RESEARCH ARTICLE

The Role of Herb and Shrubs in the Cycling of Elements in a Tropical Dry Deciduous Forest in North-West India

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Abstract

The Bala Fort tropical dry deciduous forest in the Aravali ranges is located in Rajasthan state in North-West India (27°4′ to 28°4′N and 76°7′ to 77°13′E). These forests support a dense stratum of perennial herbs and shrubs under the relatively open tree canopy. Therefore, the impact of a dominant herb and shrubs has been evaluated on the cycling of sodium, potassium, calcium and phosphorus in this forest. The percentage of sodium was lower, while that of the other three elements was higher in the biomass of the selected species in comparison to soil. Among the four plant species only the shrub *Justicia adhatoda* lost a higher percentage of sodium (0.268) than present in the soil (0.203). *Grewia flavescens* and *Capparis sepiaria* retain sodium in their plant body. However, through litter fall, the former returned a higher amount of sodium to the soil. The herb, *Achyranthes aspera* exhibited unusually higher percentages of potassium 4.464, 3.818 and 2.916 in leaves, stems and roots, respectively than the three shrub species. The percentage of calcium was higher in the biomass and litter of shrubs than in the herb. Hence, the shrubs return a larger amount of calcium to the soil than the herb. The herb *Achyranthes aspera* and the shrubs *J. adhatoda* and *G. flavescens* exhibited almost equal percentages of phosphorus, while *Capparis sepiaria* showed less percentage in biomass. The percentage of phosphorus was higher in the litter of all the selected shrubs as compared to living biomass indicating its poor retranslocation during leaf shedding. On the basis of the standing crop, the herb *A. aspera* plays an important role in the nutrient cycling of potassium and phosphorus, whereas the deciduous shrubs *J. adhatoda* and *G. flavescens* in calcium and phosphorus cycles. The deciduous shrubs *J. adhatoda* and *G. flavescens* contribute more than the evergreen shrub *Capparis sepiaria* in the nutrient cycling of this forest.

Keywords: Biomass; Litter; Nutrient conservation; Retranslocation; Soil.

Highlights

- The tropical dry deciduous forest with a relatively open forest canopy is located in the semi-arid region of Rajasthan in North-West India.
- The ground vegetation of this forest is dominated by the annual herb *Achyranthes aspera* and the shrubs *Justicia adhatoda*, *Grewia flavescens*, and *Capparis sepiaria*.
- The herb *A. aspera* transfers a large amount of sodium to its roots at the time of senescence, which may be an efficient way of conserving this element. It also traps a considerable amount of sodium and potassium in its biomass during the rainy season on hill slopes, which otherwise would have been washed away with runoff water.
- All the selected species allocate a higher amount of calcium to their above-ground parts to increase their photosynthetic area and compete with other associated species.
- *G. flavescens*, a deciduous shrub, allocates more calcium to the stem, while Capparis sepiaria, an evergreen shrub, allocates it to both the stem and leaves.
- The deciduous species *G. flavescens* and *J. adhatoda* play a more important role than the evergreen shrub *Capparis sepiaria* in the cycling of selected elements. Shrubs play a more significant role in the cycling of calcium and phosphorus.

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INTRODUCTION

The availability of water and the cycling of nutrients influence the productivity of terrestrial ecosystems (Duvigneaud and Denaeyer-De Smet 1973). Nutrients transferred from living biological compounds to soil through litterfall is the beginning of nutrient cycling (Gray and Schlesinger 1981). Plant litter returns the nutrients from vegetation to soil through mineralization and plays an important role in the circulation of nutrients in the ecosystem (Khanna and Ulrich 1991; Santa Regina *et al.*, 1997; Gallardo *et al.,* 1998). Litter dynamics has been studied in many tropical forest ecosystems in India (Rai *et al.,* 1986; Khiewtam and Ramakrishan 1993; Pandey *et al.,* 2007). Besides litter

