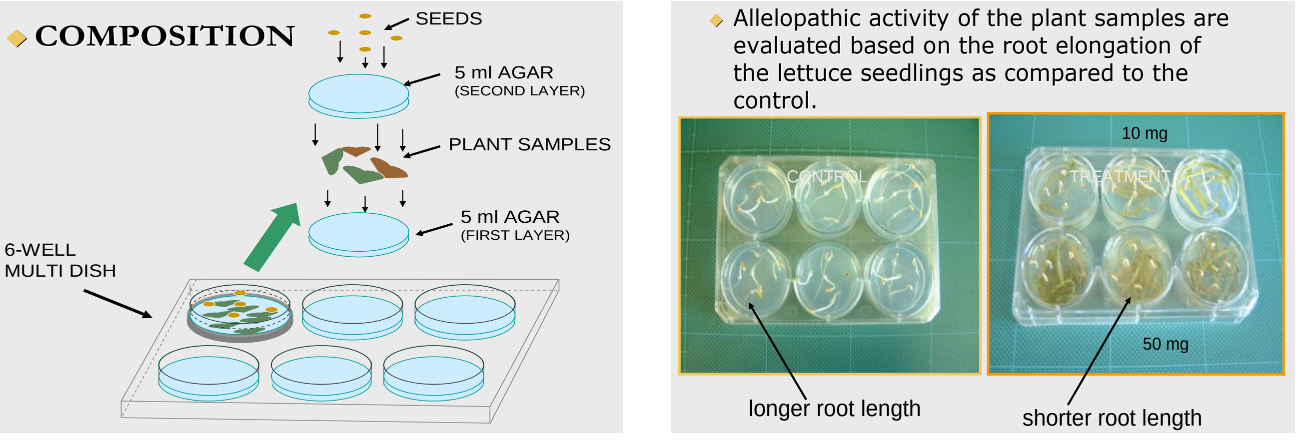

Fig. 1. Sandwich Method to evaluate allelopathic activity of leachates from plants leaves.

Results

The growth and germination of lettuce seeds portray allelopathic effects in sandwich method due to leachates released from different parts of medicinal plants. The results demonstrated that 4 plants exhibited strong inhibitory effect, 14 plants presented medium inhibitory and 13 plants showed the low inhibitory effect while rests of the plants exhibited very low or nil inhibitory effect on the lettuce seeds. Contemporary, the 7 plants substantially stimulated the growth of lettuce seeds in sandwich method while rests of the plants exhibited very low or nil stimulatory effect. The detail of plant species, their families and allelopathic effects is illustrated in Table 1. *Boerhavia procumbens, Jacaranda mimosifolia, Datura metel* and *Asparagus adscendens* revealed strong inhibitory effect on the germination and seedling growth. The results pointed out the medium inhibitory effect in 14 species including *Berberis vulgaris, Urtica dioica, Tagetes erecta, Calotropis procera, Hedera helix, Plectranthus rugosus, Tabernaemontana corymbosa, Centaurea iberica, Buxus papillosa, Datura innoxia, Cyperus rotundus, Hibiscus rosa-sinensis, Sisymbrium irio* and *Clematis gouriana*. However, the *Buxus wallichiana, Cirsium arvense, Sida cordata, Xanthium strumarium, Geranium, Delphinium aquilegifolium, Withania somnifera, Trichodesma indicum, Digera muricata, Solanum erianthum, Solanum surattense, Typha minima* and *Potamogeton lucens* expressed the low inhibitory effect on the germination and growth of lettuce seeds. Meanwhile, the stimulatory allelopathic effects were recorded from the dry leaves of *Viburnum grandiflorum, Maytenus royleanus, Phoenix sylvestris, Woodfordia fruticose, Beaucarnea recurvata, Poa annua,* and *Viola odorata* on lettuce germination and seedling growth (hypocotyl and radicle length).

