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# ALLELOPATHY BY *LANTANA CAMARA* L.

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**Abstract**

*Lantana camara* L., is a common wild shruby ornamental and hedge plant growing from plains to an elevation upto 1500m in Pakistan. Aqueous extracts of all parts of *Lantana camara* have strong allelopathic effect on the germination and growth of various test species. However, the relative toxicity of various parts varied among themselves and against the various test species used. Hot water extracts from leaves were more toxic than stems followed by fruit extracts. Alcoholic extracts did not affect the germination of three test species. Natural rain leachates of different plant parts invariably suppressed the germination and growth of various test species. *Lantana* soil when tested showed no inhibitory effects on the germination and growth of test species. Soil analysis indicated that $CaCO_3$ and organic matter were low in control soil compared with *Lantana*-affected soil. Among major elements only P was higher in control soil than *Lantana*-affected soil. The cell sizes of both plumule and radicle in all the test species reduced, especially in leaf extracts. The most affected species was *Allium cepa.* Paper chromatography suggested the presence of p-OH-benzoic acid, p-coumaric acid, caffeic acid, vanillic acid, ferulic acid, syringic acid and gentisic acid. These compounds have known inhibitory activity against many species.

## Introduction

*Lantana camara* L., is a common wild shrubby plant growing from plains to 1500m in Pakistan. It is also used as ornamental and hedge plant. It propagates easily from seeds and cuttings. Being non-palatable, it has better chances of growth and invasion. One of the reasons for its successful invasion might be allelopathy and non-palatabily. Achhireddy *et al*. (1984) found that foliar leachates of *Lantana camara* and soil in which it had grown had no effect on the final germination percentages or seedling growth of *Morrenia odorata* while roots and shoots showed allelopathic effects. Angiras *et al*., (1988a) found that aqueous extracts from *Lantana* parts had no effect on germination of maize, soybean and chickpea. Later on Angiras *et al*., (1988b) reported that aqueous extracts reduced germination of chickpea. Shrivas & Bajpai (1988) reported that flower extracts, followed by seed and stem extracts of *Lantana indica* were more inhibitory against germination, fresh and dry weight of seedling of *Dalbergia sissoo*. Singh *et al*., (1988) observed that germination of wheat cv. sonalika seeds was inhibited to greater extent by boiled and unboiled extracts of *Lantana camara* due to presence of phenolic compounds (Singh *et al*., 1989). Parsad & Srivastava (1991) observed teletoxic effect of *Lantana camara* on germination and growth of rice. Saxena (2000) found *Lantana camara* as most allelopathic plant against *Eichornia crassipes*. Sharma *et al.,* (1992) reported anti-feedant activity of *Lantana camara*. Arora & Kohli (1993a, b) found that crude volatile oil extracted from the young leaves of *Lantana camara* var. *camara* had adverse effects on leaf chlorophyll content, seed germination and seed vigour of parent *Lantana camara* plant. Sahid & Sugau (1993) noticed that emergence and dry weight of many vegetable species were affected due to *Lantana camara*. It appears that allelopathy governs the community dynamics, pattern and productivity in natural and agroecosystem (Rice, 1984; Putname & Chung, 1986; Irshad & Cheema, 2004; Jabeen & Ahmed, 2009; Barkatullah *et al.*, 2010). Marwat & Khan (2006) reported allelopathic proclivities of tree leaf extracts on seed germination and growth of wheat and wild oats. Cheema & Khaliq (2000) used allelopathic behaviour of *Sorghum* for controlling weeds. Jefferson &. Pennacchio (2003) reported the allelopathic effects of foliage extracts from four Chenopodiaceae species on seed germination. Hussain *et al.*, (2004) reported that *Broussonetia papyrifera* reduced the germination and growth of test species due to allelopathy. Startsev *et al.,* (2008) reported the effects of leaf litter on the growth of boreal feather mosses. Samreen *et al.*, (2009) stated that *Calotropis* exhibits allelopathy against some crops. The present investigation was carried out to further test the allelopathic nature of *Lantana camara* against two fodder grasses and lettuce and to determine the allelopathic substances and its mechanism of release. The findings will broaden the existing knowledge about allelopathy by this plant.

## Materials and Methods

Plant parts i.e., stems, leaves and fruits of mature *Lantana camara* L., were separately collected from Peshawar University Campus during October and dried at room temperature (25°C - 30°C). Glassware was thoroughly washed with tap water and sterilized at 170°C for at least 4 hours. *Pennisetum americanum*, *Lactuca sativa* (L.) and *Setaria italica* (L.) P. Beauv. were used as the test species.