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decomposition, nutrient transfer from leaves to branches during the senescence of leaves known as translocation of nutrients, is an important component of nutrient cycling (Helimissari 1992; Lal *et al.,* 2001a; Niinemets and Tamm 2005; Vergutz *et al.,* 2012; Parrag-Aguado *et al.,* 2014). Initial nutrient requirements of emerging leaves may be met by the nutrients withdrawn from senescing leaves (Lal *et al.,* 2001b). Several workers have evaluated the retranslocation of nutrients at the ecosystem level (Hagan-Thorn *et al.,* 2006; Duchsene *et al.,* 2012; Vergutz *et al.,* 2012; Achat *et al.,* 2018).

In India, comprehensive studies on nutrient cycling have also been carried out in Central Himalaya forests (Negi *et al.,* 1983; Singh *et al.,* 1984; Singh and Singh, 1987; Chaturvedi and Singh 1987; Rawat and Singh, 1988), in Eastern Himalaya forests (Singh and Ramakrishnan 1982; Das and Ramakrishnan 1985) and in dry deciduous forests (Singh and Misra 1979; Singh and Singh 1985). However, nutrient cycling in dry tropical forests has been given less attention than to moist tropical forests (Jaramillo and Sanford 1995). Further, no serious attempt has been made to understand the cycling of essential elements in the underneath vegetation, particularly in the dry deciduous forests of Aravali hills. The tropical, dry deciduous forests of the Aravali Mountain range have a relatively open tree canopy, which allows the luxurious growth of herbs and shrubs. It is, therefore, hypothesized that the ground flora in these forests play an important role in the cycling of nutrients. Hence, in the present study an attempt has been made (i) to evaluate the role of common herb *Achyranthes aspera* L. and shrubs *G. flavescens* Juss., *Justicia adhatoda* L. and *Capparis sepiaria* L. in the cycling of Sodium, Potassium, Calcium and Phosphorus and (ii) to understand the difference between the cycling pattern of these four elements in deciduous shrub and evergreen shrub in a tropical dry deciduous forest located in Rajasthan state of northwestern India.

METHODS

The study site

The Bala-Fort Reserve Forest is located in the Alwar district of Rajasthan (27°4′ to 28°4′ N and 76°7′ to 77°13′ E), which may be classified as a tropical dry deciduous forest as per the criteria given by Champion and Seth (1968). The undisturbed west-facing hill slope of this forest was selected as the study site (Mishra *et al.,* 2020). The climate of this region is hot and dry, with three distinct seasons in a year. The summer season from mid-March to June is extremely hot, with the temperature soaring to 46.7°C. The hot Westerly winds blow during the month of May and June known as 'loo' during this season. The rainy season is from July to mid-September which witness 90% of the average annual rainfall (732 mm). The dry cold winter season prevails from October to February with temperatures dropping to 2^0C in months of December and January with little rainfall (Yadav and Gupta 2006). This forest is dominated by the tree species *Anogeissus pendula* and other associated tree species are *Acacia leucophloea, Acacia catechu, Boswellia serrata, Butea monosperma* and *Lannea coromandelica*. The common shrubs are *J. adhatoda, Capparis sepiaria, Commiphora wightii* and *Grewia flavescens,* while the dominant herbs are *Achyranthes aspera, Brachiaria ramosa* and *Desmodium repandum* (Yadav and Yadav 2005). Although leaf initiation and senescence are observed around the year, leaf initiation on a larger scale was observed in July-August for *J. adhatoda* and *G. flavescens*. *Capparis sepiaria* showed leaf initiation from September to December. Leaf fall of *G. flavescens, J. adhatoda* and *Capparis sepiaria* was observed in large amounts in October, April and July, respectively.