Discussions

The *Boerhavia procumbens* exhibited the maximum inhibition of germination and seedling growth of *Lactuca sativa* (lettuce) among 196 species. It has numerous medicinal uses but its allopathic effects are least reported in literature. However, *Boerhavia procumbens* has been considered as a threat to sustainable agriculture due to its vast distribution and impact on crop production (Nasim & Shabbir, 2012). Gambaro *et al*., (1988) and Binutu and Lajubutu, (1994) had confirmed the release of secondary metabolites such as flavonoids, flavones, triterpenes, steroids and iridiodsfrom flowers and leaves of *Jacaranda mimosifolia*. *J. mimosifolia*, posed inhibitory effect on the growth of wheat (Mongelli *et al*., 1997; Gambaro *et al*., 1988; Binutu and Lajubutu, 1994). Rojas *et al*., (2006) reported the high anti-microbial activity of *J. mimosifolia* against different bacteria. Nawaz *et al*., (2013) noticed inhibitory allelopathic effect of *J. mimosifolia* on the growth of lettuce. Witt *et al*., (2017) enlisted the *Jacaranda mimosifolia* among the plants which threatened the Ngorongoro Conservation Area due to the release of allelochemicals.

Al-Snafi, (2017) reported the presence of cardiac glycosides, amino acids, alkaloids, tannins, flavonoids, saponins, carbohydrates and phenols in aqueous and methanolic extract of *Datura metel.* Ramachandran (2017) tested the ability of *Datura metel* to control the noxious weeds particularly *Parthenium hysterophorus* L in a laboratory bioassay. The aqueous extract of *Datura metel* had successfully inhibited the early seedling growth and germination of *P. hysterophorus* L. Similarly, Chaudhary & Iqbal (2013) also confirmed the allelopathy of *Datura metel* on *P. hysterophorus* and suggested the use of *Datura metel* for management of *P. hysterophorus*. Kagale *et al*., (2004) effectively controlled pathogens (cause crop diseases) by the application of aqueous and methanolic leaf extract of *Datura metel* under greenhouse condition. Thakur (2016) reported the release of phytochemicals including phenols, saponins, sterols, ketones, tri-terpenoids, glycosides, steroids, nitrogenous constituents and aliphatic compounds from *Asparagus adscendens.* However, the allelopathic effect of *Asparagus adscendens* are least reported but the current study indicated the inhibitory allelopathic effect of *Asparagus adscendens* on germination and growth of lettuce.

Amini *et al*., (2016) recorded the strong inhibitory allelopathic effect of *Berberis vulgaris* on *Lactuca sativa* (lettuce) seedling growth and germination out of 68 plant species leaf litter through sandwich method. Similarly, Mardani *et al*., (2016) reported the allelopathic effect of *Berberis vulgaris* while studying 178 Caucasian plant species impact on *Lactuca sativa* (lettuce) growth in sandwich method. Peterson *et al*., (2005) reported the rusting and damage to stems of cereal and wheat from *Berberisvulgaris* due to release of allelochemicals. However, the finding of the present study also revealed the inhibitory allelopathic effect of *Berberis vulgaris* on lettuce germination and seedling growth.

Table 1. Allelopathic effect of 196 tested medicinal plants.