**Effect of extracts:** Five grams dried crushed leaves, stems and fruits were soaked in 100 ml of distilled water at 25°C for 24 and 48 hours and filtered. These extract were tested against test species on 2-folds of filter paper in petri dishes along with a distilled water control. For each treatment, 10 replicates, each with 10 seeds were made. The petri dishes were incubated at 25°C for 72 hours. Germination, growth of plumule and radicle were noted. Twenty seedlings were randomly taken out for fresh and dry weight determination. Seedlings were dried at 65°C for 72 h. Moisture contents were calculated on oven dried basis (Hussain, 1989). In another set of experiment 5 gm dried plant parts were boiled separately in 100 ml of water for 5 minutes, filtered and cooled to room temperature and used as above. Yet in another set of experiment alcoholic extracts were prepared

by soaking 5 gm dried plant parts in 100 ml alcohol at room temperature for 24 hours to get alcohol soluble substances. The alcoholic extracts were dried at 65°C to get dry residue. This dry residue was dissolved in 100 ml of distilled water and tested against test species as stated above.

**Effect of natural rain leachates:** Twenty gm dried leaves and fruits were crushed and spread on a single sheet of filter paper in large funnels lying over flasks. The funnels and flasks were placed on 1 m high bench during the slow drizzle in January. The leachate collected in the flask was used against the same test species as before. In control simple rainwater was used.

**Soil residual toxicity**

**a. Soil bed bioassay:** Soil from underneath *Lantana camara* thickets (Lantana soil) was collected and dried at room temperature while soil for control was collected from the same vicinity but without Lantana. One gm of *Lantana* or control soil was used as seed-bed in petridish. Soil was topped with a single sheet filter paper. The petridishes were moistened with 15 ml distilled water. After 3 days, seeds of test species were placed on filter papers and incubated for 72 hours as before.

**b. Soil extract bioassay:** Five gm of both test and control soil was dissolved in 100 ml distilled water and filtered after 24 hrs. It was used against the same test species as before. After 72 hrs, the germination, plumule and radicle length were recorded.

Soil samples were physico-chemically analyzed following standard techniques (Jackson, 1962; Hussain, 1989) for comparison.

**Effect on cell development:** Five gm leaves or fruits were boiled in 100 ml distilled water for 5 minutes and filtered. The extract was used against same 3 test species as before. The tips from plumules and radicles were removed and treated with concentrated chloral hydrate solution for 24 hours. Length and breadth of 10 cells in 3rd cortical layer over a fixed area was measured microscopically.

**Identification of phytotoxins:** Natural rain leachates collected earlier was concentrated to 1/3$^{rd}$ of its original volume and acidified with 1N HCl to pH 2-3. To this concentrate double amount of ether was added. The mixture was vigorously re-flux shaken for at least 30 min in separation flask thereafter separating flask was left till the separation of two; ether and aqueous layers. The ether layer was saved for concentration while the aqueous fraction was shaken for another two extractions. All the three ether fractions were combined and concentrated in rotavapor. The dry residue, taken in methanol, was spotted on Whatman No.1 filter paper strips along with standard compounds including caffeic acid, ferulic acid, *p*-OH Benzoic acid, *p*-coumaric acid, chlorogenic acid, ellagic acid, vanillic acid, benzoic acid and quercetin. The chromatograms were run in 6% acetic acid (6% V/V acetic acid) and BAW (*n*-butanol:acetic acid:water = 63:10:27 ml) solvent system in descending order. The chromatograms were inspected under long (366 nm) and short (254 nm) UV light. The chromatograms were then sprayed with spraying reagent for further confirmation. The different colours and Rf values of standard and unknown compounds were compared for identification.

**Results**

**Aqueous extract bioassay:** Germination of *Pennisetum* in fruit extract, *Setaria* in leaves and 48 hrs fruit extract; and that of *Lactuca* in all the treatments was reduced (Table 1). The radicle growth of *Pennisetum* in leaves and fruits extracts; that of *Setaria* and *Lactuca* in all the treatments significantly decreased (Table 1). The plumule growth of *Pennisetum* in fruit extract and that of *Setaria* and *Lactuca* in all the treatments significantly decreased (Table 1).

The fresh weight of *Pennisetum* declined in stem extracts while that of *Setaria* decreased only in leaf extracts and that of *Lactuca* in stem extracts (Table 1). Dry weight of *Pennisetum* in stem extract; that of *Setaria* in leaf extracts and *Lactuca* in stem extracts declined (Table 1). Moisture contents of *Pennisetum* and *Lactuca* in leaf and fruit extracts, and of *Setaria* in stem and fruit extracts reduced (Table 1).

The hot water extracts reduced germination of *Lactuca* and *Pennisetum* in all the treatments and that of *Setaria* in leaves only (Table 2). Radicle growth of all the test species in all the treatments, except *Setaria* and *Pennisetum* in fruit extracts, declined (Table 2). Plumule growth of all the test species in all the treatments except *Setaria* in fruit extract dwindled (Table 2).

