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*Full Length Research Paper*

# Evaluation of the impact of *Lantana camara* L. invasion, on four major woody shrubs, along Nayar river of Pauri Garhwal, in Uttarakhand Himalaya

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**Situated in North-Western Himalayas, owing to large variations in the altitude and climatic zones, Pauri Garhwal possesses a rich diversity of flora and fauna. Composition and structure of vegetation of the Garhwal region is being modified due to the invasion of *Lantana camara* L. Its rapid spreading, entangling nature of canopy of many individuals of a population and allelopathic nature pose serious threat to native forest flora. Beside its natural tendency to invade, the area having sub-tropical climate integrates suitably to its luxurious growth. *Z. mauritiana* Lam., *M. koenigii* (L.) Spreng, *J. adhatoda* L. and *C. opaca* Stapf ex Haines are four native shrub species found abundantly along Nayar river of Garhwal Himalaya. In this study, impact of *L. camara* invasion on these four major native shrubs was determined. Further, effort was made to correlate it with plant morphology and nutrient status of soil. Although, *L. camara* upsets importance value indices (IVI) of all four shrubs, its impact on *M. koenigii* and *J. adhatoda* was relatively more alarming, later was found to have morphologically weak structure and meager distribution in *L. camara* invaded localities of study area. It appeared that in comparison to other shrubs, owing to their morphology these two shrubs were subjected to greater competition against *L. camara.* The decrease in population of these major shrub species will have crucial effect on associated species and consequently on whole ecosystem.**

**Key words:** Competition, Himalaya, invasive, Lantana, shrub.

## INTRODUCTION

*Lantana camara* L. (Verbenaceae) is among top ten invasive weeds on the earth (Sharma et al., 2005). In its native range in Tropical America, *L. camara* generally remains confined to small thickets up to 1m diameter (Palmer and Pullen, 1995). However, in its naturalized range, like current study area it forms dense monospecific thickets, with individual reaching of 2 - 4 m height and spreading in 2 - 4 m diameter. This weed grows well on nutrient deficient barren soils (Bhatt et al., 1994) and increased light availability (Gentle and Duggin, 1997). There are allelochemicals present in all parts of shrub. When released in surroundings these chemicals interfere with germination and growth of many species (Ambika et al., 2003; Bais et al., 2004).

Equipped with these features, *L. camara* has potential to prevent natural regeneration of some tree species, block succession and replace native species (Morton, 1994; Ambika et al., 2003). Thus ultimately it threatens biodiversity of naturalized areas. In N. W. Himalayan region, *L. camara* was introduced during 1905 in Kathgodam (Hakimuddin, 1929; Hiremath and Sundaram, 2005), 110 km away from current study area in Pauri Garhwal. Now after a century, this invasive species is a major ecological problem in this area (Rajwar, 2007). It covers a vast area along horizontal and vertical geographical coordinates. *L. camara* is naturalized up to 1900 m altitude or somewhere beyond that also. The point of worry is that this area under *L. camara* invasion posses-ses highest forest cover in North-Western Himalaya and North India (Gaur, 1999; ISFR, 2009) and also holds important place in conservation of biodiversity. *Ziziphus mauritiana* Lam., *Murraya koenigii* (L.) Spreng., *Justicia adhatoda* L. and *Carissa opaca* Stapf ex Haines are the

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**Abbreviations: mEq**, Milliequivalent.