*Voucher No./ Species Name (Scientific)	Family	Extension (%)		Criterion
		Radicle 10mg	Hypocotyl 10mg	Radicle 10mg
026*. *Boerhavia procumbens* Banks ex Roxb.	Nyctaginaceae	0	0	***
096. *Jacaranda mimosifolia* D.Don	Bignoniaceae	2.666667	8.064516	***
060. *Datura metel* L.	Solanaceae	4	3.225806	***
016. *Asparagus adscendens* Roxb.	Asparagaceae	4.938272	12.94118	***
024. *Berberis vulgaris* L.	Berberidaceae	5.761317	11.76471	**
183. *Urtica dioica* L.	Urticaceae	7.407407	15.29412	**
177. *Tagetes erecta* L.	Asteraceae	8	16.12903	**
034. *Calotropis procera* (Aiton) R. Br.	Apocynaceae	9.82659	35.42857	**
090. *Hedera helix* L.	Araliaceae	11.56069	43.42857	**
136. *Plectranthus rugosus* Wall. ex Benth.	Lamiaceae	12.42938	32.46073	**
176. *Tabernaemontana corymbosa* (variegated)	Apocynaceae	13	12.90323	**
042. *Centaurea iberica* Trevir. ex Spreng.	Asteraceae	13.06122	37.59398	**
031. *Buxus papillosa* C.K. Schneid.	Buxaceae	13.2948	58.28571	**
059. *Datura innoxia* Mill.	Solanaceae	13.68821	36.99422	**
057. *Cyperus rotundus* L.	Cyperaceae	14.28571	31.78808	**
092. *Hibiscus rosa-sinensis* L.	Malvaceae	14.66667	22.58065	**
170. *Sisymbrium Sect Irio* DC.	Brassicaceae	15	28.43602	**
048. *Clematis gouriana* Roxb. ex DC.	Ranunculaceae	15.73034	28.24859	**
032. *Buxus wallichiana* Baill.	Buxaceae	17.6	54.92228	*
046. *Cirsium arvense* (L.) Scop.	Asteraceae	18.57923	82.35294	*
168. *Sida cordata* (Burn. f.) Bross. -Waalkes	Malvaceae	20.09132	41.55844	*
195. *Xanthium strumarium* L.	Asteraceae	21.22449	51.12782	*
062. *Delphinium aquilegifolium* (Boiss.) Bornm.	Ranunculaceae	23.69942	65.14286	*
192. *Withania somnifera* (L.) Dunal	Solanaceae	23.75	37.91469	*
181. *Trichodesma indicum* (L.) Lehm.	Boraginaceae Juss.	24.04372	67.22689	*
063. *Digera muricata* (L.) Mart	Amaranthaceae Juss.	24.5098	70.87379	*
172. *Solanum erianthum* D. Don	Solanaceae Juss.	24.81203	54.30464	*
173. *Solanum surattense* Burm. f.	Solanaceae Juss.	25.5144	42.04545	*
182. *Typha minima* Funck ex Hoppe	Typhaceae Juss.	27.27273	42.85714	*
141. *Potamogeton lucens* L.	Potamogetonaceae	27.39726	28.57143	*
109. *Malva parviflora* L.	Malvaceae	27.7551	57.14286	
102. *Lagerstroemia indica* L.	Lythraceae	28	29.03226	
128. *Parthenium hysterophorus* L.	Asteraceae	28.80886	58.06452	
013. *Argyrolobium roseum* Jaub. & Spach	Fabaceae	29.09091	63.09524	
052. *Conyza Canadensis* (L.) Cronquist	Asteraceae	29.33333	45.16129	
105. *Leucas capitate* Desf.	Lamiaceae	29.86667	60.10363	
157. *Rumex nepalensis* Barker & C.H. Wright	Polygonaceae	30.0578	75.42857	
148. *Ranunculus muricatus* L.	Ranunculaceae	31.21387	72	
169. *Silene vulgaris* (Moench) Garcke	Caryophyllaceae	32.09877	55.29412	
147. *Ranunculus arvensis* L.	Ranunculaceae	32.94798	98.28571	
127. *Oxalis repens* Thunb.	Oxalidaceae	33.83459	64.90066	
014. *Arisaema triphyllum* (L.) Schott.	Araceae	34.22053	77.45665	
143. *Pteris cretica* L.	Pteridaceae	34.31373	60.19417	
027. *Bougainvillea glabra* Choisy	Nyctaginaceae	34.66667	48.3871	
124. *Oxalis corniculata* L.	Oxalidaceae	35.05155	60.24096	
067. *Duchesnea indica* (Andrews) Teschem	Rosaceae	35.26012	85.71429	
004. *Achillea millefolium* L.	Asteraceae	35.74144	34.68208	
151. *Rosa brunonii* Lindl.	Rosaceae	35.83815	83.42857	
037. *Cannabis sativa* L.	Cannabaceae	36.06557	90.7563	
189. *Vicia sativa*L.	Fabaceae	36.21399	56.81818	
146. *Quisqualis indica* L.	Combretaceae	37.5	75.82938	

Table 1. (Cont'd.).