Fresh and dry weight of all test species was reduced by leaf extract only (Table 2), Moisture contents of *Pennisetum* in fruit extract and that of *Lactuca* and *Setaria* in leaves and stem extracts was depressed (Table 2).

Alcoholic extracts did not affect the germination of three test species (Table 3). However, reduction in the radicle and plumule growth of all the test species was recorded in all the treatments, with the exception of plumule growth of *Pennisetum* and *Lactuca* in fruits extracts (Table 3). Fresh and dry weight of all the test species was suppressed by alcoholic extract of leaves (Table 3). Moisture contents of all the test species also got reduced in various treatments except *Setaria* in leaves and *Lactuca* in fruit extracts (Table 3).

**Effect of natural rain leachates:** Germination of all test species, with the exception of *Pennisetum* in leaves and *Setaria* in fruit extracts, declined significantly in rain leachates (Table 3). The radicle and plumule growth of test species in all the treatments, except radicle growth of *Pennisetum* and *Setaria* in fruits leachates and plumule growth of *Setaria* in fruits leachates, were significantly inhibited (Table 3). Fresh and dry weight of all the test species remained unaffected in all the treatments (Table 3). Moisture contents of *Pennisetum* and *Lactuca* in leaves and fruits leachates and *Setaria* in fruit leachates was reduced (Table 3).

**Soil residual toxicity:** Soil analysis (Table 4) indicated that $CaCO_3$ and organic matter were low in control soil compared with *Lantana* affected soil. Among major elements only P was higher in control soil than *Lantana*-affected soil. Other two elements N and K were low in control soil. pH for both the soil samples were similar. There were not much differences in the control and *Lantana* soils.

**Table 1. Effect of aqueous extract on germination, plumule, radical growth, fresh and dry weight and moisture contents of the test species. Each value is a mean of 10 replicates each with 10 seedlings. Fresh and dry weights are means of 25 randomly selected seedlings.**

| Test species | *Pennisetum americanum* | | | *Sataria italica* | | | *Lactuca sativa* | | |
|---|---|---|---|---|---|---|---|---|---|
| **Soaking duration (h)** | **Leaves** | **Stems** | **Fruits** | **Leaves** | **Stems** | **Fruits** | **Leaves** | **Stems** | **Fruits** |
| | | | | | **Germination %** | | | | |
| Control | | 62.67 | | | 89.67 | | | 71.67 | |
| 24h | 50 | 56 | **38 | **61 | 76 | 82 | **25 | *57 | **22 |
| 48h | 70 | 62 | **43 | **30 | 87 | *75 | **14 | *59 | **20 |
| | | | | | **Radical growth (mm)** | | | | |
| Control | | 28.39 | | | 16.02 | | | 8.42 | |
| 24h | **8.73 | 27.35 | **2.97 | 5.87 | 14.75 | 1.62 | 0.56 | 3.32 | 0.31 |
| 48h | *20.19 | 30.79 | **5.59 | 1.08 | 18.23 | 4.16 | 0.34 | 3.84 | 0.84 |
| | | | | | **Plumule growth (mm)** | | | | |
| Control | | 8.78 | | | 22.11 | | | 10.76 | |
| 24h | 8.57 | 11.10 | 5.73 | 1.08 | 18.23 | 4.16 | 1.45 | 4.11 | 0.83 |
| 48h | 10.77 | 10.21 | 5.68 | 8.55 | 13.33 | 14.1 | 0.78 | 4.67 | 1.54 |
| | | | | | **Fresh weight (mg)** | | | | |
| Control | | 100 | | | 46 | | | 51.50 | |
| 24h | 95 | 60 | 100 | 30.50 | 76.50 | 55.50 | 60 | 44 | 64.50 |
| 48h | 100 | 60 | 65 | 26.50 | 65 | 59 | 60 | 42 | 60 |
| | | | | | **Dry weight (mg)** | | | | |
| Control | | 58.50 | | | 42 | | | 43.50 | |
| 24h | 69.50 | 31 | 74 | 25 | 73.50 | 55 | 55 | 37.50 | 62 |
| 48h | 75 | 33.50 | 40.50 | 20 | 63.50 | 58.50 | 55 | 36 | 56.50 |
| | | | | | **Moisture contents (%)** | | | | |
| Control | | 70.94 | | | 9.52 | | | 18.39 | |
| 24h | 36.69 | 93.55 | 35.14 | 22 | 4.08 | 0.91 | 9.09 | 17.33 | 4.03 |
| 48h | 33.33 | 79.10 | 60.49 | 32.50 | 2.36 | 0.85 | 9.09 | 16.67 | 6.19 |

* = Significantly different from control at p=0.05
** = Significantly different from control at p=0.01