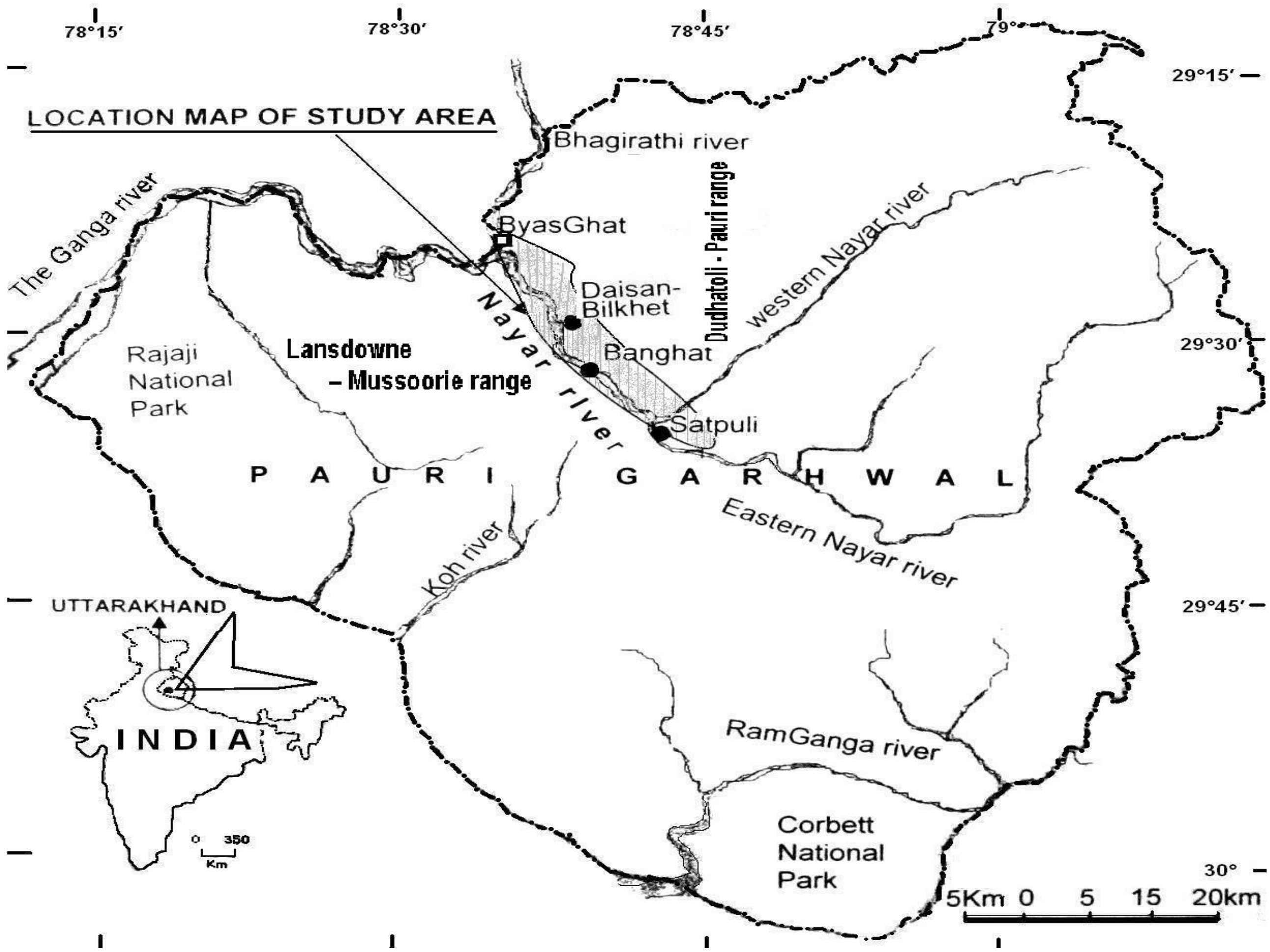


**Figure 1.** Map showing the location of study area with in Pauri Garhwal (India).

most widely distributed shrubs in the study area. These are medicinally and economically useful. *J. adhatoda* is useful in cough syrups, bronchitis, fever, and as a vegetable. *M. koenigii* leaves are flavoring agent and insecticide. *Z. mauritiana* is important in social forestry; its fruits are edible and bark decoction halts diarrhea and dysentery. All of them also provide a very rich source of bee-forage (Gaur, 1999), prevent soil erosion and have great importance in overall plant richness of the area. Therefore, the impact of *L. camara* invasion on richness and distribution of above mentioned major shrubs was evaluated. In addition, root structure -distribution in different strata of soils, shoot structure of all shrubs and soil nutrition were analyzed to find out if there is any relation between levels of impact of invasion and relative occupation of strata by invader and native species.

