Running title: Variations in Traffic Related Metal Pollution and its Phytomonitoring

**Spatio-Temporal Variations in Traffic Related Metal Pollution and its Phytomonitoring along two roads in the Punjab, Pakistan**

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**Novelty statement**

Zinc was acknowledged as essential nutrient for plants; its deficiency not only impedes plant growth, that’s why soil deficits in Zn are enriched with Zn fertilizers to fulfill the nutritional requirements of plants. However, being the most mobile and bioavailable nutrient its higher concentration in soil may cause phytotoxicity in plants. So, the present study was aimed to monitor the Zn contamination in roadside soil and plants. Information being obtained can contribute in identification of phytomonitors of metal pollution. These phytomonitors native plant species are quite economic, convenient and aesthetically pleasing technique in which the natural ability of environment is benefited to restore itself. Hence, this study will help understanding the physiological mechanism under metal stress through the prestigious PAKJAS journal.

**Abst­­ract**

Zinc (Zn) is an essential plant nutrient but it is become toxic heavy metal when increased from its permissible limit. Current two years studywas conducted to monitor the level of traffic related metal (zinc) pollution along two roads in Punjab, Pakistan by using native plant species i.e. *Cenchrus cilliaris*, *Cynodon dactylon*, *Calotropis procera*, *Nerium oleander* and *Ricinus communis*. From the roadside, soil and leaf samples of selected plants were collected from five sites along each road for analysis and control samples were collected from a distance of ~50 meters of sites. The data were recorded during mid of four seasons and analyzed with the help of Atomic Absorption Spectrophotometer. The results showed higher Zn contents in roadside soil and plants as compared to control samples. Metal contents at N-5 were higher as than that of Faisalabad to Okara road (FOR). Among the seasons, Zn concentration was highest during summer and minimum during winter in both plants and soils. Furthermore, *Ricinus communis* accumulated maximum Zn than other plant species; therefore, it may be proposed as a suitable choice for phytomonitoring purposes.

**Keywords:** Phytomonitoring; zinc; vehicular pollution; Soil; *Cenchrus cilliaris*; *Cynodon dactylon*; *Calotropis procera*; *Nerium oleander*; *Ricinus communis*; Atomic Absorption Spectrophotometer; Traffic.

**Introduction**

Zinc (Zn) was acknowledged as essential nutrient for plants in 1926 and soon after for mammals in 1934 (Nielsen 2012). It is vital for many enzymes of protein synthesis, energy transfer and nitrogen metabolism. Its deficiency not only impedes plant growth and yield, but also adversely affects human health (Cakmak 2002; Graham 2001) that’s why soil deficits in Zn are enriched with Zn fertilizers to fulfill the nutritional requirements of plants (Wyszkowska 2013). However, being the most mobile and bioavailable nutrient its higher concentration in soil may cause phytotoxicity in plants (Reichman 2002; Sagardoy 2009).

Supra-optimal Zn concentration in plants causes leaf chlorosis, instabilities in photosynthesis and chlorophyll synthesis (Wang *et al.* 2009). Its excess also induces oxidative damage, disturbs the protein synthesis, development of organelles in plants (Panda *et al.* 2003; Wang *et al.* 2009).

Zinc is a common pollutant in the area of traffic routes (Malinowska *et al.* 2015), most of its quantity comes from petrol, lubricant oil leaks, brake linings, by wear and tear of tyres and from galvanized parts of automobiles (Nazzal *et al.* 2013; Thorpe and Harrison 2008) as well as from soot and heavy metal oxides, which runoff into roadside soil after precipitation (Malinowska *et al.* 2015). The plants growing on such soils accumulate metals in them that may enter into human and animal body through consumption of these plants (Liu *et al.* 2007; Nauciene *et al.* 2002).

The contamination of roadside soil by trace metals is directly proportional to traffic density on roads (Werkenthin *et al.* 2014) moreover, level of vehicular released metals in roadside soil and plants got increased considerably during last few years (Onder and Dursun 2006). Celik *et al.* (2005) reported four times higher metal concentration in roadside vegetation than control sites vegetation. This concentration drops with distance from roadsides (Joshi *et al.* 2010; Mmolowa *et al.* 2010; Werkenthin *et al.* 2014). Seasonal and spatial variations also influence metal contents in soil (Pathak 2015). The use of native plant species to monitor the level of metal contamination is quite economic, convenient and aesthetically pleasing technique in which the natural ability of environment is benefited to restore itself (Hernandez-allica *et al.* 2008).