**Table 2. Effect of hot water, Lantana-soil bed bioassay and Lantana-soil extract bioassay on germination, plumule and radical growth, fresh and dry weight and moisture contents of test seedlings. Each value is a mean of 10 replicates each with 10 seedlings.**

| Test species | Hot water extract | | | | Lantana-soil bed bioassay | | Lantana-soil extract bioassay | |
|---|---|---|---|---|---|---|---|---|
| | **Control** | **Leaves** | **Stems** | **Fruits** | **Control soil-bed** | **Lantana-soil bed** | **Control soil-extract** | **Lantana-soil extract** |
| | | | | | **Germination %** | | | |
| *Pennisetum americanum* | 59 | 51 | 34 | 50 | 60 | 52 | 51 | 58 |
| *Sataria italica* | 87 | 61 | 85 | 92 | 90 | 96 | 74 | 75 |
| *Lactuca sativa* | 69.67 | 11 | 43 | 36 | 92 | 67 | 72 | 66 |
| | | | | | **Radical growth (mm)** | | | |
| *Pennisetum americanum* | 9.54 | 6.82 | 3.09 | 9.03 | 8.59 | 5.99 | 7.07 | 6.59 |
| *Sataria italica* | 9.99 | 0.54 | 3.40 | 9.35 | 8.87 | 11.26 | 5.40 | 4.82 |
| *Lactuca sativa* | 6.67 | 0.12 | 0.88 | 3.06 | 7.20 | 10.38 | 8.57 | 7.33 |
| | | | | | **Plumule growth (mm)** | | | |
| *Pennisetum americanum* | 2.63 | 5.79 | 3.20 | 5.60 | 2.46 | 2.47 | 2.82 | 3.11 |
| *Sataria italica* | 8.65 | 3.58 | 3.61 | 12.15 | 3.99 | 6.71 | 2 | 2.08 |
| *Lactuca sativa* | 8.96 | 0.61 | 3.04 | 3.92 | 8.26 | 8.19 | 6.01 | 6.25 |
| | | | | | **Fresh weight (mg)** | | | |
| *Pennisetum americanum* | 80.47 | 55.18 | 64.74 | 74.92 | 65.65 | 65 | 79.12 | 84.46 |
| *Sataria italica* | 50.54 | 33.50 | 45.53 | 59.92 | 55.91 | 56.75 | 63.26 | 57.35 |
| *Lactuca sativa* | 48.29 | 36.72 | 58.20 | 59.53 | 50.99 | 56.81 | 61.68 | 61.81 |
| | | | | | **Dry weight (mg)** | | | |
| *Pennisetum americanum* | 58.46 | 39 | 46.68 | 59.26 | 56.14 | 51.25 | 58.42 | 61.81 |
| *Sataria italica* | 44.66 | 28.50 | 41.62 | 54.32 | 52.27 | 52.10 | 55.42 | 50.06 |
| *Lactuca sativa* | 39.96 | 29.50 | 53.50 | 50.26 | 44.75 | 49.35 | 51.50 | 52.08 |
| | | | | | **Moisture contents (%)** | | | |
| *Pennisetum americanum* | 37.65 | 41.50 | 38.69 | 26.42 | 16.94 | 26.83 | 35.43 | 36.63 |
| *Sataria italica* | 13.17 | 17.54 | 9.39 | 10.31 | 6.95 | 8.93 | 14.12 | 14.56 |
| *Lactuca sativa* | 20.84 | 24.47 | 8.71 | 18.44 | 13.95 | 15.11 | 19.77 | 18.67 |

* = Significantly different from control at p=0.05
** = Significantly different from control at p=0.01

**Table 3. Effect of alcoholic extracts and natural rain leachates on germination, plumule and radical growth, fresh and dry weight and moisture contents of test seedlings. Each value is a mean of five replicates each with 10 seedlings.**