Table 1: The soil characteristics of the middle part of the West facing hill slope in the Bala-fort Forest (± SE)

Parameters	*Soil depth (cm)*	*Soil pH*	*Organic carbon (%)*	*Electrical conductivity ($dS\,m^{-1}$)*
Values	10.9 ± 0.2	7.5 ± 0.003	1.18 ± 0.02	3.67 ± 0.2

The soil is brown in color and sandy loam and very shallow on hill slopes of the mountain ranges. The soil depth decreases with an increase in the height of the slope. The soil pH varies from 7.2 to 7.6 in different micro-environments with a slight increase towards the top of the hill slope (Table 1). The organic carbon increased from the base to the top of the hill slope but a percentage of carbon was higher at the middle of the west-facing hill slope in this forest.

The electrical conductivity increased with increase in height of the hill slope. The soil moisture contents generally increased with increase in height of the slope in rainy season, however, during dry period it was always higher in the valley than that of the hill slope. From August onwards middle part of the West facing hill slope have more moisture contents which may be due to the growth of herbaceous vegetation during rainy season and dense canopy cover as compared to the base and the top of the hill slope.

The percentage of various elements was estimated in the soil of the study site with the help of XRF technique. The highest percentage of Iron (1.76) was observed followed by Potassium (1.21%) and Calcium (0.7%) and Magnesium (0.7%). Percentage of other elements in the soil is relatively low but within the optimum range (Fig. 1).

Sampling procedures

To evaluate the cycling of selected elements, the litter fall, standing crop and standing state of elements were estimated in the soil of the middle part of the west-facing hill slope in the

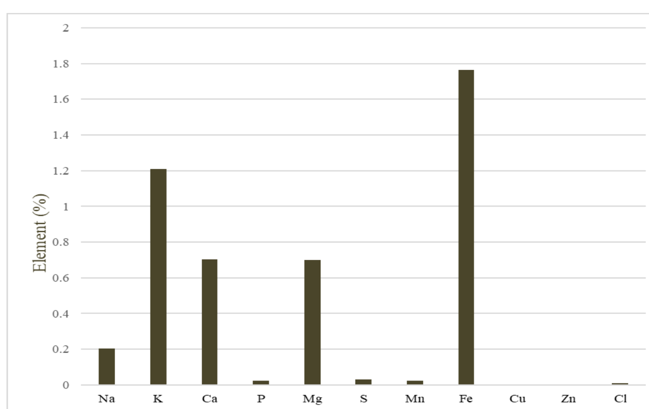

Fig. 1: Percentage of elements in the soil on the middle part of the west-facing hill slope in the Bala-fort Forest.

Bala-fort Forest. The litterfall was estimated by collecting litter at quarterly intervals from 12 randomly laid litter traps, each of 50cm × 50cm × 15cm dimensions, from the middle of the West facing hill slope in the Bala-fort Forest. Litter was collected from each litter trap and sorted out manually. Sorted litter of the four plant species was dried separately at 80°C in a hot air oven till a constant dry weight was achieved (Misra 1968). Ten grams of dried samples of each species were powdered and one gram was used for nutrient (Sodium, Potassium, Calcium and Phosphorus) analysis. Three replicates were taken for each treatment.

The biomass of the four selected plant species was estimated by harvest method. The shoot biomass estimated by harvesting at least 10 different-sized plants of each species from the middle part of the west-facing hill slope. The roots of *J. adhatoda* and *Achyranthes aspera* were also harvested. However, the roots of *Capparis sepiaria* and *G. flavescens* were not harvested as it might have led to destruction of many other neighbouring plants. As per the norms of the forest department, the uprooting of *G. flavescens* and *Capparis sepiaria* is prohibited. In case of *G. flavescens* and *Capparis sepiaria*, the numbers of primary and secondary branches per plant were counted and about 20 secondary branches were harvested to evaluate the above-ground biomass. The above-ground biomass of *G. flavescens* and *Capparis sepiaria* were estimated by factorial method, i.e. average number of primary branches × average number of secondary branches × average biomass of a secondary branch. All the biomass samples were dried at 80°C in a hot air oven to constant weight. The average biomass per plant was multiplied by the average density per 100 m^2 to obtain biomass gram per 100 m^2. The biomass of *J. adhatoda, G. flavescens, Capparis sepiaria* and *Achyranthes aspera* was 1820, 1430, 289 and 30 g per 100m^2 respectively (Mishra 2014).

