Research Article

Germination and Seedling Growth of *Convolvulus arvensis* L. and *Cyperus rotundus* L. under the Allelopathic Influence of *Eucalyptus camaldulensis* (L.) Leaves

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Abstract | The utilization of allelopathic properties of plants is thought to be an effective and environment-friendly approach for weed management. A pot experiment to evaluate the allelopathic potential of leaves of *Eucalyptus camaldulensis* (L.) against *Convolvulus arvensis* (L.) and *Cyperus rotundus* (L.) was undertaken during summer 2011. The study was conducted at Department of Agronomy, Sindh Agriculture University, Tandojam, Pakistan. The experiment was laid out in three replicated completely randomized design. The treatments consisted of control (untreated), eucalyptus water extract at 10, 20 and 30 ml kg^{-1} soil, eucalyptus powder at 10, 20 and 30 g kg^{-1} soil, eucalyptus powder at 10 g kg^{-1} soil+water extract at 10 ml kg^{-1} soil, eucalyptus powder at 20 g kg^{-1} soil+water extract at 20 ml kg^{-1} soil and eucalyptus powder at 30 g kg^{-1} soil+water extract at 30 ml kg^{-1} soil. Data showed that all the treatments of eucalyptus leaves water extract and powder caused substantial ($P \leq 0.05$) decrease in germination and seedling growth of *C. arvensis and C. rotundus* as compared to control. Integrated application of eucalyptus powder at 30 g kg^{-1} soil+eucalyptus water extract at 30 ml kg^{-1} of soil and eucalyptus powder at 20 g kg^{-1} soil+eucalyptus water extract at 20 ml kg^{-1} soil showed highest inhibitory effect. In both aforesaid treatments, lowest and statistically similar values of germination, root/ shoot length and fresh/ dry weight $seedling^{-1}$ were recorded for both *C. arvensis* and *C. rotundus*, respectively. The water extract of *E. camaldulensis* showed superiority in allelopathic effects over its powder. Inhibitory effect of water extract or powder increased at higher rate (30 ml or 30 g kg^{-1} soil). Hence, results conferred that eucalyptus leaves possess allelopathic potential which could be utilized for suppression of weeds under field conditions.

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Introduction

The infestation of weeds in the crop field having allelopathic properties may cause serious menace to the crop yield (Weston et al., 2013). Field bindweed (*Convolvulus arvensis* L.) and purple nutsedge (*Cyperus rotundus* L.) are classified as world's worst weeds (El-Rokiek et al., 2010). These weeds are also widely spread in cultivated fields of Pakistan and are considered extremely tough competitors of crops for resources (Khan et al., 2008; Ali et al., 2016). In addition to competition, both weeds possess allelopathic properties and found to inhibit growth of crop plants (Geethambigai and Prabhakaran, 2014). The interfer-

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ence of *C. arvensis* and *C. rotundus* with crops may cause 20-70% yield loss (Shahrokhi et al., 2011). The prevailing weed management methods are either costly or health hazardous. Therefore, the plant derived compounds can be a possible alternative to synthetic herbicides and may be used as natural herbicides (Khan et al., 2015).

The accumulation of compounds with allelopathic potential may cause toxicity which ultimately affect the crop growth and yield (Ghnaya et al., 2015). Many researchers concentrate allelopathy with only inhibitory effects (Saeed et al., 2013). *E. camaldulensis* (L.) release volatiles like phenolic acids, benzoic and cinnamic which suppress the growth of weeds and crops growing in its vicinity. The main sources of releasing toxic compounds in eucalyptus are its leaves (Dadkhah and Asadi, 2010). Aqueous leachates of fresh leaves of eucalyptus significantly reduced the initiation of propagules and early growth of *C. rotundus* seedlings (Ranganathan and Kandasamy, 2008). Similarly, Khan et al. (2008) revealed that 5 ml of aqueous extract of *E. camaldulensis* leaves significantly lowered fresh and dry weight of *C. arvensis* and other weeds in contrast to water application. In addition, the extracts of several weeds have been reported to retard the growth of mixed population of several weeds (Afridi and Khan, 2014; 2015).