*Voucher No./ Species Name (Scientific)	Family	Extension (%)		Criterion
		Radicle 10mg	Hypocotyl 10mg	Radicle 10mg
097. *Jasminum officinale* L.	Oleaceae	38.2716	87.15084	
064. *Dioscorea deltoidea* Wall. ex Griseb.	Dioscoreaceae	38.78116	83.87097	
123. *Otostegia limbata* (Benth.) Boiss.	Lamiaceae	39.11111	56.79012	
150. *Rhynchosia minima* (L.) DC.	Fabaceae	39.70588	85.43689	
126. *Oxalis oregana* Nutt.	Oxalidaceae	39.86254	72.28916	
180. *Tecoma stans* (L.) Juss. ex Kunth	Bignoniaceae	40	56.87204	
094. *Indigofera tinctorial* L.	Fabaceae	40.74074	74.86034	
058. *Dalbergia sissoo* Roxb. ex DC.	Fabaceae	42.5	45.81359	
080. *Ficus microcarpa* L.f.	Moraceae	42.66667	84.77366	
088. *Geranium pusillum* L.	Geraniaceae	42.69663	70.0565	
085. *Flacourtia indica* (Burm. f.) Merr.	Salicaceae	42.93785	80.62827	
009. *Amaranthus hybridus* L.	Amaranthaceae	43.34601	80.92486	
149. *Ranunculus repens* L.	Ranunculaceae	43.3526	83.42857	
036. *Canna generalis* L.H. Bailey	Cannaceae	43.75	58.45182	
154. *Rubus fruticosus* L.	Rosaceae	43.82716	106.1453	
051. *Convolvulus arvensis* L.	Convolvulaceae	44.3609	82.11921	
020. *Bauhinia variegate* L.	Fabaceae	45.26749	64.70588	
023. *Berberis lyceum* Royle	Berberidaceae	45.62738	68.20809	
011. *Androsace sarmentosa* Wall	Primulaceae	45.66474	93.71429	
095. *Ipomoea carnea* Jacq.	Convolvulaceae	45.71429	102.2556	
155. *Rubus hispidus* L.	Rosaceae Juss.	45.98338	89.24731	
053. *Cornus macrophylla* Wall.	Cornaceae	46.09053	65.88235	
050. *Commelina benghalensis* L.	Commelinaceae	46.57534	76.62338	
113. *Mirabilis jalapa* L.	Nyctaginaceae	46.66667	53.22581	
029. *Broussonetia papyrifera* (L.) L'Hér. ex Vent	Moraceae	46.7354	77.10843	
108. *Mallotus philippensis* (Lam.) Mull. Arg	Euphorbiaceae	47.14829	86.7052	
098. *Jasminum sambac* L.	Oleaceae	47.19101	77.9661	
125. *Oxalis corymbosa* DC	Oxalidaceae	47.34694	102.2556	
010. *Amaranthus viridis* L.	Amaranthaceae	47.36842	90.06623	
185. *Verbena tenuisecta* Briq.	Verbenaceae	47.36842	70.19868	
120. *Olea ferruginea* Wall ex Aitch.	Oleaceae	47.45763	92.1466	
005. *Adiantum capillus*-veneris L.	Pteridaceae	47.46667	86.01036	
028. *Bougainvillea spectabilis* Willd.	Nyctaginaceae	47.5	58.45182	
045. *Chrysanthemum morifolium* ramat.	Asteraceae	47.87879	79.7619	
072. *Erigeron canadensis* L.	Asteraceae	47.90875	86.7052	
191. *Withania coagulans* (Stocks) Dunal	Solanaceae	48	81.48148	
082. *Ficus polita* Vahl	Moraceae	48.10997	62.6506	
179. *Taraxacum officinale* L.	Asteraceae	48.14815	84.9162	
139. *Polygonum plebeium*R. Br.	Polygonaceae	48.53333	77.72021	
101. *Justicia adhatoda* L.	Acanthaceae	48.75346	82.7957	
065. *Dodonaea viscosa* (L.) Jacq.	Sapindaceae	48.88889	65.84362	
075. *Euphorbia pulcherrima* Willd. ex Klotzsch	Euphorbiaceae	48.97959	82.70677	
056. *Cynodon dactylon* (L.) Pers.	Poaceae	49.33333	78.1893	
178. *Tagetes patula* L.	Asteraceae	49.33333	69.35484	
061. *Debregeasia salicifolia* (D. Don) Rendle	Urticaceae	49.38272	84.70588	
159. Salix babylonica L.	Salicaceae	49.71098	83.42857	
054. *Cuphea hyssopifolia* Kunth	Lythraceae	50	63.19115	
019. *Baccharoides anthelmintica* (L.) Moench.	Asteraceae	50.20576	76.13636	
135. *Plantago ovata* Forssk.	Plantaginaceae	50.22831	79.22078	
044. *Chenopodium ambrosiodes* L.	Amaranthaceae	50.27322	87.39496	
039. *Carthamus oxyacantha* M. Bieb.	Asteraceae	50.61224	76.69173	