## Study area

Pauri Garhwal (29°45´ to 30°15´ N Latitude and 78°24´ to 79°23´ E Longitude) is a district of Uttarakhand State, Northern India. The study was carried out in a zone 600 to 1,000 m above sea level, on both sides of River Nayar from Satpuli to Byasghat. This is a stretch of 20 Km, present between two ranges (Dudhatoli - Pauri range in north and Lansdowne - Mussoorie range in south) of lesser Himalayas. Nayar is an important perennial river in this region; it contributes to water of Ganges at Byasghat (Figure 1).

## METHODS

One hundred twenty quadrants were laid randomly in *L. camara* invaded areas. For each of them, more that 50 m away, a quadrant was laid in nearby non-invaded area with negligible (small seedlings) or without *L. camara* invasion. These quadrants served as control. In totality, 240 quadrants with dimension of 4 × 4 $m^2$ were laid within one year. In all quadrants individuals of *Z. mauritiana*, *M. koenigii*, *J. adhatoda* and *C. opaca* and *L. camara* were counted carefully and basal areas were recorded at 10 cm above ground. Frequency, density, per cent basal area and importance value index (IVI) were calculated according to Misra (1968). The following ecological indices were calculated, using ecological software package from Ludwig and Raynold (1988):

**Table 1.** Ecological indices of *L. camara* in invaded and non-invaded localities.

| Ecological Indices | | Locality | |
|---|---|---|---|
| | | Invaded | Non-invaded |
| Richness | Margalef's index ($R_1$) | 0.58 | 0.58 |
| | Menhinick's index ($R_2$) | 0.16 | 0.16 |
| Diversity | Simpson's index (λ) | 0.33 | 0.35 |
| | Shannon's index (H') | 1.28 | 1.29 |
| | Hills numbers ($N_1$) | 3.59 | 3.62 |
| | Hills numbers ($N_2$) | 3.06 | 2.83 |
| | Evenness ($E_1$) | 0.79 | 0.80 |

a) Species richness – Margalef's index that is $R_1 = S - 1 / \ln(n)$ (Margalef, 1958) and Menhinick's index that is $R_2 = S / \sqrt{n}$ (Menhinick, 1964), in both cases S is total number of species in sample and *n* is total number of individuals in sample;

b) Species diversity – Shannon's index that is $H' = -\sum_{i=1}^{s} n_i/N \ln n_i/N$ (Shannon and Wiener, 1963), Simpson's index that is $\lambda = \sum_{i=1}^{s} (n_i/N)^2$ (Simpson, 1949), in these two cases N denotes total number of individuals in all species in sample, *n* is the number of individuals belonging to the $i^{-th}$ species and S is total number of species in sample. Hill's diversity numbers that is $N_1 = \exp(H')$ and $N_2 = S / \sqrt{\lambda}$; and Evenness that is $E_1 = N_2 - 1/N_1 - 1$(Hill, 1973) were also calculated; in these three cases $N_1$ and $N_2$ are Hill's numbers, H′ is Shannon's index, λ is Simpson's index and S is total number of species in the sample.

Thirty two soil samples, 16 each from invaded and non - invaded localities were collected. Each of them was homogenous mixture of five, 0 - 12 cm deep soil samples collected from 5 nearby quadrats. Sampling was done during different periods of one year. All these samples were tested for Potassium following Bower and Gschwend (1952); Calcium and Magnesium following Black (1973); Nitrogen following A.O.A.C. (1960) and Phosphorus following Olson et al. (1954). Four mature and healthy plants of each species from similar surroundings were selected. These plants were measured for height. Further, during careful excavation of underground parts, average spread of roots in four opposite directions; root depth of primary (1*) root; average depth for origin of second / tertiary (2*/3*) roots and depth for deepest root were recorded. Spreading and deep feeding nature of root system was determined by dividing the depth of deepest root (DDR) by spread of roots (RS) or height of the plant (PH). Variance and absolute correlation between data were determined respectively by Tukey's and Pearson's tests. SPSS software was used for this purpose.

