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Distribution and Growth of Ground Vegetation in Relation to Environmental Factors in the Bala-fort Reserve Forest Alwar, Rajasthan

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The Bala-fort forest is located in the Sariska Tiger reserve in Alwar, Rajasthan (27°4' to 28°4' N and 76°7' to 77°13' E). It is a tropical dry deciduous forest with dense ground vegetation. The influence of spatial heterogeneity and soil nutrients was evaluated on the distribution and growth of selected common herb and shrubs on the west facing hill slope in this forest. The density of herb *Achyranthes aspera* was highest among the four selected species (3320 stems $100m^{-2}$) in the valley and lowest (1970 stems$100m^{-2}$) in the middle part of the slope. Among the shrubs *Justicia adhatoda* exhibited highest density (42 stems $100m^{-2}$) in the valley, *Grewia flavescens* 34 stems $100m^{-2}$ at the base and *Capparis sepiaria* 17 stems $100m^{-2}$ in the valley. According to frequency, *Capparis sepiaria* exhibited clumped dispersion whereas the other three selected species showed uniform dispersion on the west facing hill slope in this forest. *Achyranthes aspera* exhibited lowest biomass (0.17 kg $100m^{-2}$) whereas *Justicia adhatoda*, *Grewia flavescens* and *Capparis sepiaria* showed 6.4, 6.6 and 2.5 kg $100m^{-2}$ total biomass respectively, in the study site. The growth of *Achyranthes aspera* and *Justicia adhatoda* in different micro-environments did not respond to four selected elements (Sodium, Potassium, Calcium and Phosphorus) whereas *Grewia flavescens* exhibited higher growth at low percentage of four elements. *Capparis sepiaria* showed higher growth at higher percentage than at lower percentage of selected elements. The results obtained indicate that distribution and growth of selected plant species was regulated by the elevation of slope, density of tree species and soil nutrients in this forest.

Key Words: Biomass, Density, Dispersion, Elements, Shrubs.

Introduction

The vegetation of a place is the result of many factors like elevation, soil characteristics and biotic interferences[1,2,3]. The high species richness on the hill slopes may be due to increased spatial heterogeneity[4]. Dixit and Rao[5] have also reported that the high growth of *Commiphora wightii* may be due to variable micro-topography and soil properties. It has also been suggested that the number of species tend to increase along the moisture gradient provided other factors being equal[6,7]. The Bala fort reserve forestis a tropical dry deciduous forest located in Alwar district of Rajasthan (27°4' to 28°4' N and 76°7' to 77°13' E). It has a relatively open forest canopy and spatial heterogeneity due to hilly topography which allows the

considerable growth of underground flora. On the basis of our field observations we hypothesize that the variations in availability of soil nutrients, biotic interference and altitudinal micro-environments regulate the growth of ground vegetation in this forest. Therefore, an attempt has been made to evaluate the distribution and growth of common herb*Achyranthes aspera* and shrubs *Justicia adhatoda, Grewia flavescens* and *Capparis sepiaria* in relation to various micro-environments and soil characteristics in this forest.

Material and methods

The study site was selected on a West facing hill slope in the Bala-fort reserve forest situated in the North-Eastern part of Rajasthan in the Aravali hills in Alwar district. The climate is hot and dry with three seasons. The summer season from mid-March to June is extremely hot with temperature soaring to 46.7^{o}C, the hot Westerly winds blow during the month of May and June known as 'loo' during this season. In this region, the rainy season from July to mid-September witness 90% of the average annual rainfall. The dry cold winter season prevails from October to February with temperatures dropping to 4^{0}C in months of December and January with little rainfall. The microenvironment of top, middle and base of hill slope and valley is highly variable. The depth of soil decreased from >1m to 10 cm, the soil pH varies from 7.6 to 7.4 with increase in the height of slope[4]. The density and frequency of the herb *Achyranthes aspera* and the shrubs *Justicia adhatoda,Capparis sepiaria* and *Grewia flavescens*, were estimated by quadrat method. First the density and frequency of the three perennial selected species were evaluated by laying randomly ten quadrats of 10m × 10m size each in the valley, at the base of the hill, the middle and the top of the West facing hill slope in the Bala-fort reserve forest. For *Achyranthes aspera*, the density and frequency were evaluated by laying randomly 20 quadrats of 1m × 1m size each at all the above four sites of the forest in the month of August.