Table 1. (Cont'd.).

*Voucher No./ Species Name (Scientific)	Family	Extension (%)		Criterion
		Radicle 10mg	Hypocotyl 10mg	Radicle 10mg
073. *Euphorbia cotinifolia* L.	Euphorbiaceae	50.66667	45.16129	
160. *Salvia aegyptiaca* L.	Lamiaceae	50.90909	94.04762	
164. *Saussurea heteromalla* (D.Don) Hand –Mazz	Asteraceae	51.02881	65.88235	
145. *Quercus dilatata Raf.*	Fagaceae	51.23457	67.03911	
186. *Vetiveria zizanioides* (L.) Nash	Poaceae	51.52355	92.47312	
131. *Phyla nodiflora* (L.) Greene	Verbenaceae	51.54639	85.54217	
002. *Acacia modesta* Wall.	Fabaceae	51.55556	75.72016	
049. *Clematis obvallata* (Ohwi) Tamura	Ranunculaceae	51.71103	91.32948	
104. *Lantana indica* Roxb.	Verbenaceae	51.85185	84.09091	
167. *Sida alba* L.	Malvaceae Juss.	51.8797	94.03974	
174. *Sonchus asper* (L.) Hill	Asteraceae	52.23368	96.38554	
193. *Woodfordia floribunda* Salisb.	Lythraceae	52.26667	102.5907	
138. *Polygonum persicaria* L.	Polygonaceae	52.43446	109.6045	
140. *Polypodium virginianum* L.	Polypodiaceae	52.44444	72.42798	
006. *Aesculus indica* (Wall. Ex Cambess.) Hook	Sapindaceae	52.46914	110.6145	
035. *Campsis radicans* (L.) Bureau	Bignoniaceae	52.5	63.19115	
069. *Duranta plumieri* Jacq.	Verbenaceae	52.5	55.29226	
196. *Zanthoxylum armatum* DC.	Rutaceae	52.88889	82.30453	
007. *Aloe barbadensis* Mill.	Asphodelaceae	53.08642	96.08939	
166. *Schefflera arboricola* Hayata	Araliaceae	53.33333	104.6632	
099. *Jatropha integerrima* Jacq.	Euphorbiaceae	53.75	91.62717	
040. *Cascabela thevetia* (L.) Lippold	Apocynaceae	54.66667	61.29032	
153. *Rosa indica* L.	Rosaceae	54.66667	61.29032	
055. *Cymbopogon citratus* (DC. ex Nees) Stapf.	Poaceae	54.84765	110.7527	
079. *Ficus carica* L.	Moraceae	55.14403	84.70588	
133. *Plantago lanceolata* L.	Plantaginaceae	55.14403	78.82353	
086. *Fragaria nubicola* (Hook. f.) Lindl. ex Lacaita	Rosaceae	55.49133	96	
089. *Geranium wallichianum* D. Don ex Sweet	Geraniaceae	56.17284	102.7933	
134. *Plantago major* L.	Plantaginaceae	56.17978	93.78531	
074. *Euphorbia helioscopia* L.	Euphorbiaceae	56.32653	93.23308	
047. *Cissampelos pareira* L.	Menispermaceae	56.36364	111.9048	
103. *Lantana camara* L.	Verbenaceae	57.39612	82.7957	
008. *Aloe vera* (L.) Burm. f.	Asphodelaceae	57.57576	88.09524	
018. *Asplenium laetum* Sw.	Aspleniaceae	57.62712	97.3822	
033. *Callistemon citrinus* Stapf	Myrtaceae	58.18182	111.9048	
115. *Myrsine africana* L.	.Primulaceae	58.22222	76.54321	
117. *Nerium oleander* L.	Apocynaceae	58.66667	65.84362	
003. *Acacia nilotica* (L.) Willd. ex Delile	Fabaceae	60.26667	79.79275	
161. *Salvia moorcroftiana* Wall. ex Benth.	Lamiaceae	60.45198	77.48691	
066. *Dryopteris ramose* (C. Hope) C. Chr.	Dryopteridaceae	60.69364	109.7143	
163. *Sargeretia thea* (Osbeck) M.C. Johnston	Rhamnaceae	61.16838	109.6386	
116. *Nasella tenuissima* (Trin.) Barkworth	Poaceae	61.33333	93.26425	
021. *Beaucarnea recurvata* lem.	Asparagaceae	61.42322	79.09605	
093. *Indigofera heterantha* Wall. ex Brandis	Fabaceae	61.42322	90.39548	
142. *Psammogeton biternatum* Edgew.	Apiaceae	61.58192	95.28796	
112. *Micromeria biflora* (Buch-Ham. ex D.Don) Benth.	Lamiaceae	62.54296	86.74699	
015. *Artemisia scoparia* Waldst. & Kit.	Asteraceae	62.66667	61.29032	
122. *Origanum vulgare* L.	Lamiaceae	62.71186	109.9476	
107. *Lythrum salicaria* L.	Lythraceae	62.85714	148.8722	
041. *Cassia fistula* L.	Fabaceae	64	70.96774	
118. *Nyctanthes arbor-tristis* L.	Oleaceae	64.60481	89.15663	