Chemical analysis

Dried samples of biomass of the four plant species were powdered and then analysed for Sodium, Potassium, Calcium and Phosphorus. Three replicates were taken for each plant part of a species. For estimating the percentage of Sodium, Potassium, Calcium and Phosphorus in the soil, five soil samples were taken from 10cm × 10cm × 10cm volume of soil from the middle of the west facing hill slope at the Bala-fort Forest. The five soil samples were mixed thoroughly to estimate the percentage of Sodium, Potassium, Calcium and Phosphorus present in the soil. The estimations of above elements were done with the help of X-ray fluorescence spectroscopic technique (XRF) (Kataoka *et al.,* 1998) at the Advanced Instrumentation Research Facility (AIRF), Jawahar Lal Nehru University, New Delhi.

RESULTS

Sodium

The percentage of sodium was higher in the soil (0.203%) in comparison to that in the biomass of all the selected plant species (Table 2). *Achyranthes aspera* showed higher percentage of sodium (0.073) in roots than in leaves (0.028) and stems (0.017). It returns sodium to the soil with the senescence of the whole plant by November. *J. adhatoda* also showed higher percentage of Sodium 0.024, 0.047, and 0.04 in leaves, stem and roots respectively than the other two shrubs. Almost equal percentage of sodium was in leaves and stem of *G. flavescens* and *Capparis sepiaria* 0.018 and 0.022 respectively. *J. adhatoda* showed the highest percentage of Sodium in November (0.268) and the lowest (0.023) in February in litter. *G. flavescens* in May and *Capparis sepiaria* in August exhibited high percentage of sodium in litter, however, the former species released higher amount of sodium through litter than the latter species. The higher percentage of sodium in litter of *G. flavescens* and *Capparis sepiaria* in August might be due to the absorption of more amount of sodium with water from the soil in the rainy season.

Potassium

Potassium is present in ample amounts (1.211%) in the soil of this forest. The percentage of potassium was higher in the biomass of all the selected plant species than that in the soil, however, it was particularly very high in leaves, stems and roots 4.464, 3.818 and 2.916 respectively of *Achyranthes aspera* (Table 3). Among the shrubs lower percentage of potassium was observed in *J. adhatoda* 0.124, 0.832 and 1.588 in leaves, stem and roots respectively than the other two shrubs. *G. flavescens* exhibited 1.865, and 0.825 percentage of potassium in leaves and stem whereas the corresponding values for *Capparis sepiaria* were 1.55 and 1.945 respectively. The highest percentage of potassium (3.785) was observed in the litter of Achyranthes *aspera* whereas it was 1.183, 0.926 and 0.742 for *Capparis sepiaria, J. adhatoda and G. flavescens* respectively. The pattern of release of potassium was different for the three shrubs as *J. adhatoda* and *G. flavescens* released a higher percentage of Potassium in November while *Capparis sepiaria* released higher Potassium in August.

Calcium

The percentage of calcium in the soil was very low (0.7) as compared to its percentage in the organic matter of different species (Table 4). The herb *Achyranthes aspera* contained higher percentage in leaves (1.07) whereas less (0.4) in stem and roots

Table 2: Percentage of Sodium in the biomass and litter of different species and in the soil on the middle part of the hill slope of the Bala Fort Forest in Alwar (± SE)