For the estimation of biomass per plant, 10 plants of *Justicia adhatoda* and *Achyranthes aspera* were harvested. In case of other two shrub species, 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 a shrub plant was estimated by factorial method, i.e. average number of primary branches × average number of secondary branches × average biomass of a secondary branch. The whole plants of herbaceous species and the above ground parts of the plants of shrubs were dried at 80^{o}C in hot air oven for 48 hours following Misra[8]. The root biomass was not estimated of the shrub species as it would have led to the destruction of large number of plant species in the forest. Finally the standing crop of the above four plant species was obtained by multiplying the density and biomass per plant of a particular 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 each micro environmental site i.e. from the valley, the base, the middle and the top of the west facing hill slope at the Bala-fort forest. The five soil samples of each site were mixed thoroughly to estimate the percentage of Sodium, Potassium, Calcium and Phosphorus present in the soil. The

estimations of these elements were done with the help of X-ray fluorescence spectroscopic technique (XRF)[9] at Advanced Instrumentation Research Facility (AIRF), Jawahar Lal Nehru University, New Delhi. In XRF, X-rays produced by a source irradiate a sample. The elements present in the sample emit fluorescent X-ray radiations with discrete energies which are characteristic for these elements. The type of elements present can be determined by measuring the energy of the radiations emitted by the sample (Qualitative analysis). The quantity of each element present can be determined by measuring the intensities of the emitted energies in the sample (Quantitative estimation).

Results and Discussion

Density

Among the shrubs *Justicia adhatoda* recorded the highest density (43.9 stems per 100m^2) followed by valley (42.4 stems per 100m^2), while the density at the base found to be the lowest (31.9 stems per 100m^2) (Table 1). *Grewia flavescens* exhibited highest density at the base of the slope followed by at the middle part of the hill slope. It does not prefer to grow in the valley and at the top of the hill slope. Its maximum density was recorded at the base of the hill slope (34.1 stems per 100m^2). The middle of the slope recorded second highest plant density of *Grewia flavescens* (13.3 stems per 100m^2) whereas the lowest density of *Grewia flavescens* (5.2 stems per 100m^2) was on the top of the hill. The density of the *Capparis sepiaria* was found to be highest in the valley (17 stems per 100m^2) whereas it showed low density on the hill slope (Table 1). The high density of annual herb *Achyranthes aspera* was estimated on all the four study sites in the month of August which grows only during the rainy season. It lasts for few months till the moisture contents of the soil remain high, afterwards it perishes. The density of *Achyranthes aspera* was highest among the four plant species but the biomass was found to be the lowest, as it is a small annual herb. It exhibited almost uniform population distribution throughout the valley and the hill slopes.

Frequency

Frequencies of different species indicate the dispersion pattern of species in the habitat. *Achyranthes aspera*, the herbis distributed throughout the hill slope as it exhibited 100% frequency in all micro-environments (Table 1). Similarly, *Grewia flavescens* and *Justicia adhatoda* also showed uniform distribution in this habitat. *Capparis sepiaria* exhibited clumped distribution as its maximum frequency was 90 percent at the top of the hill slope and in the valley, whereas it was about 60 percent in the middle and at the base of the West facing hill slope in Bala-fort forest.

Biomass

Among the four selected species of the study site biomass of *Achyranthes aspera* was lowest (0.17 kg m^{-2}) whereas *Justicia adhatoda*, *Grewia flavescens* and *Capparis sepiaria* produced higher total biomass on the hill slope i.e., 6.4, 6.6 and 2.5 kg per 100m^2 (Table 1). The biomass production was very low in *Achyranthes aspera* in comparison to the three shrubs. This may be because of its annual habit.

Nutrients in soil

The highest percentage of Sodium was observed to be present in the soil of the valley (1.26%) and it declined abruptly on the elevations of the hill slope (Table 2). Potassium showed maximum percentage at the base of the hill slope (2.05%) which decreases with the elevation of the slope.

Table 1.: Density (stems per 100m^2) (±SE), frequency (%) and Biomass Density (g per 100m^2) (±SE) of selected plant species on the West facing hill slope and valley in the Bala-fort forest.

