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Full Length Research Paper

Nitrogen and Phosphorus Resorption Efficiency in Some Leguminous and Non-Leguminous Tropical Tree Species Planted on Coal Mine Spoil in a Tropical Dry Environment

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Nitrogen and phosphorus resorption efficiencies were evaluated in three years old, eight tropical tree species planted on coal mine spoils. Of these eight species, Albizia lebbeck, Albizia procera, Dalbergia sissoo and Millettia pinnata were the leguminous species, while the Azadirachta indica, Holoptelea integrifolia, Madhuca longifolia and Terminalia arjuna were the non-leguminous species. Both groups of plants have shown higher resorption efficiencies for both nitrogen and phosphorus, but they potentially differed in terms of nitrogen and phosphorus resorption efficiency. Non-leguminous species have shown higher efficiency for nitrogen resorption and lower efficiency for phosphorus resorption while contrary to this; leguminous species have shown lower efficiency for nitrogen resorption and higher efficiency for phosphorus resorption.

Keywords: Coal Mine Spoil, Nitrogen Resorption Efficiency, Phosphorus Resorption Efficiency, Singrauli Coal-fields, Tropical Tree Species.

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INTRODUCTION

Nutrient resorption is the physiological process, enabling the plants to withdraw nutrients from sensing leaves which are later invested in the emergence of new structures. Nutrient resorption is a key component of nutrient conservation strategies (Vergutz *et al.,* 2012). It is an important adaptation to infertile soils, since it reduces nutrient loss (Chapin, 1980) and increase the plant use efficiency (Vitousek, 1982). Most of the resorption studies demonstrate that plants growing in nutrient deficient habitats have a higher nutrient resorption efficiency suggesting that effective resorption is a mechanism to minimize nutrient loss in low nutrient environments (Tilton, 1977; Ostman and Weaver, 1982; Flanagan and Van Cleve, 1983; Boerner, 1984; Ralhan and Singh, 1987; Pugnaire and Chapin, 1993; Singh, 2004, 2011, 2014).

The coal mine spoils on which the present resorption study conducted is severely disturbed and nutrient deficient habitat. Nitrogen and phosphorus are the two major limiting nutrients in the mine spoil (Mays and Bengston, 1978). The plants growing in such habitats are supposed to have higher nutrient resorption efficiency. The objective of the present investigation, therefore, was to evaluate the extent of nitrogen and phosphorus resorption efficiencies in some young tropical tree species planted on coal mine spoil. The potential difference between legumes and non-legumes for nitrogen, and phosphorus resorption efficiency was also examined.

MATERIAL AND METHODS

Site description

The study was conducted at the Bina coal mine in the Singrauli Coal-fields, India. The Coal-fields of Singrauli cover an area of about 2200 km^2 (23^{o}47-24^{o}15' N; 81^o 48$'$-82^{o}52$'$ E and elevation of 280-519 m above mean sea level), of which 80 km^2 lies in Sonabhadra district of Uttar Pradesh and rest in the Sidhi district of Madhya Pradesh. The climate is tropical monsoonal and the year is divisible into a mild winter (November-February) and hot summer (April-June) and a warm rainy season (July-September). The Mean monthly maximum temperature within the annual cycle ranges from 6.4 to 28^{o}C and mean monthly maximum from 20 to 42^{o}C. The annual rainfall averages 1069 mm of which 90% occur during the period June to September. Winter rains are negligible. The potential natural vegetation is a dry deciduous forest (Champion and Seth, 1968) consisting of *Senegalia catechu, Diosopyros melanoxylon, Wrightia antidysenterica, Boswellia serrata, Lagerstroemia parviflora, Cassia fistula, Madhuca longifolia, Butea monosperma, Wrightia tomentosa, Anogeissus latifolia Woodfordia fruticosa, Phyllanthus emblica, Holoptelea integrifolia, Melia azedarach* etc.

Experimental design and methods

Nursery raised 1-year-old individuals of the following eight tropical tree species were planted on fresh flat mine spoil in July 1993. *Albizia lebbeck* (L.) Willd., *Albizia procera* Benth., *Azadirachta indica* A. Juss., *Dalbergia sissoo* Roxb., *Holoptelea integrifolia* (Roxb.) Planch., *Madhuca longifolia* (J. Konig) J. F. Macbr., *Millettia pinnata* (L.) Panigrahi and *Terminalia arjuna* Wt. & Arn. The seedlings were planted in 20 m x 20 m plots with spacing of 2 m x 2 m. Minimum of three replicate plots were maintained for each species. The total nitrogen (N) and total phosphorus (P) reported at the site were 0.012% and 0.0087%, respectively, indicating that the coal mine spoil is extremely deficient in these two nutrients.