Species	*Biomass*			*Litter fall*				*Soil*
	Leaf	*Stem*	*Root*	*August*	*November*	*February*	*May*	*Middle of the slope*
J. adhatoda	0.024± 0.004	0.047 ± 0.014	0.040 ± 0.007	0.126 ± 0.004	0.268 ± 0.028	0.023 ± 0.005	0.181 ± 0.062	0.203 ± 0.007
G. flavescens	0.018 ± 0.002	0.021 ± 0.005	--------	0.092 ± 0.009	0.042 ± 0.012	0.053 ± 0.017	0.155 ± 0.031	
Capparis sepiaria	0.018 ± 0.001	0.022 ± 0.006	--------	0.049 ± 0.014	0.027 ± 0.005	0.041 ± 0.016	0.019 ± 0.001	
Achyranthes aspera	0.028 ± 0.007	0.017 ± 0.002	0.073 ± 0.005	--------	0.010 ± 0.001	--------	--------	

Table 3: Percentage of Potassium in the biomass and litter of different species and in the soil on the middle part of the hill slope of the Bala Fort Forest in Alwar (± SE)

Species	*Biomass*			*Litter fall*				*Soil*
	Leaf	*Stem*	*Root*	*August*	*November*	*February*	*May*	*Middle of the slope*
J. adhatoda	1.236 ± 0.143	0.832 ± 0.053	1.588 ± 0.069	0.726 ± 0.027	1.746 ± 0.108	0.926 ± 0.028	0.607 ± 0.085	1.211 ± 0.035
G. flavescens	1.865 ± 0.120	0.825 ± 0.104	--------	0.574 ± 0.016	0.742 ± 0.040	0.503 ± 0.073	0.637 ± 0.079	
Capparis sepiaria	1.555 ± 0.172	1.945 ± 0.081	--------	1.183 ± 0.076	0.703 ± 0.104	0.746 ± 0.061	0.764 ± 0.037	
Achyranthes aspera	4.464 ± 0.439	3.818 ± 0.162	2.918 ± 0.153	--------	3.785 ± 0.192	--------	--------	

each. The shrubs showed higher amount of calcium than the herb. *J. adhatoda* contained higher percentage of calcium in leaves (2.1) and less in stem (0.7) and roots (0.5) while *G. flavescens* exhibited lower percentage of calcium in leaves (1.67) than in stem (2.32) and *Capparis sepiaria* has almost equal amount (1.7) and (1.5) in both leaves and stem, respectively. The percentage of calcium in the litter was the highest in *J. adhatoda* in February (7.99) followed by *G. flavescens* (5.8) and the lowest in *Capparis sepiaria* (3.7) in August. The amount of litter contributed by *J. adhatoda* and *G. flavescens* is higher than *Capparis sepiaria*.

Phosphorus

The percentage of phosphorus in the soil of middle part of the hill slope was much less (0.024) as compared to that in living biomass and litter of the four selected species (Table 5). The herb *Achyranthes aspera* exhibited higher percentage of phosphorus in leaves (0.115) than in stem (0.073) and roots (0.045) while the shrub *J. adhatoda* showed higher percentage of phosphorus in roots (0.106) than in leaves (0.065) and stem (0.071). *G. flavescens* and *Capparis sepiaria* showed higher percentage of phosphorus in leaves than in the stem, however, the former contained higher percentage of phosphorus than the latter species. The evergreen shrub *Capparis sepiaria* contained highest percentage of phosphorus in litter in August (0.11) whereas the deciduous shrub *G. flavescens* (0.191) in February and *J. adhatoda* (0.15) in May. *Capparis sepiaria* showed considerable decline in phosphorus in the litter in dry season.