## RESULTS AND DISCUSSION

In this study *L. camara* invaded localities were compared with non-invaded localities which were regarded as a representative of *L. camara* free localities of past, and the difference in both of these was observed as change brought about after *L. camara* invasion. In terms of diversity and richness calculated exclusively for these five shrubs there was very little difference in between invaded and non-invaded localities (Table 1).

This difference cannot describe the change occurring after *L. camara* invasion. However in comparison to non-invaded localities there were extremely lower values of IVI of all four native shrubs under study in invaded ones. It was found that while IVI of *M. koenigii* decreased from 146.41 to 77.23 and that of *L. camara* increased from 27.94 to 148.4. Thus, invasion occurred mainly in the areas which were previously occupied by *M. koenigii*. However, In terms of per cent decrease in IVI, *J. adhatoda* was affected most severely. After losing 62.70% of its value, IVI of *J. adhatoda* was critically low (12.63) in *L. camara* invaded areas than that (33.88) of non-invaded ones. Such a large decrease in IVI of *J. adhatoda* was mainly due to its relatively sparse distribution and unhealthy individuals in invaded localities against non-invaded ones. *Z. mauritiana* and *C. opaca* were also negatively affected; their IVI were reduced respectively by 18.13 and 38.85% (Figure 2). It was found that soils from *L. camara* invaded localities had significantly lesser nutrients against non-invaded localities. The amount of K, Mg, Ca, N and P were respectively, 8.80, 24.62, 9.52, 29.47 and 24.81% lower in soils from invaded localities. Further the differences were highly significant in the case of Ca, N and P (Table 2). When decreased IVI value of native shrubs are tried to be characterised in terms of competition for natural resources, soil nutrients and light resource appeared as two prime factors. Decreased value of IVI of *M. koenigii* may be attributed to its smaller height and to some extent the similar structure and root distribution compared to *L. camara*. Due to which former was in direct competition with *L. camara* for light and nutrient resources. However, in comparison to *L. camara* and *J. adhatoda* root structure of *M. koenigii* was relatively deeper (Figure 2).

The root structure of *J. adhatoda* resembled *L. camara* in many features (Table 3). It was evident from average root depth, root depth to root spread ratio, root to shoot ratio, depths of origin of secondary, tertiary roots of *L. camara* and *J. adhatoda*, that both were shallow, less penetrating and occupied same zone of horizon. In contrast, root structure and distribution of Z. *mauritiana* and *C. opaca* species which appeared to have lesser