Several plant species have been reported as good indicator/monitor of metal pollution. Amongst them, the role of *Nerium oleander* (Mignorance and Oliva 2006), *Robinia pseudo-acacia* (Celik *et al.,* 2005), *Eucalyptu* spp., *Prosopis juliflora* and *Dalbergia sissoo* (Naveed *et al.* 2010), *Casuarina equisetifolia* (Aissa and Keloufi 2012), *Ageratum conyzoides* (Deepalakshmi *et al,* 2014) and *Synedrella nodiflora* and *Chromolaena odorata* (Okoronkwo *et al.* 2014) to monitor environmental metal pollution has already been studied. So the present study was aimed to monitor the Zn contamination in roadside soil and plants. Information being obtained can contribute in identification of phytomonitors of metal pollution.

**Material and Methods**

**Study area:** Punjab, the most populated province of Pakistan, has a huge network of roads. “National Highway (N-5)”and “Faisalabad to Okara Road (FOR)” are two high trafficked roads in the central Punjab. “Faisalabad to Okara Road (FOR)” is 103 Km long and interconnect Faisalabad to Okara by passing the Ravi River. This road has numerous human settings (villages, towns), cultivated field areas and marketplaces along it. Animal driven carts, motorbikes, rickshaw, vans and mini buses are major contributors of traffic load on this road. National Highway 5 (N-5) is 1819 km long and interconnects Karachi to Torkham. A section of it from Okara to Lahore (129 Km) was selected for study. This road is quite busy and in good state having several urban settlements along it. The vehicles on N-5 includes multi wheeler loaders, air conditioned buses, vans, mini buses, oil tankers, trucks and cars and remains busy throughout the year.

**Sampling and Metal Analysis:** Excluding the markets and residential areas, five sites were selected randomly along each (FOR and N-5) road (Figure 1). Samples and data were collected in the mid of each of four seasons of the year (2015-2016 and 2017-2018) pooled data of both years were presented in this study. The five commonly growing native plant species (*Cenchrus ciliaris* L., *Cynodon dactylon* L., *Calotropis procera* A*., Ricinus communis* L., and *Nerium oleander* L.) were selected for study at each site along both roads (Table 1). Leaves from each selected plant and soil samples (up to 10cm deep) were collected at each site along roadside. Same plant species and soil samples were collected at a distance of ~ 50 m from roadside and labelled as control (Jian-Hua et al., 2009). All leaf samples were washed with deionized distilled water to get rid of soil particles and dried in an oven (65ᵒC) then ground to powder using Wiley Mill. Collected soil samples were sieved (2-mm) and dried in oven (65ᵒC) for 72 hours. By using HNO3 and H2O2, all samples (plant and soil) were digested on a hot block digester (Environmental Express, Mt. Pleasant, SC) by following USEPA method 3050B for metal analysis (de Oliveira et al., 2015) which were analyzed by atomic absorption spectrophotometer (AAS). Standard plant leaves and soil reference materials (accuracy=100±20%), Internal standards and reagent blanks were used to ensure precision and accuracy in analysis.

Statistical analyses were carried through program COSTAT computer package by Cohort software (2003) Monterey, California, USA. Means were compared with LSD test (α = 0.05) (Steel and Torrie, 1997). The correlation was determined by Excel, 2016.

**Results**

**Zn contents in roadside soil:**Zn contents in roadside soil have been summarized in Table 2. Zinc contents along both roads were higher than the control samples. During all seasons, highest Zn concentration was recorded at “Tandaliawala” site along “FOR” and “Chung” site along “N-5”. Furthermore, seasonal variations were also noticed in soil Zn content as the maximum Zn content were recorded during summer and least during winter season along both roads.