Green leaves were sampled in the first week of September 1996 and senesced leaves were sampled in the first week of December 1996. Senesced leaves were collected by lightly shaking the same branches from which mature green leaves were sampled. Leaf samples were collected from five marked individuals from the middle of the crown for each species from three replicate plots. The samples from five individuals were mixed from each replicate plots and brought to the laboratory in polyethylene bags. Blocks of 1cm^2 were cut oven dried at 65^{o}C, weighed and ground. Nitrogen was determined by the microkjeldahl technique (Jackson, 1958) and phosphorus was analyzed after digestion in a mixture of $HClO_4$, HNO_3, and H_2SO_4 (1:5:1) using phosphomolybdic acid blue colour method (Jackson, 1958). The nutrient mass was computed as the product obtained by multiplying dry mass (cm^2) of leaves by their nutrient concentration. Percent resorption of nutrients was calculated using the formula: 100 x (nutrient mass cm^{-2} in mature leaf - nutrient mass cm^{-2} in senesced leaf), nutrient mass cm^{-2} in mature leaf (Ralhan and Singh, 1987).

RESULTS

Foliar nitrogen concentration in mature and senesced leaves was higher for all the leguminous species as compared to non-leguminous species (Table 1). Whereas no such definite trend emerged for foliar P concentration in mature leaf but the foliar phosphorus concentration in senesced leaves was higher in non-leguminous species in comparison to leguminous species (Table 2).

The nitrogen resorption efficiency ranged between 38.35% (*A. procera*) to 68.46% (*A. indica*) (Table 1) whereas the phosphorus resorption efficiency ranged between 46.46% (*M. longifolia*) to 70.90% (*A. lebbeck*) (Table 2). The trend for nitrogen and phosphorus resorption efficiency distinctly differed between legumes and non-legumes. All the leguminous tree species have resorbed less nitrogen but have shown high efficiency for phosphorus resorption. Contrary to this, all the non-leguminous tree species have shown higher efficiency for nitrogen resorption but lower efficiency for phosphorus resorption excepting *A. indica.* Generally the non-leguminous tree species having less foliar nitrogen concentration in mature leaf have resorbed proportionately greater amount of nitrogen whereas no such trend emerged for phosphorus resorption.

Table 1: Nitrogen (N) concentration and mass in mature and senesced leaves, resorbed nitrogen pool, and nitrogen resorption efficiency in tree species planted on coal mine spoil

Tree species (Family)	Mature Leaf		Senesced Leaf		Resorbed Pool (µg cm^{-2})	Resorption Efficiency (%)
	Concentration (%)	Mass (µg cm^{-2})	Concentration (%)	Mass (µg cm^{-2})		
Albizia lebbeck (L.) Willd. (Fabaceae)	1.89 ± 0.05	153.80 ± 6.0	1.19 ± 0.03	84.36 ± 2.88	69.44 ± 3.4	45.11 ± 1.0
Albizia procera Benth. (Fabaceae)	1.90 ± 0.09	207.45 ± 13.25	1.20 ± 0.08	128.26 ± 11.20	79.18 ± 2.6	38.35 ± 2.0
Azadirachta indica A. Juss. (Meliaceae)	1.64 ± 0.05	146.0 ± 4.43	0.78 ± 0.02	46.0 ± 1.68	100.0 ± 4.2	68.46 ± 1.5
Dalbergia sissoo Roxb. (Fabaceae)	2.01 ± 0.04	188.92 ± 4.88	1.14 ± 0.03	95.18 ± 2.55	93.74 ± 6	49.53 ± 2.1
Holoptelea integrifolia (Roxb.) Planch. (Ulmaceae)	1.48 ± 0.04	149.36 ± 5.23	0.82 ± 0.04	51.85 ± 2.93	97.51 ± 3.8	65.28 ± 1.5
Madhuca longifolia (J. Konig) J. F. Macbr. (Sapotaceae)	0.96 ± 0.03	95.33 ± 2.90	0.42 ± 0.01	36.86 ± 1.85	58.61 ± 1.51	61.36 ± 1.3
Millettia pinnata (L.) Panigrati (Fabaceae)	2.10 ± 0.03	163.76 ± 2.34	1.31 ± 0.03	86.93 ± 3.0	76.83 ± 2.4	46.92 ± 1.5
Terminalia arjuna Wt. & Arn. (Combretaceae)	0.95 ± 0.03	118.62 ± 4.16	0.38 ± 0.02	46.40 ± 2.67	72.21 ± 1.5	60.93 ± 1.0

Table 2: Phosphorus (P) concentration and mass in mature and senesced leaves, resorbed phosphorus pool, and phosphorus resorption efficiency in tree species planted on coal mine spoil