Several studies on weed management at different research institutes in Sindh, Pakistan are being conducted through mechanical, manual and chemical methods (Chachar et al., 2009). There is little information available on utilizing allelopathic properties of several plants for weed management in Sindh. Therefore, this experiment was carried out to investigate the allelopathic influence of *E. camaldulensis* leaves as water extract and powder on germination and seedling growth of *C. arvensis* and *C. rotundus* under laboratory conditions.

Materials and Methods

A pot study was conducted at Department of Agronomy, Sindh Agriculture University, Tandojam, Pakistan during summer 2011. The experiment was laid out in three replicated completely randomized design. The pots having size of 30x15x15cm were filled with 5 kg soil and soil was moistened with water. Allelopathic potential of *Eucalyptus camaldulensis* (L.) powder and water extract was evaluated against two noxious weeds i.e. *Convolvulus arvensis* (L.) and *Cyperus rotundus* (L.). The propagules of weeds (rhizomes for *C. arvensis* and tubers for *C. rotundus*) were sown in pots on 15th June, 2011. The boxes were placed at room temperature (20-25°C). The sandy loam soil was collected from Latif minor, Sindh Agriculture University, Tandojam for experimental purpose. The treatments details are given as under:

- T1 = Control (untreated)
- T2 = Eucalyptus water extract at 10 ml kg^{-1} soil
- T3 = Eucalyptus water extract at 20 ml kg^{-1} soil
- T4 = Eucalyptus water extract at 30 ml kg^{-1} soil
- T5 = Eucalyptus powder at 10 g kg^{-1} soil
- T6 = Eucalyptus powder at 20 g kg^{-1} soil
- T7 = Eucalyptus powder at 30 g kg^{-1} soil
- T8 = Eucalyptus powder at 10 g kg^{-1} soil+Eucalyptus water extract at 10 ml kg^{-1} soil
- T9 = Eucalyptus powder at 20 g kg^{-1} soil+Eucalyptus water extract at 20 ml kg^{-1} soil
- T10 = Eucalyptus powder at 30 g kg^{-1} soil+Eucalyptus water extract at 30 ml kg^{-1} soil

Collection of Allelopathic Herbage and Weed Propagules

The mature leaves of eucalyptus and propagatory material of weed was collected from Students' Experimental Farm, Department of Agronomy, Sindh Agriculture University, Tandojam. The allelopathic material was dried under sun, chopped into small pieces and ground to powder by grinder. The water extract was prepared by soaking powder in tap water for 24 hours followed by the method developed by Cheema et al. (2002). The ratio between allelopathic herbage and water was 1:10 (w/v). The water extract was filtered through muslin cloth.

Application of Water Extracts and Soil Incorporation of Powder

The water extract prepared from eucalyptus was sprayed on soil immediately after sowing of weeds as per treatments. As regards soil incorporation, the powder of eucalyptus was mixed thoroughly with soil as per treatments before sowing of weeds. The propagatory material of test weeds (five rhizomes of *C. arvensis* and five tubers of *C. rotundus*) was sown in rows, respectively. Five rows of weeds were maintained in each box. The soil in each box was moistened regularly as and when needed by tap water.

Data Collection and Statistical Analysis

The sprouts were counted at 10 days after sowing

Table 1: *Impact of eucalyptus leaves water extract and powder on germination (%) of weeds*

Treatments	*Convolvulus arvensis* (L.)	*Cyperus rotundus* (L.)
Control (untreated)	96.0 a	95.7a
Eucalyptus water extract at 10 ml kg^{-1} soil	88.0 b	89.0 b
Eucalyptus water extract at 20 ml kg^{-1} soil	85.7 c	86.7 c
Eucalyptus water extract at 30 ml kg^{-1} soil	84.3 c	85.3 c
Eucalyptus powder at 10 g kg^{-1} soil	84.0 c	83.7 d
Eucalyptus powder at 20 g kg^{-1} soil	82.0 d	82.0 d
Eucalyptus powder at 30 g kg^{-1} soil	80.0 e	80.3 e
Eucalyptus powder at 10 g kg^{-1} soil + Eucalyptus water extract at 10 ml kg^{-1} soil	79.0 e	79.0 e
Eucalyptus powder at 20 g kg^{-1} soil + Eucalyptus water extract at 20 ml kg^{-1} soil	76.7 f	76.3 f
Eucalyptus powder at 30 g kg^{-1} soil + Eucalyptus water extract at 30 ml kg^{-1} soil	75.0 f	74.7 f
S.E ±	**0.8330**	**0.8563**
LSD $_{0.05}$	**1.7500**	**1.7991**