**Zn contents in roadside plant leaves:** Zn content in plant leaves have been depicted in Table 3. Among all plants along “FOR”, maximum Zn accumulation (83.01 mg kg-1) was found in *Ricinus communis* and minimum (57.43 mg kg-1) in *Cenchrus ciliaris* (Figure 2). Similarly, along the second road “N-5”, maximum Zn concentration (88.01 mg kg-1) was also noted in *Ricinus communis* and minimum (61.18 mg kg-1) in *Cenchrus ciliaris* (Figure 3). The spatial comparison along “FOR” showed that Zn content in plant leaves at “Tandaliawala” site was highest (92.53 mg kg-1) among all sites while “Satghara More” site presented least Zn content (66.98 mg kg-1) along this road (figure 4). Along “N-5” highest Zn content in plant leaves (101.1 mg kg-1) were observed at “Chung” and lowest (67.26 mg kg-1) at “Pattoki” site (figure 5). Nevertheless, Zn content in all trafficked sites were significantly higher than the non-trafficked site. The seasonal comparison for accumulation of Zn in plant leaves along both roads were noted in the following order Summer > Autumn > Spring > Winter ((figure 6,7).

**Comparison among Roads (“FOR” and “N-5”) for Zn contents in soil and plant leaves:** A comparison between roads for Zn content in both plant leaves and soil showed highest Zn content along N-5 and least along ‘FOR” (Figure 8, 9).

**Correlation of traffic density with soil and plant metal**:

Correlations were calculated to estimate the relationship between traffic density and metal content in soil and plant leaves. During all four seasons, a strong correlation was found between average daily traffic and metal content in soil and plant leaves along both roads (Table 4).

**Discussion**

The present study revealed that Zn content in roadside soil along both “Faisalabad to Okara” and “Okara to Lahore” roads was significantly higher than control (~50 meters away from road) site. Many studies have already described that the Zn content in roadside soil decreased exponentially with per increase in distance from road (Akan *et al.* 2013; Akbar *et al.* 2006; Jankowski *et al.* 2015; Rolli *et al.* 2016). Significant amounts of Zn in roadside soil come from wear and tear of tyres, from galvanized parts of automobiles (Hjortenkrans 2008), soot and metal oxides, which run off from the road, into soil after precipitation (Malinowska *et al.* 2015). Furthermore, the release of metals also varies with vehicle type and age, type of fuel used, driving speed and road structure (Smith 1976).

Significant variations among sites along both roads (FOR and N-5) have been noted for mean Zn content in soil. Highest Zn content along “FOR” was recorded at “Tandaliawala” site (162.6 mg kg-1) and along “N-5” it was highest at “Chung” site (183.1 mg kg-1). This was due to high vehicle traffic in these areas. Many studies have reported that sites with high vehicular density are more contaminated with metals (Apeagyei *et al.* 2011; Duong and Lee 2011; Popescu 2011). At “Pattoki” site minimum contamination was noted. It could be supported by the fact that “Pattoki” site is protected by significant number of plants which include herbs shrubs and trees and the metal content in roadside soil with vegetation shield are significantly lower than those without vegetation (Liu *et al.* 2012). Khan *et al.* (2011) reported that Zn content in soil ranged from 13.8 to 180 mg kg-1 along National Highway (Hyderabad, Pakistan). The Zn content in soil found during present study were higher than that of reported by others such as, 90.43 µg g-1 in Nigeria (Akan *et al.* 2013), 123.2 mg kg-1 in Karak, Jordan (Al-Khashman 2004) and lower than 499.20 mg kg-1 in Delhi (Banerjee 2003). However, the limit of zinc in soil is 100-150 mg kg-1 (European Commission Director General Environment, ECDGE., 2010).

A comparison between roads showed higher Zn content along “N-5” as compared to “FOR”. This might be due to high traffic density along “N-5”. The contamination of Zn along roads is always directly linked to the age of road and “FOR” is a newly constructed road so it’s not only about the traffic density at a specific time but a lifetime traffic flow count as well (Morse *et al.* 2016). The presence of Zn in the roadside soil indicated that vehicles are the key anthropogenic source of Zn pollution and the Zn contents may vary at different sites due to meteorological variations, road structure and traffic density (Khan *et al.* 2011).