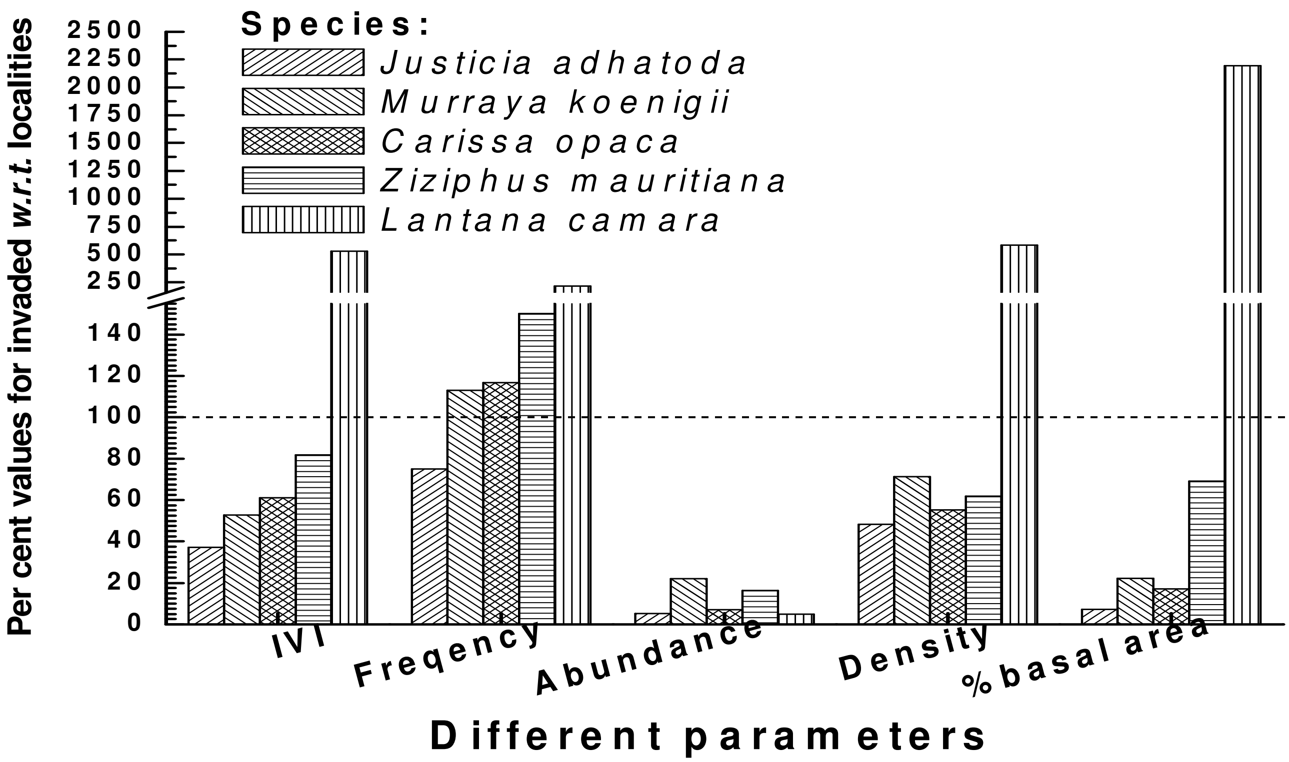


**Figure 2.** Percent values of IVI, frequency, abundance, density and percent basal area of five major shrubs in *L. camara* invaded with respect to non-invaded localities.

**Table 2.** Comparison of nutrients present *L. camara* invaded and non-invaded soils.

| Parameters | Annual mean | | % difference |
|---|---|---|---|
| | Non-invaded soil | Invaded soil | |
| Potassium (mg / kg) | 216 ± 82.3 | 197± 81.4 | 8.80 |
| Calcium (mEq /100 g) | 0.65 ± 0.26 | 0.49 ± 0.3 | 24.62* |
| Magnesium (mEq /100 g) | 0.42 ± 0.49 | 0.38 ± 0.45 | 9.52 |
| Nitrogen (kg/ ha) | 380 ± 57.7 | 268 ± 47.3 | 29.47* |
| Phosphorus (kg/ ha) | 27 ± 5.43 | 20.3 ± 4.61 | 24.81* |

*Significant at level $P < 0.05$ estimated by Tukey's test.

negative impact of invasion were remarkably different; they were deep feeders in comparison to *L. camara* (Table 3).

The similarity correlation between *L. camara* and *J. adhatoda* in terms of ratios pertaining to deep feeding and spreading nature of roots was greater than any other shrub under study (Figure 3). Thus, possibly due to sharing of same zone in soil *J. adhatoda* and *L. camara* were competing with each other for their requirement of nutrients and *L. camara* with its high efficiency of scarce nutrients uptake (Bhatt et al., 1994), deprived *J. adhatoda* from nutrients. Due to this similarity in root distribution *J. adhatoda* might also be subjected to more negative effect of allelochemicals released by *L. camara* roots. *Z. mauritiana* and *C. opaca* were also negatively affected, yet, they seem rather more resistant to its invasion due to their relatively higher, large sized canopy and significantly different deeper penetrating root system (Table 3). Relatively shallow root system of *L. camara* renders subsoil nutrients out of its reach (Gentle and Duggin, 1997). In this way these two shrubs appear to escape some of the competition for nutrients and inhibitory effect of allelochemicals released by roots of *L. camara* (Achhireddy and Singh, 1984; Ambika et al., 2003). Surprisingly, there was relatively higher frequency of occurrence of *C. opaca*, *M. koenigii* and *Z. mauritiana* in invaded localities compared to non-invaded ones (Figure 1). It may be linked to co-evolution, the plants might have