Table 1. (Cont'd.).

*Voucher No./ Species Name (Scientific)	Family	Extension (%)		Criterion
		Radicle 10mg	Hypocotyl 10mg	Radicle 10mg
068. *Duranta erecta* L.	Verbenaceae	65.33333	79.03226	
106. *Ligustrum lucidum* W.T. Aiton	Oleaceae	66.66667	62.90323	
087. *Fragaria vesca* L.	Rosaceae	67.41573	124.2938	
100. *Juglans regia* L.	Juglandaceae	67.48971	94.11765	
114. *Murraya paniculata* (L.) Jack	Rutaceae	67.5	66.35071	
043. *Cestrum diurnum* L.	Solanaceae	68	79.03226	
121. *Opuntia monacantha* Haw.	Cactaceae	68.26667	121.2435	
119. *Oenothera rosea* L' Hér. ex Aiton	Onagraceae	68.78613	172.5714	
158. *Saccharum spontaneum* L.	Poaceae	68.92655	97.3822	
152. *Rosa centifolia* L.	Rosaceae	69.33333	79.03226	
184. *Verbascum Thapsus* L.	Scrophulariaceae	69.80609	94.62366	
129. *Phalaris minor* Retz.	Poaceae	69.92481	101.9868	
175. *Strobilanthes glutinosus* Nees in Wall.	Acanthaceae	71.16105	93.78531	
030. *Bryophyllum pinnantum* (Lam.) Kurz	Crassulaceae	71.25	77.40916	
171. *Solandra maxima* (Sessé & Moc.) P.S. Green	Solanaceae	73.0038	112.1387	
077. *Fagonia indica* Burn. f.	Zygophyllaceae	73.06667	125.3886	
144. *Punica granatum* L.	Lythraceae	73.25103	89.41176	
078. *Ficus benghalensis* L.	Moraceae	74.0113	115.1832	
070. *Elaeagnus angustifolia* L.	Elaeagnaceae	74.1573	107.3446	
165. *Saxifraga rotundifolia* L.	Saxifragaceae	74.28571	99.24812	
081. *Ficus palmata* Forssk.	Moraceae	74.66667	131.6062	
132. *Pinus wallichiana* A.B. Jacks.	Pinaceae	76.40449	101.6949	
012. *Anisomeles indica* (L.) Kuntze	Lamiaceae	76.8	115.0259	
001. *Abies pindrow* (Royle ex D. Don)	Pinaceae	78.39506	108.3799	
017. *Asparagus recemosus* Willd.	Asparagaceae	79.77839	120.4301	
091. *Helicteris isora* L.	Steruliaceae	81.09966	118.0723	
111. *Mentha arvensis* L.	Lamiaceae	82.397	102.8249	
162. *Salvia nemorosa* L.	Lamiaceae	82.397	106.2147	
084. *Ficus virgata* Reinw. ex Blume	Moraceae	82.47423	97.59036	
083. *Ficus religiosa* L.	Moraceae	82.71605	117.3184	
156. *Rumex hastatus* D. Don	Polygonaceae	83.14607	126.5537	
187. *Viburnum cotinifolium* D. Don	Adoxaceae	85.18519	102.7933	
076. *Euphorbia royleana* Boiss.	Euphorbiaceae	86.4	93.26425	
071. *Elettaria cardamomum* (L.) Maton	Zingiberaceae	87.03704	139.6648	
038. *Carissa opaca* Stapf ex Haines	Apocynaceae	88.64266	120.4301	
025. *Bergenia ciliate* Stemb.	Saxifragaceae	90.12346	128.4916	