The vehicular released metal that gets deposited on roadside soil may enter into plants thus plants act as a sink of metal accumulation (Liu *et al.* 2012). These plants could be used as indicator of metal pollution (Berlizov *et al.* 2007). In present study maximum Zn contents in plants were recorded in “Tandaliawala “site along “FOR” and “Chung” site along “N-5”. The uptake of Zn by plants at different sites showed a linear relationship with Zn content in soil and these results are in confirmation with Kabata-Pendias (2011).

During present study, the mean Zn contents in plant leaves along “FOR” and “N-5” were recorded in the following order *Ricinus communis* > *Cynodon dactylon* > *Calotropis procera* > *Nerium oleander* > *Cenchrus ciliaris.* The Zn content in plant leaves varied significantly among different species (Nabulo *et al.* 2006) due to environmental factors and genotypes (Kabata-Pendias 2011). Hesami *et al.* (2018) noticed 740 mg kg-1 Zn uptake in *Roemeria hybrid*. In Gillgit, Pakistan, the highest Zn content (271.0 mg kg-1) was found in *Brassica campestris* and 247.0 mg kg-1 in *Malva sylvestris* (Khan *et al.,* 2010). The standard limit of Zn in plant is 100 mg kg-1 (Allen *et al.* 1974). However, the safe limit of Zn for plant recommended by FAO/WHO (2011) is 60.0 mg kg-1. The mean Zn content in all plant species along both roads under investigation were above the permissible limit except for *Cenchrus ciliaris* along “FOR”, while those at control site were within the safety limit. Concentrations of zinc in plants at polluted sites persisted to be significantly higher than control site plants. This showed a direct relationship of plant metal content with traffic volume signifying vehicles as the major source of heavy metals. All the selected plants are good indicator of Zn toxicity however, *Ricinus communis* with highest levels of zinc could be used as the best Zn indicator among all selected plant species and can be used to monitor and ameliorate heavy metal pollution along roadsides. All the plant species and soil samples showed highest Zn contents in summer and lowest in winter season. This might be due to high traffic density and wear of tyres at high temperature. Aksoy *et al.* (2000), Naveed *et al.* (2010) and Zaidi *et al.* (2005) made the similar observations.

A significant amount of Zn was found in petrol, diesel, used motor oil and soot (Table 5). A high level of Zn in diesel and lubrication oil was detected by Betha *et al.* (2012). Chin-Hsiang *et al.* (2009) reported that the relative contents of Zn by weight were 19.9% in diesel soot. Traces of Zn (0.7%) in soot were detected by Uy *et al*. (2014). Metal in soot was also reported by Fino *et al.* (2016). Diesel soot is responsible for 1/4th of total perilous atmospheric pollution (Omidvarborna *et al.* 2014). Hence we can conclude that a considerable amount of Zn come into the surroundings from vehicle soot (Malinowska *et al.* 2015).

***Conclusion:***

Metal (Zn) contamination in the soil and plants along roadside was higher as compared to the control site (~ 50 meters from roadside). These concentrations were higher than the permissible levels set by WHO/FAO. This shows that environment along these roads is contaminated with vehicular released Zn metal. This could be hazardous for crops along roads and human residing near roads. Safety measures are requisite to overcome this toxicity problem. The results also indicated that all selected plants are reasonable indicators of vehicular related Zn pollution in the area. The maximum Zn uptake was detected in *Ricinus communis* durig Summer season so it could be a good choice for phytomonitoring purpose.

***Acknowledgement:***

This research project was funded by Higher Education Commission (HEC) of Pakistan (Indigenous Ph.D. Fellowship Program).

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**Table 1:** Description (botanical and vernacular names) of plant species grown in the study area

|  |  |  |  |
| --- | --- | --- | --- |
| **Botanical name** | **English name** | **Vernacular name** | **Abbreviations used** |
| *Cenchrus ciliaris* L. | Buffel grass | Dhaman | *C. ciliaris* |
| *Cynodon dactylon* L. | Bermuda grass | Khabbal | *C. dactylon* |
| *Calotropis procera* A. | Apple of Sodom | Ak | *C. procera* |
| *Nerium oleander* L*.* | Oleander | Kaner | *N. oleander* |
| *Ricinus communis* L. | Castor oil plant | Arind | *R. communis* |