| Parameters | Alcoholic extract | | | Natural rain leachates | | |
|---|---|---|---|---|---|---|
| **Test species** | ***Pennisetum americanum*** | ***Sataria italica*** | ***Lactuca sativa*** | ***Pennisetum americanum*** | ***Sataria italica*** | ***Lactuca sativa*** |
| | **Germination %** | | | | | |
| Control | 48.50 | 80.50 | 74.50 | 56.50 | 82.50 | 50.50 |
| Leaves | 53 | 76 | 61 | 54 | 68 | 25* |
| Fruits | 50 | 72 | 78 | 48 | 91 | 21* |
| | **Radical growth (mm)** | | | | | |
| Control | 6.19 | 6.25 | 8.71 | 15.01 | 9.99 | 4.78 |
| Leaves | 1.87* | 0.81* | 2.39* | 5.20* | 4.86* | 1.37* |
| Fruits | 5.20 | 3.53* | 6.11* | 14.04 | 18* | 2.15* |
| | **Plumule growth (mm)** | | | | | |
| Control | 2.88 | 2.38 | 7.40 | 8.08 | 7.78 | 5.61 |
| Leaves | 1.99 | 1.22 | 3.03* | 3.96* | 2.78* | 1.62* |
| Fruits | 2.87 | 1.70 | 6.67 | 6.44 | 12.93 | 2.31* |
| | **Fresh weight (mg)** | | | | | |
| Control | 71.62 | 52.67 | 54.94 | 90.66 | 59.31 | 61.37 |
| Leaves | 54.09 | 46.73 | 44.75 | 81.92 | 55.73 | 59.60 |
| Fruits | 74.75 | 59.92 | 59.53 | 79.83 | 59.05 | 59.86 |
| | **Dry weight (mg)** | | | | | |
| Control | 51.91 | 47.10 | 46.34 | 59.32 | 51.80 | 50.48 |
| Leaves | 40.76 | 41.60 | 38.56 | 58.35 | 48.99 | 51.09 |
| Fruits | 59.26 | 54.32 | 50.26 | 58.12 | 52.30 | 51.82 |
| | **Moisture contents (%)** | | | | | |
| Control | 37.97 | 11.82 | 18.57 | 52.83 | 14.49 | 21.57 |
| Leaves | 32.69 | 12.33 | 16.05 | 38.04 | 13.76 | 16.66 |
| Fruits | 26.13 | 10.31 | 18.44 | 37.35 | 12.91 | 15.50 |

* = Significantly different from control at p=0.05

**Table. 4. Physico-chemical analysis of soils (Fertility status).**

| Soil sample | Texture | Percent | | Major elements (ppm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | CaCO3 | Org matter | N (%) | P | K | pH | EC | TTS% | Clay% | Silt % | Sand % |
| Control | Silt loam | 12.50 | 1.55 | 0.77 | 27.84 | 270 | 7.7 | 0.13 | 0.04 | 13.4 | 57.2 | 29.4 |
| Lantana-soil | Loam | 13.75 | 1.69 | 0.084 | 14.4 | 405 | 7.7 | 0.20 | 0.07 | 15.4 | 45.2 | 39.4 |

When seeds were placed on soil beds, it was observed that germination of *Lactuca* was reduced to 72% (Table 2). The radicle growth of only *Pennisetum* was inhibited (Table 2). Fresh and dry weights of all the test species remained unaffected; while moisture contents of all the test species increased (Table 2). Similarly soil extracts when used, did not exhibit toxicity, except *Lactuca*.

**Effect on cell development:** The cell sizes of both plumule and radicle in all the test species reduced, especially in leaf extracts. It was obvious that toxins decreased the growth of cells thus reducing their size. The most affected species was *Allium cepa* (Table 5).

**Identification of phytotoxin:** Paper chromategraphy suggested the presence of *p*-OH-benzoic acid, *p*-coumaric acid, caffeic acid, vanillic acid, ferulic acid, syringic acid and gentisic acid. All these compounds have been invariably reported from allelopathic plants including *Lantana* (Jain *et al.,* 1989; Rice, 1984; Putnam Chung, 1988; Hussain *et al.,* 2004; Hussain *et al.*, 2010; Khan *et al.*, 2010; Sher *et al*., 2011). These compounds have known inhibitory activity against many species.

The allelopathic effects of *Lantana cammara* can be further tested for use as herbicide/ weedicide, and this might bring a great change in management of weeds.

**Table 5 . Effect of hot water extract on development of meristematic cells of radicle and plumule of test species. Each value is a mean of 100 cells.**

| | Parameter | Control | | Extracts | | | |
|---|---|---|---|---|---|---|---|
| | | | | Leaves | | Fruits | |
| | | Length (*u*) | Breadth (*u*) | Length (*u*) | Breadth (*u*) | Length (*u*) | Breadth (*u*) |
| *Pennisetum americanum* | Radicle | 12 | 14.52 | 9.84* | 11.87 | 10.20 | 13.86 |
| | Plumule | 62.47 | 30.99 | 37.84* | 19.99* | 60.12 | 24.28* |
| *Sataria italica* | Radicle | 10.47 | 13.29 | 9.02 | 3.31* | 9.43 | 13.09 |
| | Plumule | 56.90 | 22.85 | 47.69 | 14.99* | 56.12 | 21.24* |
| *Lactuca sativa* | Radicle | 12.18 | 13.26 | 10.14 | 3.31* | 9.50* | 11.86 |
| | Plumule | 97.82 | 15.35 | 36.69* | 14.28* | 83.82 | 14.28* |
| *Allium cepa* | Radicle | 62.26 | 28.56 | 27.99* | 15.14* | 26.13* | 14.56* |
| | Plumule | 80.25 | 25.70 | 63.83* | 14.28* | 37.27* | 19.99* |