**Table 3.** Comparison of morphology of five major shrubs along Nayar river in Pauri Garhwal.

| Parameter (cm) | *L. camara* | *Z. mauritiana*[1] | *C. opaca*[2] | *M. koenigii* | *J. adhatoda* |
|---|---|---|---|---|---|
| Height of plant (PH) | 215.00 ± 7.07[a] | 164.75 ± 38.6[b] | 71.75 ± 13.02[b] | 175.7 ± 13.4[b] | 172.75 ± 54.7[b] |
| Root, lateral spread (RS) | 96.11 ± 8.34[a] | 85.1 ± 110.1[a] | 33.25 ± 9.11[a] | 104.7 ± 28.8[a] | 97.10 ± 70.0[a] |
| Root depth 1* root | 41.75 ± 8.10[a] | 67.0 ± 32.17[ab] | 48.50 ± 9.40[a] | 91.75 ± 24.8[a] | 38.75 ± 6.60[a] |
| Depth of origin 2* roots | 10.38 ± 3.11[a] | 26.92 ± 4.53[b] | 25.67 ± 5.74[b] | 15.50 ± 3.57[a] | 12.25 ± 2.50[a] |
| Depth of origin 3* roots | 11.42 ± 3.27[a] | 42.63 ± 13.76[c] | 28.73 ± 8.14[bc] | 31.0 ± 8.43[bc] | 20.00 ± 4.24[ab] |
| Deepest root depth (DDR) | 43.6 ± 4.57[a] | 75.25 ± 27.2[bc] | 54.25 ± 7.8[ab] | 101 ± 20.22[c] | 39.25 ± 6.4[a] |
| Ratio: DDR / RS | 0.45 ± 0.04[a] | 1.68 ± 0.84[b] | 1.72 ± 0.47[b] | 1.02 ± 0.35[ab] | 0.61 ± 0.44[a] |
| Ratio: DDR / PH | 0.20 ± 0.02[a] | 0.45 ± 0.07[b] | 0.76 ± 0.08[c] | 0.57 ± 0.08[b] | 0.24 ± 0.04[a] |

Mean values with common letters are not significantly different at P < 0.1, according to Tukey's test, ± is Standard deviation 1 and 2; Height and root depth of *Z. mauritiana* and *C. opaca* are given in order to provide an estimate of proportionate shoot and root structure of this species. As their average height in this region is around 3 m therefore their dimensions may be more than double of that represented in table, other features like number of roots and root shoot ratio might remain same. Large sized plants were not excavated as they were difficult to uproot and may have caused destruction of already threatened nearby flora.