**Table 2:** Zinc content in roadside soil

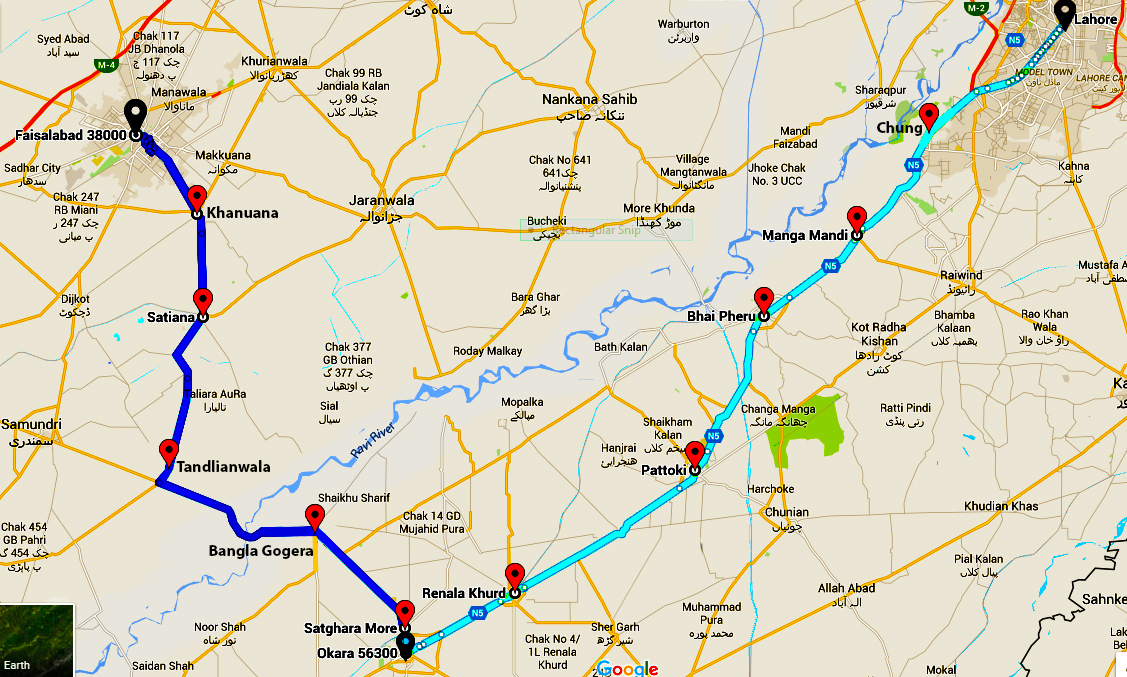
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| --- | --- | --- | --- | --- | --- | --- |
| **Sites along Faisalabd to Okara Road** | | | | | | |
| **Seasons** | **Control** | **Khanuana** | **Sataiana** | **Tandaliawala** | **Bangla Gogera** | **Satghara More** |
| Summer | 35.14±4.55 | 158.09±11.47 | 167.73±6.01 | 183.43±4.65 | 145.10±12.25 | 136.76±5.40 |
| Autumn | 28.43±3.91 | 151.12±4.73 | 169.41±6.53 | 174.84±2.54 | 117.09±4.67 | 128.36±5.30 |
| Winter | 13.26±4.12 | 101.91±6.05 | 113.01±3.86 | 139.32±7.57 | 83.10±6.43 | 78.96±6.72 |
| Spring | 19.12±7.78 | 134.66±4.65 | 127.13±2.22 | 153.08±6.62 | 104.42±4.80 | 87.36±5.72 |
| **Sites along Okara to Lahore Road** | | | | | | |
|  | **Control** | **Renala Khurd** | **Pattoki** | **Bhai Phero** | **Manga Mandi** | **Chung** |
| Summer | 38.47±3.93 | 164.71±4.60 | 139.31±6.01 | 189.18±4.02 | 199.75±3.71 | 209.73±7.44 |
| Autumn | 15.14±5.32 | 140.29±4.24 | 119.03±6.67 | 154.17±4.46 | 176.30±5.46 | 192.17±3.11 |
| Winter | 14.96±4.19 | 81.31±6.51 | 64.98±4.46 | 110.89±10.75 | 130.45±2.57 | 154.45±1.99 |
| Spring | 24.35±3.30 | 84.77±7.02 | 71.88±6.52 | 134.75±8.47 | 157.73±3.83 | 176.07±10.19 |