* = Significantly different from control at p=0.05

## Discussion

The present study suggests that all parts of *Lantana camara* have strong allelopathic effect on the germination and growth of various test species. However, the relative toxicity of various parts varied among themselves and against the various test species used. The results agree with other similar studies who also reported differential allelopathy of plants and differential response of test species to same extract (Kadioglu & Yanar, 2004; Iman *et al*, 2006; Salam & Kato-Noguchi 2008, Samreen *et al.*, 2009). Aqueous extracts obtained at room temperature were more toxic than boiled water extract. This agrees with the findings of Angiras *et al*. (1988a) who reported similar results. The inhibitory effects of unboiled extract of various parts were in the order of fruits > leaves > stems. While the phytotoxicity of hot water extracts was in the order of leaves > stems > fruits which suggest that the toxins present in fruit extracts were more thermolabile than those present in stems and leaves. Arora & Kohli (1993) also suggested that extracts from fruits and inflorescences were more toxic than leaves. Similarly, Noor *et al.* (1995) reported that aqueous extracts from fruits of *Prosopis juliflora* were more inhibitory than aqueous extract from leaves. The reduction in germination, growth, fresh and dry weight and moisture contents was probably due to water soluble toxins. Similar results for other plants have been reported by Shrivas & Bajpai (1988) and Kadioglu & Yanar (2004). Likewise, Hussain *et al.* (2004) reported that leaves extracts from paper mulberry were more inhibitory than other parts. The findings also are line with those of Batlang & Shushu (2007) who reported leaf and root extracts to be inhibitory against other species. Hot water extracts from leaves were more toxic than stems followed by fruit extracts. The results agree with those of Prasad & Shrivastva (1991) who observed that hot water extract of *Lantana camara* reduced the germination and growth of rice seedlings. Similarly, Batlang & Shushu (2007) reported inhibitory effect of hot water extracts of sunflower.

Alcoholic extracts also inhibited the test species. However, the inhibition was less compared to aqueous extracts. This suggested that the toxins present in different parts were better extractable in water than in alcohol and that the various toxins were differentially extractable in water and alcohol. Alcoholic extracts from leaves were more inhibitory than other parts. The findings are similar to those of Borges *et al.* (1993) who reported almost similar trend for alcoholic and aqueous extracts from leaves on *Vigna radiata, Lactuca sativa* and *Lycopersicum esculenton* seedlings. Kadioglu & Yanar (2004) reported inhibition of test species by methanolic extracts.

In nature toxins from different parts of *Lantana camara* might be released by rains. In the present study natural rain leachates of different plant parts invariably suppressed the germination and growth of various test species. Rain leachates from leaves were more inhibitory than those from of fruits. Similar results for foliar leachates of *Lantana camara* on the growth and germination of *Morrenia odorata* have been reported by Achhireddy *et al.* (1984). The findings are also in line with those of other workers (Nsolomo *et al.*, 1995; Hussain *et al.*, 2004) who also reported the effect of leaf leachates to be more allelopathic. On the contrary fruits and flowers were inhibitory than other parts (Hussain *et al.*, 2004; Shrivas & Bajpai, 1988).

Toxins released by allelopathic donor plants ultimately get deposited in adjacent soil. The affectivity of toxins in soil, however, depends upon a number of factors including texture, accumulation capability and microbial activity. The toxins must accumulate to a physiological active level for exhibition of allelopathy. *Lantana* soil when tested showed no inhibitory effects on the germination and growth of test species. The result coincides with findings of Sahid & Sugau (1993) and Achhireddy *et al.*, (1984) who reported that *Lantana* affected soil did not influence the crop. Likewise, studies made by Sundaramourty *et al.*, (1992) also concluded that soil collected from beneath *Acacia tortillus* and *Prosopis cineraria* had no significant inhibition. It is suggested that soil might have not accumulated sufficient concentration of toxins to become inhibitory. It was also true in this case as the soil was collected after rains that had reduced for leached away toxins that might have been present. The growth of radicle and plumule depends on the cell division and their elongation. In many cases both the cell division and elongation is inhibited (Rice, 1984; Hussain *et al.*, 1984). In the present case we did not check for cell division but elongation of cells was definitely inhibited. A significant decrease in cell size of test species was observed. The cells in control treatment had large size than those grown in the test condition. Leaf extracts reduced the cell size more than fruit extract. Roots grown in leaves extract had smaller size than those grown in fruit extracts. Putnam & Chung (1986) and Hussain *et al.* (1984) also reported cell inhibition by allelopathy.