Means not sharing same letter in a column are significantly different at 0.05 probability level

(DAS) for recording germination (%). For recording data on root length (mm), shoot length (mm) and fresh weight $seedling^{-1}$ (mg) the respective seedlings of weeds were uprooted at 30 DAS. In order to record dry weight, weed seedlings were kept in oven at 70 ^{0}C for 72 hours. The data collected was subjected to statistical analysis through computer software Statistix 8.1 (Statistix, 2006). For comparing treatment means superiority, the LSD test was applied at probability level 0.05.

Results and Discussion

Germination (%) of Weeds

Germination is considered as the crucial stage of any plant and thus determines the growth and development of plants (Kashmir et al., 2016). Data (Table 1) shows that water extract and powder of eucalyptus leaves significantly ($P \leq 0.05$) reduced germination of both *C. arvensis* and *C. rotundus* as compared to control (untreated). Nevertheless, the treatments of water extracts and powders differed markedly from each other in phytotoxic efficacy on germination. In case of *C. arvensis*, the minimum and statistically at par values for germination (75.0.0 and 76.7%) were recorded in integrated application of eucalyptus powder at 30 g kg^{-1} soil+eucalyptus water extract at 30 ml kg^{-1} soil and eucalyptus powder at 20 g kg^{-1} soil+eucalyptus water extract at 20 ml kg^{-1} soil, respectively. For *C. rotundus*, the least germination (74.7 and 76.3%) with statistically similar values was recorded under eucalyptus powder at 30 g kg^{-1} soil+eucalyptus water extract at 30 ml kg^{-1} soil and eucalyptus powder at 20 g kg^{-1} soil+eucalyptus water extract at 20 ml kg^{-1} soil. The perusal of data confirmed the inhibitory effects of eucalyptus on germination of both weeds i.e. *C. arvensis* and *C. rotundus*. The results are supported by Nouri et al. (2012) who reported that when the germinating seeds of any plant species are exposed to allelochemicals, their germination is decreased drastically. In our experiment, combined application of water extract and powder of eucalyptus resulted in least germination as compared to sole application. Water extracts of eucalyptus proved more phytotoxic compared with powders. The results are matching with the findings of Ghanuni et al. (2015) who reported that soil in pot treated with leaf extract of *E. camaldulensis* at highest concentration (100%) exhibited a significant reduction in the germination of *C. rotundus*. Similarly, Saeed et al. (2013) concluded that maximum inhibition in germination of *Datura* spp., *Sonchus* spp. and *Sinapis* spp. was noted when the aqueous extracts of *E. camaladulensis* leaves were used at concentrations of 15% w:v.

Root and Shoot Length of Weeds

Statistical analysis of data (Table 2) indicated that water extract and powder of eucalyptus leaves caused significant ($P \leq 0.05$) decrease in root and shoot length of test weeds as compared to control treatment. In case of *C. arvensis*, the integrated application of eucalyptus

Table 2: *Impact of eucalyptus leaves water extract and powder on root and shoot length (mm) of weeds*