**Table 3:** Zinc content in roadside plant leaves

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | | **Sites along Faisalabd to Okara Road** | | | | | | |
| **Seasons** | **Plants** | **Control** | **Khanuana** | **Sataiana** | **Tandaliawala** | **Bangla Gogera** | **Satghara More** | **Mean** |
| **Summer** | *C. ciliaris* | 12.55±3.07 | 85.56±3.01 | 85.59±4.51 | 92.89±2.10 | 88.91±4.53 | 64.77±4.73 | 83.54±10.92 |
|  | *C. dactylon* | 17.73±2.11 | 100.88±6.52 | 108.08±6.05 | 114.69±5.05 | 104.59±5.68 | 92.47±3.53 | 104.14±8.27 |
|  | *C. procera* | 14.05±1.73 | 90.54±3.11 | 103.90±8.00 | 108.96±3.92 | 91.67±2.12 | 47.47±8.54 | 88.51±24.26 |
|  | *N. oleander* | 13.46±3.72 | 89.22±6.00 | 78.92±6.10 | 101.65±3.52 | 79.55±3.84 | 75.22±2.95 | 84.91±10.69 |
|  | *R. communis* | 18.97±3.84 | 118.51±7.01 | 99.44±4.78 | 127.56±12.04 | 112.25±3.01 | 98.47±7.90 | 111.25±12.48 |
| **Autumn** | *C. ciliaris* | 11.47±1.86 | 74.62±4.22 | 55.24±2.83 | 57.33±5.44 | 71.77±3.53 | 58.11±3.50 | 63.41±9.04 |
|  | *C. dactylon* | 15.76±1.17 | 92.29±5.79 | 100.30±4.46 | 95.76±3.55 | 85.81±3.63 | 60.46±3.49 | 86.92±15.71 |
|  | *C. procera* | 13.72±1.82 | 88.56±2.64 | 92.01±4.63 | 98.56±2.81 | 85.16±2.96 | 75.54±3.56 | 87.97±8.53 |
|  | *N. oleander* | 11.37±1.56 | 80.02±4.03 | 61.33±3.02 | 93.86±3.05 | 77.84±3.61 | 68.12±2.51 | 76.23±12.41 |
|  | *R. communis* | 16.16±2.67 | 101.84±3.51 | 107.83±4.57 | 114.38±3.71 | 96.78±2.54 | 66.53±4.58 | 97.47±18.51 |
| **Winter** | *C. ciliaris* | 7.65±1.78 | 61.84±1.59 | 64.57±3.60 | 60.94±9.75 | 54.14±9.27 | 48.19±2.50 | 57.94±6.66 |
|  | *C. dactylon* | 9.47±1.69 | 70.76±2.55 | 76.64±7.20 | 84.51±2.01 | 58.99±3.06 | 65.28±3.51 | 71.24±9.89 |
|  | *C. procera* | 9.06±2.10 | 70.59±5.62 | 75.69±3.16 | 82.64±2.63 | 65.89±2.93 | 59.81±12.30 | 70.92±8.79 |
|  | *N. oleander* | 8.30±0.33 | 63.09±2.68 | 53.66±4.72 | 76.81±2.57 | 59.48±4.01 | 53.80±3.56 | 61.37±9.51 |
|  | *R. communis* | 11.28±1.56 | 86.19±3.50 | 92.52±6.74 | 100.14±6.08 | 79.17±2.50 | 70.97±3.04 | 85.80±11.35 |
| **Spring** | *C. ciliaris* | 8.81±1.49 | 62.34±2.87 | 68.15±4.57 | 75.09±2.50 | 53.77±3.79 | 54.07±3.07 | 62.68±9.19 |
|  | *C. dactylon* | 12.77±2.83 | 81.52±2.65 | 88.11±2.84 | 81.95±5.18 | 82.80±3.47 | 74.83±3.58 | 81.84±4.73 |
|  | *C. procera* | 11.72±1.98 | 66.43±2.40 | 61.11±5.73 | 90.79±2.52 | 61.82±9.09 | 67.35±3.86 | 69.50±12.21 |
|  | *N. oleander* | 9.71±2.12 | 71.97±4.20 | 78.74±1.57 | 84.71±3.05 | 69.09±2.50 | 58.07±2.12 | 72.52±10.10 |
|  | *R. communis* | 13.82±2.49 | 93.81±3.97 | 81.95±6.96 | 107.53±2.64 | 96.15±2.53 | 80.19±2.50 | 91.93±11.21 |