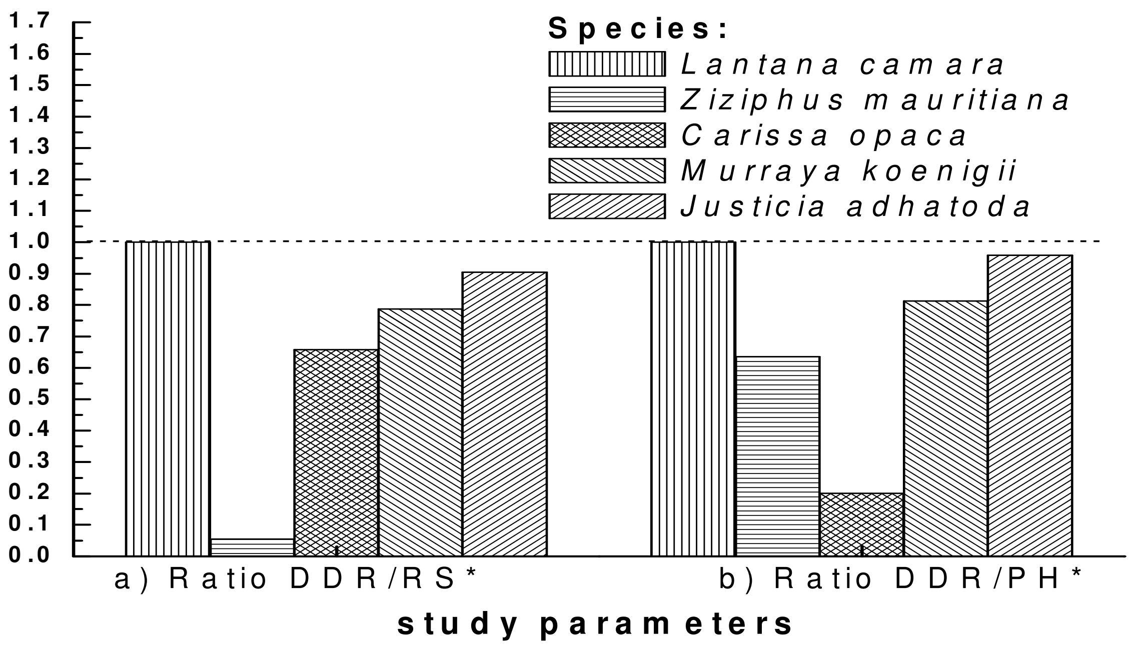


**Figure 3.** Absolute similarity correlation between ratios, referring to penetrative-ness and spreading nature of roots. Here, DDR = Deepest root depth, RS = Lateral spread of roots, PH = Height of plant.

evolutionary interlink in the form of beneficial or inhibitory impact on other plants through allelochemicals (Bias et al., 2006) or other physical interactions. It is observed that in non-invaded localities these shrubs were either growing luxuriously (as depicted by higher density, abundance and basal areas) or not (lesser frequency). *L. camara* might have interfered in above mentioned situation by changing the soil microbial community (Xingjun et al., 2005) and consequently these species were now found more frequently in invaded localities. But, density and health (growth) of these shrubs was very poor in comparison to non-invaded localities and these were generally present in the form of young seedlings. Increased *L. camara* population may lead to ecological disturbance that can change foraging behavior of native pollinators, which consequently may result in reduced reproductive output of some native species (Murali et al., 1996; Ghazoul, 2004). Compared with non invaded ones in *L. camara* invaded areas of this region, shrub other than this weed may have up to 50% reduction in the total IVI (Dobhal et al., 2009). The decrease in population of these shrubs is a subject of concern, because, after losing their larger population to *L. camara* invasion there is a possibility that these species may face an inbreeding depression (Ghosh, 2004). There were not just decreased population but with large patches of *L. camara* monocultures, the populations of native shrubs in invaded localities were becoming discontinuous. These populations were either having weak plants (with lesser basal area) or small patches of healthy individuals. It is known that isolated plants or fragmented populations suffer reduced fecundity due to declining pollination efficiency. Further, loss of plants can trigger chained extinction throughout the community (Wilcock and Neiland, 2002; Ghazoul and Shaanker, 2004).

## Conclusion

A century after its introduction in a place 110 km away, now *L. camara* is a major shrub in Nayar river region. It is a serious threat to all major native shrubs growing along Nayar River. While all the four native shrubs under current study were affected by quick spread and characteristic ability of *L. camara* to grab empty niche. It appears that due to smaller height and sharing of same zones in soil, mainly *J. adhatoda* and to some extent *M. koenigii* were affected directly and more severely by structural distribution (above ground and below ground stratification of plant parts), competitive ability and allelopathic potential of *L. camara*. Thus restoration of population of such shrubs, which are relatively close competitor of *L. camara* in terms of resources and allelopathic interactions, should gain prime importance in conservation. In this region the large reproducing populations of this invasive species are assuring its easy and exploding spread, while after losing their large populations to *L. camara* invasion or other anthropogenic factors, these native shrubs now have lesser and patchy distribution of reproducing population to resist further *L. camara* invasion. Thus, now there is a possibility that loss of population of these species will be exponential, which will also have effect on associated species and consequently on whole ecosystem and to some extent on the economy of this region.

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