Parameters	Hill Slope	*Justicia adhatoda*	*Grewia flavescens*	*Capparis sepiaria*	*Achyranthes aspera*
Density	Top of the hill slope	36.0±4.0	5.2±1.1	2.9±0.5	2770±601
	Middle of the hill slope	43.9±3.8	13.3±1.7	2.8±0.6	1970±407
	Base of the hill slope	31.9±3.9	34.1±5.6	1.5±0.5	2970±517
	Valley	42.4±3.6	8.6±1.8	17.0±3.0	3320±599
Frequency	Top of the hill slope	100	80	90	100
	Middle of the hill slope	100	100	70	100
	Base of the hill slope	100	100	60	100
	Valley	100	100	90	100
Biomass Density	Top of the hill slope	1492±167	559±120	299±58	43±9
	Middle of the hill slope	1820±160	1430±192	289±70	30±6
	Base of the hill slope	1322±164	3667±607	155±54	46±8
	Valley	1758±149	925±194	1753±315	51±9
	Total	6392	6581	2496	170

Table 2.: The presence of selected elements (%) in soil of various micro-environments in the Bala fort reserve forest (±SE).

Micro-environment	Elements			
	Sodium	Potassium	Calcium	Phosphorus
Top of the hill slope	0.21±0.01	0.99±0.02	0.90±0.07	0.037±0.01
Middle of the hill slope	0.20±0.01	1.21±0.04	0.70±0.03	0.02±0.001
Base of the hill slope	0.25±0.02	2.05±0.08	0.44±0.03	0.03±0.004
Valley	1.26±0.58	1.49±0.34	0.38±0.10	0.03±0.01

The soil of the valley too exhibits less amount of Potassium as compared to the base of the hill slope. The percentage of Calcium in the soil was highest at the top of the hill slope (0.9%) which declined gradually with decrease in the elevation of the West facing hill slope (Table 2). Phosphorus also exhibited highest percentage (0.04%) in the soil of the top of the slope which declined slightly at lower elevations. These observations suggest that the distribution pattern of the four selected elements is highly variable. Sodium and Potassium are present in higher percentage at lower elevations whereas Calcium and Phosphorus are present in relatively higher percentage at higher elevations. However, Phosphorus is almost uniformly distributed in four micro-environmental situations. The proportion of Sodium, Potassium, Calcium and Phosphorus was found to be within the optimum range.

Achyranthes aspera exhibited higher biomass when the percentage of Calcium was low in the soil (Fig 3) whereas *Achyranthes aspera* did not exhibit any specific trend with respect to the percentage of Potassium in the soil of the West facing hill slope (Fig 2). *Achyranthes aspera* exhibited higher biomass at lower percentage of Phosphorus. Among the shrubs, *Justicia adhatoda* did not exhibit any specific trend with respect to the percentage of Calcium in the soil, *Capparis sepiaria* showed higher biomass with the decline in percentage of Calcium whereas *Grewia flavescens* did not exhibit any specific trend with respect to Calcium in the soil (Fig 3).

Justicia adhatoda is sensitive to high percentage of Potassium but showed no specific trend with respect to Phosphorus in the soil (Fig 4).