190. *Viola odorata* L.	Violaceae	92.78351	110.8434	
137. *Poa annua* L.	Poaceae	96.2963	159.7765	
022. *Beaucarnea recurvata* lem.	Asparagaceae	96.57795	117.9191	
194. *Woodfordia fruticose* (L.) Kurz	Lythraceae	98.76543	102.3529	
130. *Phoenix sylvestris* (L.) Roxb.	Arecaceae	106.1728	120	
110. *Maytenus royleanus* (Wall.) Cuford	Celastraceae	115.5894	121.3873	
118. *Viburnum grandiflorum* Wall. ex DC.	Adoxaceae	168.5393	160.452	
Mean		49.73785	78.8211	
SD		22.1134	28.52576	
Mean-1SD		27.62445	50.29533	
Mean-1.5SD		16.56775	36.03245	
Mean-2SD		5.511053	21.76957	
Mean-2.5SD		-5.54565	7.506687	

Criteron shows strong inhibirtory eefect on the radicle by deviation value:*M-1(SD), **M-1.5(SD), *** M-2(SD) and****M-2.5(SD). SD: standard deviation of rdicle. M: mean of radicle

Bojović *et al*., (2015) identified the inhibitory allelopathic effect of *Urtica dioica* on the growth of oat. Khan *et al*., (2011) reported the strong inhibitory effect of methanolic extract of *Urtica dioica* on the germination and growth of radish among 13 medicinal plants collected from the Margalla Hills Islamabad. According to Džafić *et al*., (2010), aqueous root extract of *Urtica dioica* affected the arbuscular mycorrhizal fungi in the maize roots which eventually decrease the growth and dry biomass of maize. Dziamski & Stypczynska (2015) reported the significant decreased in growth and root weight of *Hordeum vulgare* L during the application of aqueous leaves and roots extracts of *Urtica dioica* due to release of allelochemicals.

Xiaoyong *et al*., (2017) noted that the flower of *Tagetes erecta* has remarkably inhibited the germination and seedling growth of lettuce. Similarly, Santos *et al*., (2015) reported the release of allelochemicals compound (phenols and flavnoids) from *Tagetes erecta* and reduction in germination and development. Duary & Mukherjee (2013) reported the suppression of *Parthenium* species due to the allopathic effect of *Tagetes erecta.* The aqueous extract of *Tagetes erecta* reduced the transpiration and respiration as well as decreases the seedling growth and germination of *Brassica oleracea* (Dragomir & Nicolae, 2014). Nguyen *et al*., (2016) observed the inhibition of seedling growth and germination of *Amaranthus tricolor* L. due to allelochemicals released from ethanolic extract of *Tagetes erecta.*