Treatments	*Convolvulus arvensis* (L.)		*Cyperus rotundus* (L.)	
	Root length (mm)	Shoot length (mm)	Root length (mm)	Shoot length (mm)
Control (untreated)	128.7 a	114.3 a	90.0 a	151.3 a
Eucalyptus water extract at 10 ml kg^{-1} soil	119.6 b	109.7 c	85.0 b	144.0 b
Eucalyptus water extract at 20 ml kg^{-1} soil	114.7 c	112.6 b	80.3 c	140.0 c
Eucalyptus water extract at 30 ml kg^{-1} soil	110.7 d	108.0 d	75.0 d	136.7 d
Eucalyptus powder at 10 g kg^{-1} soil	113.6 c	105.0 e	76.0 e	136.3 d
Eucalyptus powder at 20 g kg^{-1} soil	109.0 e	98.3 f	71.0 f	132.0 e
Eucalyptus powder at 30 g kg^{-1} soil	106.0 f	94.3 g	70.3 f	128.0 f
Eucalyptus powder at 10 g kg^{-1} soil+ Eucalyptus water extract at 10 ml kg^{-1} soil	99.3 g	89.3 h	72.0 g	123.7 g
Eucalyptus powder at 20 g kg^{-1} soil+ Eucalyptus water extract at 20 ml kg^{-1} soil	94.0 h	87.0 i	68.0 h	119.3 h
Eucalyptus powder at 30 g kg^{-1} soil+ Eucalyptus water extract at 30 ml kg^{-1} soil	92.0 h	86.7 i	66.7 h	117.3 h
S.E ±	**1.0623**	**0.7027**	**0.4635**	**0.7235**
$LSD_{0.05}$	**2.2317**	**1.4764**	**1.3737**	**1.9200**

Means not sharing same letter in a column are significantly different at 0.05 probability level

Table 3: *Impact of eucalyptus leaves water extract and powder on fresh and dry weight seedling^{-1} (mg) of weeds*

Treatments	*Convolvulus arvensis* (L.)		*Cyperus rotundus* (L.)	
	Fresh weight	Dry weight	Fresh weight	Dry weight
	(mg seedling^{-1})			
Control (untreated)	1466.7 a	563.7 a	831.6 a	352.0 a
Eucalyptus water extract at 10 ml kg^{-1} soil	1266.6 b	501.6 b	784.0 b	345.0 b
Eucalyptus water extract at 20 ml kg^{-1} soil	1166.7 c	497.0 b	780.0 b	341.0 c
Eucalyptus water extract at 30 ml kg^{-1} soil	1066.6 d	475.7 c	775.3 b	336.0 d
Eucalyptus powder at 10 g kg^{-1} soil	1216.6 b	488.0 c	777.0 b	338.0 d
Eucalyptus powder at 20 g kg^{-1} soil	1050.0 d	476.3 c	771.0 b	332.0 e
Eucalyptus powder at 30 g kg^{-1} soil	958.3 e	459.3 d	767.6 c	327.7 f
Eucalyptus powder at 10 g kg^{-1} soil+ Eucalyptus water extract at 10 ml kg^{-1} soil	850.0 f	445.7 e	763.0 c	323.0 g
Eucalyptus powder at 20 g kg^{-1} soil+ Eucalyptus water extract at 20 ml kg^{-1} soil	764.0 g	438.0 f	746.0 d	315.0 h
Eucalyptus powder at 30 g kg^{-1} soil+ Eucalyptus water extract at 30 ml kg^{-1} soil	736.7 g	431.7 f	739.3 d	310.7 h
S.E ±	**32.466**	**4.2394**	**7.1917**	**1.0588**
$LSD_{0.05}$	**68.208**	**8.9067**	**15.109**	**2.2244**

Means not sharing same letter in a column are significantly different at 0.05 probability level

powder at 30 g kg^{-1} soil+eucalyptus water extract at 30 ml kg^{-1} soil and eucalyptus powder at 20 g kg^{-1} soil+eucalyptus water extract at 20 ml kg^{-1} soil demonstrated strong phytotoxic activity and conferred lowest root length (92.3 and 94.0 mm) and shoot length (86.7 and 87.0 mm) showing statistically non-significant differences with each other, respectively. For *C. rotundus*, the least and statistically similar root length (66.7 and 68.0 mm) and shoot length (117.3 and 119.3 mm) were documented under combined application of eucalyptus powder at 30 g kg^{-1} soil+eucalyptus water extract at 30 ml kg^{-1} soil and eucalyptus powder at 20 g kg^{-1} soil+eucalyptus water extract at 20 ml kg^{-1} soil, respectively. Water extract of eucalyptus was

found more phytotoxic than powder in suppressing growth of weeds. The strong phytotoxic effect of water extract was possibly due to its solubilized form. Our findings are at par with Khaliq et al. (2013) who reported that in a pot study eucalyptus aqueous extract resulted in highest suppression (60%) in shoot length of purple nutsedge. The results of this study are also in line with Khan et al. (2008) who suggested that seedling growth of *C. arvensis* was adversely affected due to phytotoxic effects of eucalyptus extract.