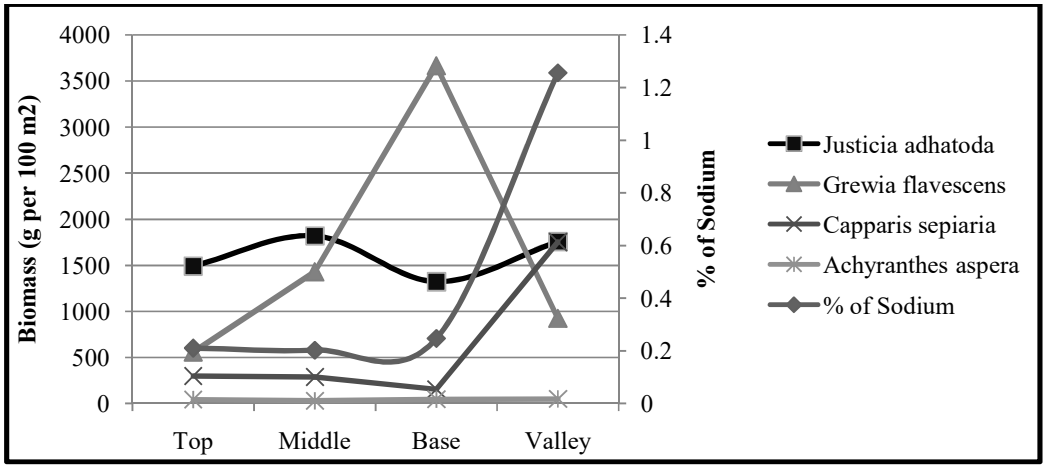

Figure 1.: Standing crop of *Justicia adhatoda, Grewia flavescens, Capparis sepiaria* and *Achyranthes aspera* in relation to the percentage of Sodium in the soil of the middle part of the West facing hill slope in the Bala-fort forest.

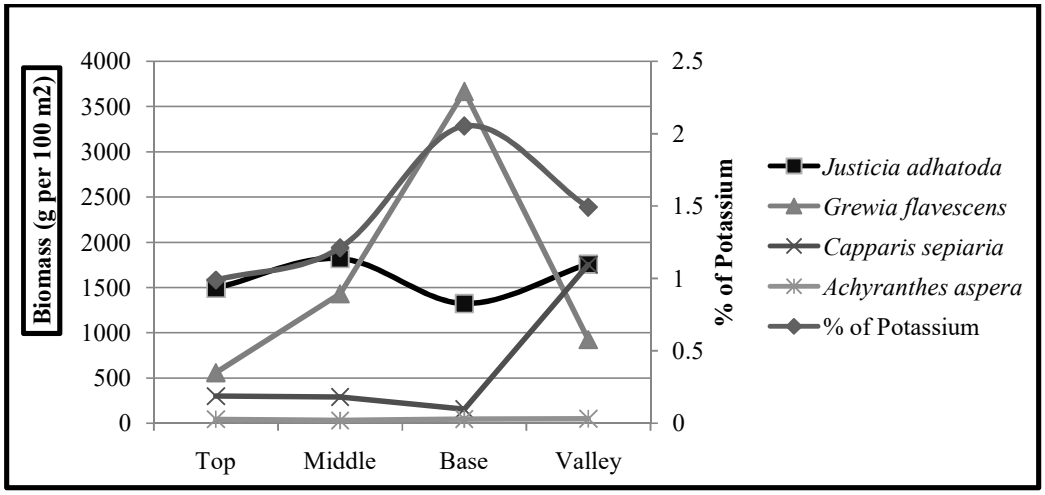

Figure 2.: Standing crop of *Justicia adhatoda, Grewia flavescens, Capparis sepiaria* and *Achyranthes aspera* in relation to the percentage of Potassium in the soil of the middle part of the West facing hill slope in the Bala-fort forest.

Relatively low density of *Achyranthes aspera* at the middle of the slope (1970 stems 100 m-2) is attributed to the dense canopy of *Anogeissus pendula* as compared to other micro-sites. Its uniform distribution is also due to the dispersal of the fruits by wild animals as they stick to their fur. Yadav and Yadav[4] have also reported higher density of *Anogeissus pendula* on the middle and base of the west facing hill slope in this forest. *Justicia adhatoda* exhibited high density in the valley and middle part of the slope as the soil is relatively more stabilized as compared to the base because of more steepness of the slope at the base of the hill. Seeds of *Justicia adhatoda* may be

carried away to the valley with run-off water. Another reason for decrease in density of *Justicia adhatoda* may be because of high density of *Grewia flavescens* at the base of the hill slope. *Grewia flavescens* exhibited highest density at base of the slope and lowest at the top of the hill slope. The highest density of *Capparis sepiaria* in the valley may be due to open tree canopy and partly to its preference for deeper soil layer (Table 1).