Tree species (Family)	Mature Leaf		Senesced Leaf		Resorbed Pool (µg cm^{-2})	Resorption Efficiency (%)
	Concentration (%)	Mass (µg cm^{-2})	Concentration (%)	Mass (µg cm^{-2})		
Albizia lebbeck (L.) Willd. (Fabaceae)	0.147 ± 0.008	11.97 ± 0.57	0.0491 ± 0.004	3.47 ± 0.33	8.50 ± 0.62	70.90 ± 3.12
Albizia procera Benth. (Fabaceae)	0.156 ± 0.004	17.02 ± 0.35	0.0536 ± 0.007	5.64 ± 0.69	11.27 ± 0.61	66.87 ± 4.0
Azadirachta indica A. Juss. (Meliaceae)	0.160 ± 0.007	14.27 ± 0.60	0.0804 ± 0.007	4.70 ± 0.41	9.56 ± 0.20	67.14 ± 1.5
Dalbergia sissoo Roxb. (Fabaceae)	0.134 ± 0.008	12.55 ± 0.78	0.0446 ± 0.004	3.73 ± 0.41	8.82 ± 0.46	70.39 ± 2.0
Holoptelea integrifolia (Roxb.) Planch. (Ulmaceae)	0.129 ± 0.004	13.04 ± 0.50	0.0982 ± 0.004	6.15 ± 0.22	6.87 ± 0.40	52.76 ± 1.8
Madhuca longifolia (J. Konig) J. F. Macbr. (Sapotaceae)	0.102 ± 0.004	10.13 ± 0.39	0.0625 ± 0.004	5.44 ± 0.43	4.69 ± 0.05	46.46 ± 2.66
Millettia pinnata (L.) Panigrati (Fabaceae)	0.160 ± 0.007	12.52 ± 0.53	0.0580 ± 0.004	3.82 ± 0.27	8.70 ± 0.36	69.50 ± 2.0
Terminalia arjuna Wt. & Arn. (Combretaceae)	0.120 ± 0.008	15.06 ± 1.03	0.0625 ± 0.008	7.57 ± 1.11	7.49 ± 0.50	50.12 ± 5.0

DISCUSSION

The higher nitrogen and phosphorus resorption by the non-leguminous species and higher phosphorus resorption by the leguminous species in the present study in three years old plantation clearly suggests that even younger plants growing in nutrient poor habitat use to develop higher efficiency for nutrient resorption to cope with the problem of nutrient stress. In contrast to present finding Côté and Camire (1987) reported lower efficiencies of nitrogen and phosphorus resorption in same aged plantations of alder and poplar growing on acid loam soil. The observation in the present investigation therefore is consistent with other field reports that effective resorption is mechanism to minimize nutrient loss in habitat of low nutrient status (Small, 1972; Stachurski and Zimka, 1975; Ostman and Weaver, 1982; Lajtha, 1987; Ralhan and Singh, 1987, Côté *et al.,* 1989; Pugnaire and Chapin, 1993; Singh, 2004, 2007, 2011, 2014).

All the leguminous species have resorbed comparatively less nitrogen than non-leguminous species. This less efficiency towards nitrogen resorption may be due to their nitrogen fixing attribute. Generally plants harbouring nitrogen fixing symbionts have low N resorption efficiency (Stachurski and Zimka, 1975; Dawson and Funk, 1981; Rodriguez-Barrueco *et al.,* 1984; Côté *et al.,* 1989; Killingbeck, 1993a; Singh, 2005, 2011, 2014). Interestingly all the leguminous species have shown higher efficiency towards phosphorus resorption. This higher affinity for phosphorus may be because of its utility during nodule formation and nitrogen fixation. Several other studies also reports that nitrogen fixing tree species have greater efficiency for phosphorus resorption (Chapin and Kedrowski, 1983; Côté *et al.,* 1989; Singh, 2004, 2005, 2011, 2014).

All the non-leguminous species were deciduous which have resorbed more nitrogen as compared to phosphorus suggesting the importance of nitrogen in these species. Greater percentage of nitrogen resorption have been reported from leaves of deciduous species than evergreen species (Ralhan and Singh, 1987; Aerts, 1996; Yuan and Chen, 2009b). A greater nitrogen resorption in deciduous species is considered an ecological need to compensate for the shorter life span of leaves and to produce heavy leaf crop annually (Chapin and Tryon, 1983).

The higher nitrogen and phosphorus resorption efficiency in *A. indica* suggests that fast growing non-leguminous species are more efficient in nutrient resorption. In fast growing species probably the actively growing foliage serve as sink for nutrients resorbed out of senescing leaves. Actively growing leaves are very effective nutrient sinks (Wells and Mertz, 1963; Krueger, 1967; Taylor, 1967; Kozlowski, 1971; Nambiar and Fife, 1987).

Generally a higher nitrogen resorption was associated with lower tissue nitrogen concentration which clearly suggests that plants with low nitrogen status are more efficient in nitrogen resorption. Similar results were reported by Pugnaire and Chapin (1993) and Kobe *et al.* (2005). Lajtha (1987), however had hypothesized that plant of low nutrient status should have low resorption efficiency because most leaf N would be structurally bound and less accessible to hydrolysis and resorption. Pugnaire and Chapin (1993) found that proposed mechanism is correct but the ecological pattern is reverse. They reported that plant growing on infertile site with low nitrogen concentration have high proportion of soluble nitrogen. Many other species have been reported to have a high proportion of soluble nitrogen when grown at low nirogen availability (Côté *et al.,* 1989; Huffaker, 1989; Navari-Izzo *et al.,* 1990).

CONCLUSION

It can be concluded from the study that high nutrient resorption is effective means by which the nutrient loss is minimized by plants growing in nutrient deficient habitats. Further the difference in nitrogen and phosphorus resorption efficiencies between legumes and non-legumes clearly suggests a strong selection for nutrient resorption between these two groups. The growth in leguminous species is phosphorus limited while in non-leguminous species it is nitrogen limited.

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