An attempt to identify phytotoxin through paper suggested the presence of *p*-hydroxbenzoic acid, *p*-coumaric acid, caffeic acid, vanillic acid, ferulic acid, syringic acid and gentisic acid. Singh *et al.*, (1989) and Jain *et al.*, (1989) identified 13 phenolic compounds including the present one by HPLC from crude aqueous extract of *Lantana camara*. Wollen *et al.*, (1997) extracted flavonoid aglycons and triterpenoids from leaf of *Lantana* species. These compounds have proven ability to exhibit allelopathy. Therefore, the present study suggests that *Lantana camara* exhibits strong allelopathy through water leachable toxins. Furthermore, volatile substances might also play role in its allelopathy which however was not tested in the present study. Rain might leach the toxins but at the same time it also wash away the allelopathic substances. Many previous workers have also reported allelopathy by *Lantana camara* (Achhireddy *et al.*, 1984, 1985) and our findings agree with them. Allelopathy is a complex ecological process that depends upon accumulation and decay of litter, soil characteristics and climate. There is need to further work on the allelopathic stress of this species under varied climatic and soil conditions and also to quantify the allelopathic compounds. It can also be a candidate for biocontrol of weeds.

### References

Achhireddy, N.R., M.Singh, L.L.Achhireddy, N.N.Nigg and S.Naggy. 1985. Isolation and partial characterization of phytotoxic compounds from Lantana (*Lantana camara*). *J. Chem.. Ecol.*, 11: 979-988.

Achhireddy, N.R., Megh Singh and M. Singh. 1984. Allelopathic effect of (*Lantana*) *Lantana camara* on milkwood vine (*Morrinia odorata*). *Weed science*, 32(6): 757-761.

Angiras, N. N., S. D. Singh and C. M. Singh. 1988b. Allelopathic effects of some weeds on germination and growth of chickpea (*Cicer arietinum*). *Ind. J. Weed Sci.*, 20(1): 85-87.

Angiras, N.N., S.D. Singh and C. M. Singh. 1988a. Allelopathic effect of weeds on germination and seedling growth of maize and Soybean. *Ind. J. Weed Sci*., 20(2): 82-87.

Arora, R.K. and R.K. Kohli. 1993a. Autotoxic impact of essential oil extracted from *Lantana camara* L. *Biologia Plantarum*, 35(2):293-297.

Arora, R.K. and R.K. Kohli. 1993b. Autotoxic effect of decomposed leaf and inflorescence of *Lantana camara* var. *camara* on its seed germination parameters. *Indian J. Ecology*, 20(2): 109-112.

Barkatullah, F. Hussain and M. Ibrar. 2010. Allelopathic potential of *Dodonaea viscosa* (L.) Jacq. *Pak. J. Bot*., 42(4): 2383-2390

Batlang, U. and D.D. Shushu. 2007. Allelopathic activity of sunflower (*Helianthus annuns* L.) on growth and nodulation of Bambara groundnut (*Vigna sublerranea* (L.)Verdc.). *Jour. Agronomy*, 6: 541-547.

Borges, E.E. de. L., E. Da. L. Lopes and G.F. Silva. 1993. Evaluation of allelopathic substances in a secondary forest I-Trees. *Revista Arvore*, 17(1): 69-84.

Cheema, Z.A. and A. Khaliq. 2000. Use of *Sorghum* allelopathic properties to control weeds in irrigated Wheat in a semiarid region of Punjab. *Agriculture Ecosystem and Environment*, 79(23): 105-112.

Hussain, F. 1989. *Field and Laboratory Manual of Plant Ecology*. NAHE, UGC, Islamabad.

Hussain, F., B. Ahmad and I. Ilahi. 2010. Allelopathic effects of *Cenchrus ciliaris* L. and *Bothriochloa pertusa* (L.) a. camus. *Pak. J. Bot.*, 42(5): 3587-3604

Hussain, F., F. Niaz, M. Jabeen and T. Burni,2004. Allelopathic potential of *Broussonetia papyrifera* Vent. *Pak. J. Pl. Sci.*, 10(2): 69-77.

Iman, A., Z. Wahab, S.M.S. Rastan and M.R.A. Halim. 2006. Allelopathic effects of sweet corn and vegetable soybean extracts at two growth stages on germination and seedling growth of corn and soybean varieties. *J. Agronomy*, 5: 62-68.

Irshad, A. and Z.A. Cheema. 2004. Influence of some plant water extracts on the germination and seedling growth of Barnyard Grass (*Echinochola crus-galli* (L.) Beave.) *Pak. J. Sci. & Ind. Res*., 47(3): 222-226.

Jabeen N. and M. Ahmed. 2009. Possible allelopathic effects of three different weeds on germination and growth of maize (*Zea mays*) cultivars. *Pak. J. Bot*., 41(4): 1677-1683

Jackson, M.L. 1962. *Soil Chemical Analysis*. Constable & Co. Ltd. London.