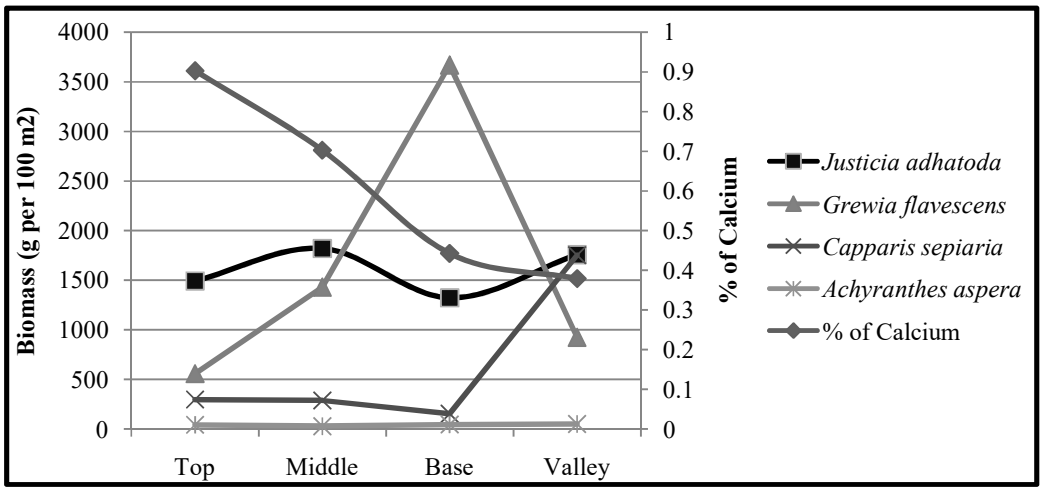

Figure 3.: Standing crop of *Justicia adhatoda, Grewia flavescens, Capparis sepiaria* and *Achyranthes aspera* in relation to the percentage of Calcium in the soil of the middle part of the West facing hill slope in the Bala-fort forest.

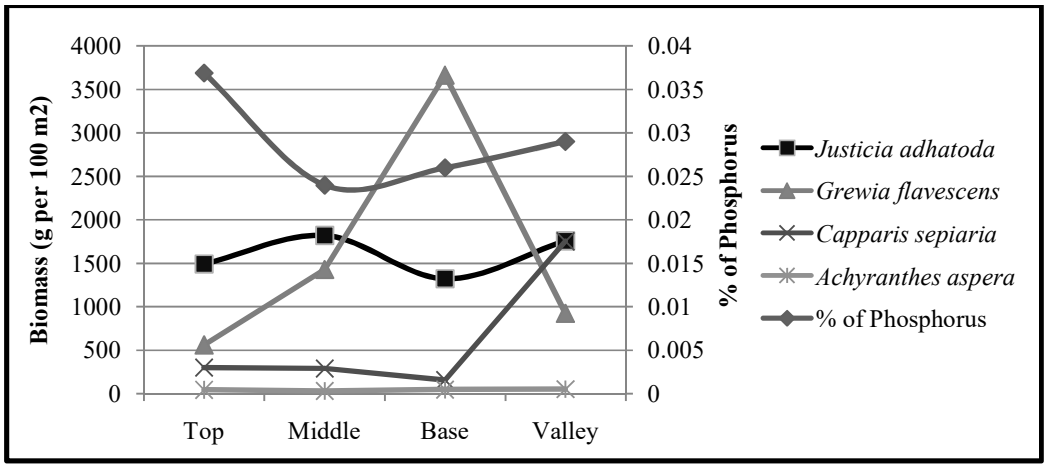

Figure 4.: Standing crop of *Justicia adhatoda, Grewia flavescens, Capparis sepiaria* and *Achyranthes aspera* in relation to the percentage of Phosphorus in the soil of the middle part of the West facing hill slope in the Bala-fort forest.

The results obtained indicate that the distribution of shrubs, *Grewia flavescens* and *Capparis sepiaria* may be influenced by the percentage of Sodium and Potassium in the soil as the former species prefers higher percentage of Potassium whereas the later prefers the higher percentage of Sodium in the soil of valley. The biomass and density of both the species are also directly correlated with the percentage of these elements

present in the different micro-environmental situations (Fig 1 and Fig 2). *Achyranthes aspera, Justicia adhatoda* and *Grewia flavescens* showed decline in biomass (Fig 1) with the increase in percentage of Sodium in the soil whereas *Capparis sepiaria* showed that it may be adapted to higher concentrations of Sodium (Fig 1). Similarly further *Capparis sepiaria* showed inverse relationship with the percentage of Potassium in the soil (Fig 2), whereas *Grewia flavescens* exhibited increased biomass with the increase in percentage of Potassium in the soil (Fig 2). The correlation between soil nutrients, tree density and diversity index also confirms a significant relationship[10-12].

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