Fresh and Dry Weight of Weeds

The data presented in Table 3 shows that eucalyptus leaves water extract and powder at lower or higher rates significantly inhibited the fresh and dry weight seedling^{-1} (mg) of weeds as compared to control (untreated). Regarding *C. arvensis*, the lowest and statistically similar fresh weight seedling^{-1} (736.7 and 764.0 mg) and dry weight seedling^{-1} (431.7 and 438.0 mg) were recorded. These records were observed under integrated application of eucalyptus powder at 30 g kg^{-1} soil+eucalyptus water extract at 30 ml kg^{-1} soil and eucalyptus powder at 20 g kg^{-1} soil+eucalyptus water extract at 20 ml kg^{-1} soil, respectively. Similarly, for *C. rotundus*, the minimum and statistically equal fresh weight seedling^{-1} (739.3 and 746.0 mg) and dry weight seedling^{-1} (310.7 and 315.0 mg) were noted in combined application of eucalyptus powder at 30 g kg^{-1} soil+eucalyptus water extract at 30 ml kg^{-1} soil and eucalyptus powder at 20 g kg^{-1} soil+eucalyptus water extract at 20 ml kg^{-1} soil. The decline in weight of targeted weeds was perhaps due to decreased root and shoot length. Our results are in agreement with Khan et al. (2008) who concluded that fresh and dry weight of *C. arvensis* was reduced significantly by application of eucalyptus aqueous extract. The findings of this study are also at par with Ranganathan and Kandasamy (2008) who suggested that leaf leachates of *E. globulus* had inhibitory effect on weight of *C. rotundus*.

Conclusions

The results concluded that water extract and powder of *E. camaldulensis* (L.) leaves caused significant inhibition in germination and seedling growth of *C. arvensis* (L.) and *C. rotundus* (L.) as compared to control. The combined application of eucalyptus water extract and powder either at 30 ml+30 g or 20 ml+20 g kg^{-1} soil exhibited highest phytotoxic efficacy resulting in lowest germination and subsequent growth of weed seedlings. Water extract was found stronger in inhibitory action than powder. Hence, phytotoxic properties of eucalyptus leaves could be utilized for effective management of weeds in cultivated fields as eco-friendly approach.

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Authors' Contributions

Muhammad Nawaz Kandhro (MNK) and Ali Nawaz Khaskheli designed and conducted experiment and collected data. Mahmooda Buriro analyzed the data. MNK wrote the manuscript, Ghulam Mustafa Laghari arranged the references, and Qamaruddin Jogi and Aijaz Ahmed Soomro evaluated and edited the manuscript.

References

Afridi, R.A., and M.A. Khan. 2015. Comparative effect of water extract of *Parthenium hysterophorus, Datura alba, Phragmites australis* and *Oryza sativa* on weeds and wheat. Sains Malays. 44(5):693-699. http://dx.doi.org/10.17576/jsm-2015-4405-08

Afridi, R.A., and M.A. Khan. 2014. Reduced herbicide doses in combination with allelopathic plant extracts suppress weeds in wheat. Pak. J. Bot. 46(6):2077-2082.

Ali, A., M.A. Khan, A. Saleem, K.B. Marwat, A.U. Jan, D. Jan and S. Sattar. 2016. Performance and economics of growing maize under organic and inorganic fertilization and weed management. Pak. J. Bot. 48(1): 311-318.

Chachar, Q.I., M.A. Chachar and S.D. Chachar. 2009. Studies on integrated weed management in wheat (*Triticum aestivum* L.). J. Agric. Technol. 5(2):405-412.

Cheema, Z.A., A. Khaliq and M. Tariq. 2002. Evaluation of concentrated sorgaab alone and in combination with three pre-emergence herbicides for weed control in cotton (*Gossypium hirsutum* L.). Int. J. Agric. Biol. 4(4):549-452.