Jain, R., M. Singh and D. Dezman. 1989. Qualitative and quantitative characterization of phenolic compounds from Latana (*Lantana camara*) leaves. *Weed Sci.*, 37: 302-307.

Jefferson, L.V. and M. Pennacchio. 2003. Allelopathic effects of foliage extracts from four Chenopodiaceae species on seed germination. *J. Arid Environments*, 55(2): 275-285.

Kadioglu, I. and Y. Yanar. 2004. Allelopathic effects of plant extracts against seed germination of some weeds. *Asian J. Pl. Sci.*, 3: 472-475.

Khan, M.A., R.A. Qureshi, S.A. Gillani, M.A. Ghufran, A. Batool and K.N. Sultana. 2010. Invasive species of federal capital area Islamabad, Pakistan. *Pak. J. Bot*., 42(3): 15291534.

Marwat, K.B. and M.A. Khan. 2006. Allelopathic proclivities of tree leaf extracts on seed germination and growth of wheat and wild oats. *Pak J. Weed Sci. Res*., 12(4): 265-269.

Noor, M., U. Salam and M.A. Khan. 1995. Allelopathic effects of *Prosopis juliflora* Swartz. *Arid Environment*, 31(1): 83-90.

Nsolomo, V.R., M.S. Mrecha and J.A. Maghembe. 1995. Effect of *Acacia xanthophloea* leachates on seed germination of some agricultural and multipurpose tree crops. *Tropical Forest Sci.*, 7(3): 398-404.

Prasad, K. and V. C.Srivastava. 1991. Teletoxic effect of weed on germination and growth of rice (*Oryza sativa*). *Ind. J. Agri. Sci.*, 61 (8): 591-592.

Putnam, A. and S. Chung. 1986. *The Science of Allelopathy*. Wiley Inter. Sci. Pub., pp. 174.

Rice, E.L. 1984. *Allelopathy*, Academy Press, New York.

Sahid, I.B. and J.B. Sugau. 1993. Allelopathic effect of Lantana (*Lantana camara*) and siam weed (*Chromolaena odora*ta) on selected crops. *Weed Sci*., 41(2):303-308.

Salam, Md-Abdus and H. Kato-Noguchi. 2008. Screening of allelopathic potential Bangladesh rice cultivars by donor-receiver bioassay. *Asian J. Pl. Sci.*, 9: in Press.

Samreen, U., F. Hussain and Z. Sher. 2009. Allelopathic potential of *Calotropis procera*, *Pak. J. Pl. Sci.*, 15(1):7-14.

Saxena, M.K. 2000. Aqueous leachate of *Lantana camara* kills water hyacinth. *J. Chemical Ecology*, 26(10): 2435-2448.

Sharma, I.N.S., A.K. Singh and S.P. Singh. 1992. Allelopathic potential of some plant substances as anti-feedant against insects and pests of Jute. In *Allelopathy in agroecosystems* (Agriculture and Forestory). (Eds.): P. Tauro and S.S. Narwal proceeding First National Symposium, CCS Haryana Agriculture University India, 12-14 Feb. 1992. pp. 166-168.

Sher, Z., F. Hussain, B. Ahmad and M. Wahab. 2011. Allelopathic potential of *Populus euphratica* Olivier. *Pak. J. Bot*., 43(4): 1899-1903

Shrivas, R.K. and S.P. Bajpai. 1988. Effect of *Lantana indica* Roxb. extract on seed germination and seedling growth of *Dalbergia sisso* R.J. *Tropical Forestery*, 4(3): 256-258.

Singh, C.M., N.N. Angiras and S.D. Singh. 1988. Allelopathic effects of some weeds on seed germination. *Ind. Weed Sci.*, 20(3): 63-66.

Singh, M., R.V. Tamma and H.N. Nigg. 1989. Identification of allelopathic compounds from *Lantana camara. J. Chem. Ecology*, 15(1): 81-89.

Startsev, N., V.J. Lieffers and S.M. Landhäusser. 2008. Effects of leaf litter on the growth of boreal feather mosses: implication for forest floor development . *Jour. Vegetation Science*, 19(2): 253-260.

Sundaromourty, S., N. Kalra and D.N. Sen. 1992. Allelopathic potential of *Acacia tortilis* on seed germination and seedling growth of some legumes In *Allelopathy in agroecosystems* (Agriculture and Forestory). (Eds.): P. Tauro and S.S. Narwal. Proceeding First National Symposium, CCS Haryana Agriculture University India, 12-14 Feb. 1992.

Wollen, Weber, Dorr-Marion,R. Muniappan and Siems-Karrsten. 1997. Flavonoid aglycons and triterpenoids from the leaf extract of *Lantana camara* and *Lantana montenidensis. Biochem. Syst. Ecol.*, 25(3): 269-270.

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