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| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | Sites along Okara to Lahore Road | | | | | | |
| **Seasons** | Plants | Control | Renala Khurd | Pattoki | Bhai Phero | Manga Mandi | Chung | Mean |
| **Summer** | *C. ciliaris* | 13.55±2.10 | 82.74±2.33 | 66.18±4.08 | 89.13±3.33 | 94.12±2.47 | 99.44±3.00 | 86.32±12.84 |
|  | *C. dactylon* | 18.73±3.01 | 108.46±7.57 | 95.73±4.22 | 91.21±4.41 | 112.27±3.44 | 122.08±2.84 | 105.95±12.53 |
|  | *C. procera* | 17.05±2.00 | 89.01±1.66 | 82.71±3.56 | 111.47±6.65 | 83.78±2.62 | 112.13±2.56 | 95.82±14.78 |
|  | *N. oleander* | 15.19±1.53 | 79.52±6.71 | 51.81±3.02 | 92.65±2.03 | 96.78±3.75 | 105.15±4.00 | 85.18±20.83 |
|  | *R. communis* | 22.31±3.80 | 112.86±4.09 | 101.25±4.77 | 117.78±3.51 | 121.91±3.07 | 130.23±5.39 | 116.80±10.78 |
| **Autumn** | *C. ciliaris* | 12.92±1.54 | 59.12±3.09 | 59.21±6.19 | 75.78±4.20 | 83.57±3.79 | 92.89±2.50 | 74.11±14.93 |
|  | *C. dactylon* | 17.00±2.92 | 87.16±3.46 | 79.86±1.12 | 93.46±3.01 | 104.07±4.88 | 113.91±3.27 | 95.69±13.51 |
|  | *C. procera* | 14.64±0.99 | 83.79±2.04 | 63.11±3.17 | 92.49±3.20 | 111.68±2.65 | 103.98±7.31 | 91.01±18.90 |
|  | *N. oleander* | 13.29±2.53 | 97.79±3.76 | 58.41±6.03 | 82.81±3.47 | 89.52±8.24 | 97.69±3.76 | 85.24±16.25 |
|  | *R. communis* | 19.08±3.18 | 97.91±3.56 | 84.82±3.55 | 106.14±5.02 | 111.01±5.31 | 118.48±3.03 | 103.67±12.92 |
| **Winter** | *C. ciliaris* | 7.27±0.57 | 52.14±1.94 | 43.95±4.36 | 67.51±5.37 | 65.98±3.36 | 73.18±1.50 | 60.55±12.08 |
|  | *C. dactylon* | 9.96±0.55 | 68.38±1.81 | 61.14±2.50 | 75.81±7.52 | 84.58±1.91 | 93.85±2.03 | 76.75±12.93 |
|  | *C. procera* | 12.94±7.62 | 64.81±1.61 | 69.61±7.59 | 86.32±7.02 | 78.18±2.50 | 86.14±3.50 | 77.01±9.68 |
|  | *N. oleander* | 4.52±1.63 | 61.94±3.77 | 48.50±2.00 | 64.10±3.10 | 72.14±9.01 | 80.15±5.50 | 65.37±11.86 |
|  | *R. communis* | 10.05±1.85 | 88.32±3.79 | 67.15±4.50 | 87.82±2.57 | 101.51±3.02 | 107.99±4.73 | 90.56±15.68 |
| **Spring** | *C. ciliaris* | 8.93±1.09 | 60.81±1.61 | 38.79±7.11 | 68.62±4.44 | 71.50±3.65 | 81.10±0.98 | 64.16±15.94 |
|  | *C. dactylon* | 11.64±1.01 | 82.18±3.50 | 71.49±4.01 | 86.82±4.53 | 97.49±4.77 | 101.81±0.72 | 87.96±12.13 |
|  | *C. procera* | 11.05±0.45 | 73.65±3.61 | 65.22±4.26 | 91.64±6.23 | 86.15±3.50 | 94.80±4.55 | 82.29±12.50 |
|  | *N. oleander* | 10.39±1.28 | 67.17±1.11 | 59.47±3.00 | 75.85±1.59 | 97.48±5.50 | 93.48±5.56 | 78.69±16.44 |
|  | *R. communis* | 14.25±1.15 | 92.14±7.25 | 76.80±2.58 | 102.18±8.42 | 106.66±3.33 | 113.82±4.54 | 98.32±14.37 |