Dadkhah, A.R., and A. M. Asaadi. 2010. Allelopathic effects of *Eucalyptus camaldulensis* on seed germination and growth of *Acroptilon re-*

pens, *Plantago lanceolata* and *Portulaca oleracea*. Res. J. Biol. Sci. 5(6):430434. http://dx.doi.org/10.3923/rjbsci.2010.430.434

El-Rokiek, K.G., S.A.S. El-Din, F.A.A. Sharara. 2010. Allelopathic behaviour of *Cyperus rotundus o*n both *Chorchorus olitorius* (broad leaved weed) and *Echinochloa crus-galli* (grassy weed) associated with soybean. J. Plant Protec. Res. 50(3):34-39.

Geethambigai, C.S., and J. Prabhakaran. 2014. Allelopathic potential of *Cyperus rotundus* (L.) and *Cynodan dactylon* (L.) on germination and growth responses of some rice cultivars. Int. J. Curr. Biotechnol. 2(12):41-45.

Ghanuni, A.M, A. Elshebani, M.A. Moftah and A.N. Lajili. 2015. Allelopathic effect of (*Eucalyptus camaldulensis*) on peanut (*Arachis hypogaea*) crop and purple nutsedge (*Cyperus rotundus*) weed. Scholarly J. Agric. Sci. 5(6):189-194.

Ghnaya, A.B., L. Hamrouni, I. Amri, H. Ahoues, M. Hanana and A. Romane. 2015. Study of allelopathic effects of *Eucalyptus erythrocorys* (L.) crude extracts against germination and seedling growth of weeds and wheat. Nat. Prod. Res. 29(23):1-7.

Kashmir, S., M.A. Khan, A.A. Shad, K.B. Marwat and H. Khan. 2016. Temperature and salinity affect the germination and growth of *Silybum marianum* (Gaertn) and *Avena fatua* (L.). Pak. J. Bot. 48(2):469-476.

Khan, M.A., I. Hussain and E.A. Khan. 2008. Suppressing effects of *Eucalyptus camaldulensis* (L.) on germination and seedling growth of six weeds. Pak. J. Weed Sci. Res. 14(3-4):201-207.

Khan, E.A., A.A. Khakwani, M. Munir and G. Ullah. 2015. Effects of allelopathic chemicals extracted from various plant leaves on weed control and wheat crop productivity. Pak. J. Bot. 47(2):735-740.

Khaliq, A., A. Matloob, M.B. Khan and A. Tanveer. 2013. Differential suppression of rice weeds by allelopathic plant aqueous extracts. Planta Daninha. 31(1):21-28. http://dx.doi.org/10.1590/S0100-83582013000100003

Nouri, H., Z.A. Talab and A. Tavassoli. 2012. Effect of weed allelopathic of sorghum (*Sorghum halepense*) on germination and seedling growth of wheat, Alvand cultivar. Ann. Biol. Res. 3(3):1283-1293.

Ranganathan, C., and O. S. Kandasamy. 2008. Allelopathic effect of *Eucalyptus globulus* (L.) on *Cyperus rotundus* (L.) and *Cynodon dactylon* (L. Pers.). J. Agron. Crop Sci. 179(2):123-126.

Saeed, J.A., E.R. Al-Rawi and F.K. Ibraheem. 2013. The effect of aqueous leaves extracts of *Eucalyptus camaldulensis* on germination and growth of three weed species. Raf. J. Sci. 24(2): 1-10.

Shahrokhi, S., B. Kheradmand, M. Mehrpouyan, M. Arboodi and M. Akbarzadeh. 2011. Effect of different concentrations of aqueous extract of bindweed, *Convolvulus arvensis* on initial growth of Abidar barley (*Hordeum vulgare*) cultivar in greenhouse. Int. Conf. Biol. Environ. Chem. IPCBEE, 24 IACSIT Press, Singapore.

Statistix. 2006. Statistix 8 user guide, version 1.0. Analytical Software, PO Box 12185, Tallahassee FL 32317 USA. Copyright © 2006 by Analytical Software.

Weston, L.A., I.S. Alsaadawi and S.R. Baerson. 2013. Sorghum allelopathy-From ecosystem to molecule. J. Chem. Ecol. 39:625–637. http://dx.doi.org/10.1007/s10886-013-0245-8