Alshahrani *et al*., (2017) investigated the allelopathy of *Calotropis procera,* ithad decrease seedling growth, inhibited the seed germination and significant change in biomass of Acacia species due to the release of allelochemicals. The aqueous extract of *Calotropis procera* contains phytotoxic compounds and inhibits the seed germination, reduce seedling biomass, root length and shoot length of cultivated crops particularly wheat (Yasin *et al*., 2012). Al-Zahrani & Al-Robai, (2007) investigated the allelopathic effect of *Calotropis procera* dry leaf aqueous extract. There was delay in germination, less germination percentage, decrease in radicle length of Cucumber, Barley, Fenugreek, Wheat and Alssana at higher concentrations of *Calotropis procera.* Mishra, (2015) reported the strong inhibitory allelopathic effect of *Calotropis procera* aqueos extract on the germination and growth of *Parthenium hysterophorus.* Gupta (2016) identified the reduction in plumule length of mungbean by leaf alcoholic extract of *Calotropis procera* in vivo conditions. *Calotropis procera* inhibited the growth of wheat, tomato and cucumber due to release of allelochemicals (El-Khatib *et al*., 2016). Aslam *et al*., (2016) observed the phytotoxic effect of *Calotropis procera* on wheat and mustard at higher aqueous extract concentration and noted the inhibitory effect on seed germination and seedling length.

Biggerstaff & Beck (2007) noted *Hedera helix* as rapidly invading species into forest ecosystems in the United States and assessed its allelopathic affect. It has exhibited negative allelopathic effect on the growth, distribution and density of *Coreopsis lancelota*. Le & Sonu (2000) identified the changed in soil traits, reduction in root and shoot length and germination of native riparian plant species due to the release of allelochemicals from *Hedera helix.* Alike, Binggeli (2005) also reported the decrease in number of native plant species due to allelopathic effect of *Hedera helix.* Additionally, it has threatened many endangered species and soil properties. The growth and germination of beans and corns was strongly inhibited by the allelochemicals from the *Hedera helix* (Marian *et al*., 2017). Copp, (2014) reported the decrease in moisture content for neighboring plants, growth suppression, and reduction in density of *Hydrophyllum tenuipes* and *Vancouveria hexandra* due to allelochemicals released from *Hedera helix.*

The plants have ability to stimulate the growth of other plants through allelopathic pathways. The results presented strong stimulatory allelopathic effect of *Viburnum grandiflorum* on germination and growth of lettuce. Similarly, the allelochemicals from *Maytenus royleanus* promoted the growth of lettuce. Shinwari *et al*., (2017) pointed out the stimulatory growth due to certain secondary metabolites from medicinal plants that can induce tolerance against diseases and abiotic stresses. *Phoenix sylvestris* and *Woodfordia fruticosa* exhibited the stimulatory allelopathic effect on the germination and growth of lettuce. Alike, *Beaucarnea recurvate, Poa annua, Viola odorata* and *Bergenia ciliata* had also shown stimulatory allelopathic effect on germination and growth of lettuce in the current study.

Conclusions

The present study concludes that *Boerhavia procumbens* exhibits the strongest inhibitory allelopathic effect and *Viburnum grandiflorum* presents strong stimulatory effect on the growth of lettuce seeds. The study identified least reported allelopathic effect of many plants particularly *Plectranthus rugosus* (inhibitory effect), *Viburnum grandiflorum* (stimulatory effect), *Maytenus royleanus* (stimulatory effect), *Phoenix sylvestris* (stimulatory effect), *Woodfordia fruticosa* (stimulatory effect), *Beaucarnea recurvate* (stimulatory effect), *Poa annua* (stimulatory effect), *Viola odorata* (stimulatory effect) and *Bergenia ciliata* (stimulatory effect). Hence, the exploration of allelopathic effects likely to improve immunity against diseases, soil properties, survival of specie, distribution, weed management, sustainable agriculture, and compatibility with climate change. Based on this study, further research is required on isolation of allelochemicals, industrial application, bio herbicides, interactions of allopathy with biodiversity conservation and adaptability with climate change for long-term environmental sustainability.

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