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**Fig. 1:** Map showing sites on “FOR” and “N-5”.

Khanuana, Sataiana, Tandaliawala, Bangla Gogera, Satghara More, Renala Khurd, Pattoki, Bhai Phero, Manga Manadi and Chung

Source: https://www.google.com/maps

**Fig. 2:** Mean Zn content (mg kg-1 dry wt.) in plant leaves along “FOR”

**Fig. 3:** Mean Zn content (mg kg-1 dry wt.) in plant leaves along “N-5”

c

d

a

b

e

**Fig. 4**: Spatial variations in mean Zn content (mg kg-1 dry wt.) in plant leaves along

“FOR”

a

b

e

d

f

**Fig. 5:** Spatial variations in mean Zn content (mg kg-1 dry wt.) in plant leaves along

“N-5*”*

d

c

**Fig. 6**: Temporal variations in mean Zn content (mg kg-1 dry wt.) in plant leaves along

“FOR**”**

b

c

d

**Fig. 7:** Temporal variations in mean Zn content (mg kg-1 dry wt.) in plant leaves along

“N-5”

**Fig. 8:** Comparison among roads for mean Zn contents (mg kg-1 dry wt.) in soil

**Fig. 9:** Comparison among roads for mean Zn contents (mg kg-1 dry wt.) in plant leaves

**Table 4:** Pearson’s correlation coefficient between average daily traffic and Zn content in soil and plant leaves during different seasons along “FOR” and “N-5”.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **FOR** | | | | **N-5** | | | |
| **Summer** | **Autumn** | **Winter** | **Spring** | **Summer** | **Autumn** | **Winter** | **Spring** |
| **Soil** | 0.98\*\*\* | 0.84\* | 0.90\*\* | 0.89\*\* | 0.95\*\*\* | 0.99\*\*\* | 0.98\*\*\* | 0.81\* |
| ***C. ciliaris*** | 0.85\* | -0.11 ns | 0.91\*\* | 0.80\* | 0.93\*\* | 0.97\*\*\* | 0.97\*\*\* | 0.96\*\*\* |
| ***C. dactylon*** | 0.95\*\*\* | 0.92\*\* | 0.80\* | 0.80\* | 0.72 ns | 0.99\*\*\* | 0.98\*\*\* | 0.83\* |
| ***C. procera*** | 0.92\*\* | 0.99\*\*\* | 0.95\*\*\* | 0.39 ns | 0.61 ns | 0.90\*\* | 0.75 ns | 0.93\*\*\* |
| ***N. oleander*** | 0.83\* | 0.51 ns | 0.68 ns | 0.97\*\*\* | 0.91\*\* | 0.64 ns | 0.99\*\*\* | 0.69 ns |
| ***R. communis*** | 0.68 ns | 0.97\*\*\* | 0.96\*\*\* | 0.65 ns | 0.97\*\*\* | 0.96\*\*\* | 0.97\*\*\* | 0.93\*\*\* |



**Table 5:** Zinc content in fuel and soot (Mean±S.D)

|  |  |
| --- | --- |
| **Fuel** | **Zn (mg L-1)** |
| **Petrol** | 12.87 ± 0.396 |
| **Diesel** | 9.818 ± 0.273 |
| **Used motor oil** | 26.83 ±0.530 |
| **Soot** | 53.68±14.14 |