DISCUSSION

The percentage of sodium (0.01) was very low in the litter of the herb, *Achyranthes aspera* as compared to its roots. This indicates that the herb transfers a large amount of sodium to roots at the time of senescence which may be an efficient way of conservation of this element. Similarly, the herb *Achyranthes aspera* exhibited a particularly very high percentage of potassium in all plant parts and return it to the soil after senescence of the whole plant by November. Thus, it traps in its biomass a considerable amount of Sodium and Potassium which may be otherwise washed out during rainy season on the hill slopes of this forest. On the contrary, the shrubs return a higher amount of sodium to soil than the herb through litter fall. Hence all the selected species play important role in the cycling of sodium. Except for the evergreen shrub *Capparis sepiaria*, the other three species under investigation have high Potassium concentrations in the leaves, compared to the stem. Rossatto *et al.*, (2015) suggested that higher concentrations of potassium in deciduous forest tree species play an important role in water level regulation in these species, particularly in stomata control, because these plants keep their leaves active during the first 2-3 months in the dry season. Rojas-Jiménez *et al.,* (2007) also suggested that foliar Potassium concentration can also play an important role in osmotic regulation in the trunks of some species. Among the shrubs, the percentage of potassium in the above-ground parts was higher in *Capparis sepiaria* than in the other two species. *Capparis sepiaria* with the onset of dry period in September retained more potassium in biomass as a result of less leaf fall as compared to the other two deciduous species. *Capparis sepiaria* exhibited an unusual behavior of losing potassium through litter fall in the month of August. This may be attributed partly to the higher absorption of potassium with ample availability of water and partly to less translocation during leaf fall may be the main reason behind losing more potassium through its litter

Table 4: Percentage of Calcium in the biomass and litter of different species and in the soil on the middle part of the hill slope of the Bala Fort Forest in Alwar (± SE)

Species	*Biomass*			*Litter fall*				*Soil*
	Leaf	*Stem*	*Root*	*August*	*November*	*February*	*May*	*Middle of the slope*
J. adhatoda	2.119 ± 0.072	0.708 ± 0.056	0.527 ± 0.108	3.863 ± 1.896	3.380 ± 0.141	7.995 ± 1.092	4.603 ± 0.607	0.703 ± 0.032
G. flavescens	1.670 ± 0.098	2.324 ± 0.151	--------	3.951 ± 0.133	3.910 ± 0.234	5.800 ± 0.933	3.818 ± 0.081	
Capparis sepiaria	1.719 ± 0.184	1.530 ± 0.132	--------	3.744 ± 0.032	2.213 ± 0.309	2.007 ± 0.088	2.221 ± 0.158	
Achyranthes aspera	1.072 ± 0.048	0.445 ± 0.034	0.406 ± 0.013	--------	1.594 ± 0.076	--------	--------	

Table 5: Percentage of Phosphorus in the biomass and litter of different species and in the soil on the middle part of the hill slope of the Bala Fort Forest in Alwar (± SE)

Species	*Biomass*			*Litter fall*				*Soil*
	Leaf	*Stem*	*Root*	*August*	*November*	*February*	*May*	*Middle of the slope*
J. adhatoda	0.0649 ± 0.014	0.071 ± 0.01	0.106 ± 0.003	0.116 ± 0.013	0.113 ± 0.006	0.144 ± 0.014	0.150 ± 0.001	
G. flavescens	0.109 ± 0.006	0.082 ± 0.013	--------	0.134 ± 0.006	0.119 ± 0.004	0.191 ± 0.020	0.127 ± 0.009	
Capparis sepiaria	0.062 ± 0.012	0.047 ± 0.004	--------	0.110 ± 0.002	0.038 ± 0.002	0.052 ± 0.001	0.050 ± 0.004	0.024 ± 0.001
Achyranthes aspera	0.115 ± 0.003	0.073 ± 0.004	0.045 ± 0.006	--------	0.063 ± 0.003	---------	---------	

in rainy season. Mishra *et al.,* (2020) has also reported negligible retranslocation of Potassium by *Capparis sepiaria* during leaf fall. All the selected species store large amounts of potassium in their organic matter and thus play an important role in the conservation of potassium in this ecosystem.

All the selected plants allocated more calcium to above-ground parts to increase their photosynthetic area to compete with other associated plant species. Because of their higher leaf Calcium concentration, deciduous forest species are able to accumulate it in leaf tissues, thus forming diverse types of Calcium crystals (Somavilla *et al.,* 2014). This accumulation of calcium may serve as a source of calcium during the process of water regulation, particularly for osmotic purposes (Ghanem *et al.,* 2010). Among the shrubs *J. adhatoda* released higher percentage of calcium through litter fall whereas *G. flavescens* and *Capparis sepiaria* tend to retain more calcium in the biomass. Gallardo *et al.,* (1998) and Parker (1996) reported that Calcium and Phosphorus return to soil largely through litter fall. *G. flavescens,* a deciduous species allocated higher calcium to the stem whereas the *Capparis sepiaria* an evergreen species allocated almost equal percentage to stem and leaves. This may also be related to the higher reallocation of calcium by the former than the latter species (Mishra *et.al.,* 2020). Hagen -Thorn *et al.,* (2004) also stated that nutrient retranslocation in plants is likely to be affected by plant genetic make-up or plant species and environmental factors. The percentage of calcium was higher in the above ground parts of *G. flavescens* than other two shrubs. *J. adhatoda and G. flavescens* contributed higher amount of litter than *Capparis sepiaria*. This suggests that the former two species return large amount of calcium to the soil through litter fall. Rossatto *et al.,* (2015) also observed a positive and significant relationship between soil and leaf nutrient concentration at least for Phosphorus and Calcium in deciduous forests. The herb *Achyranthes aspera* exhibited less percentage of calcium in biomass, hence, it plays a little role in the conservation of calcium in this forest. The herb *Achyranthes aspera* and shrub *J. adhatoda* and *G. flavescens* exhibited higher percentage of phosphorus than the evergreen shrub *Capparis sepiaria* in biomass. The percentage of phosphorus was almost the same in the herb *Achyranthes aspera* and *J. adhatoda*, however, the former allocated only (0.04) to roots *whereas* the latter allocated higher percentage to roots (0.11). This characteristic feature may be concerned with their growth habit as the herb allocates more phosphorus to above-ground parts to increase its reproductive capacity while the shrub allocates more phosphorus to roots to increase its competitive ability. Thus, *Achyranthes aspera* is an r-strategist and *J. adhatoda* is a k-strategist species as per r- and k-continuum concept of MacArthur and Wilson (1967). The percentage of phosphorus was higher in the litter as compared to the intact leaves in the selected shrub species which indicates that phosphorus is not retranslocated to living plant parts at the time of senescence of leaves. Mishra *et al.,* (2020) also observed very less retranslocation of phosphorus in these species. The comparative evaluation of the percentage of selected elements except calcium, the deciduous shrubs exhibited higher concentration in living tissues than in evergreen shrubs. This finds support from several workers who reported that generally deciduous plants have higher foliar nutrients compared to non-deciduous plants in tropical or temperate forests (Aerts 1996; Aerts and Chapin 2000; Franco *et al.,* 2005). Similarly, Machado *et al.,* (2016) also observed higher content of Potassium and Phosphorus in deciduous species than in non-deciduous species. The evergreen shrub, *Capparis sepiaria* almost has the same percentage of selected elements in the leaf and stem as in the case of the other two deciduous shrubs. A large amount of litter is present in the soil of this forest in summer season (Yadav 2005) which indicates that litter acts as a store of nutrients in the dry season. The highest living biomass (g per 100 m^2) was exhibited by *J. adhatoda* (1820) followed by *G. flavescens (*1430), *Capparis sepiaria* (289) and the lowest by *Achyranthes aspera* (30). Hence it may be suggested that the former two species play the maximum role while the latter two species have less role in the nutrient cycling of selected elements in this dry deciduous forest.

CONCLUSION

It may be concluded that shrubs play a more important role in the cycling of Calcium, Phosphorus, and Potassium whereas *Achyranthes aspera* in the cycling of Potassium and Phosphorus in this forest. The observations also suggest that the deciduous shrubs *Justicia adhatoda* and *Grewia flavescens* play more important role than the evergreen shrub, *Capparis sepiaria* in this tropical dry deciduous forest.

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