

## Effect of fertilization on N and P resorption efficiency of selected leguminous and nonleguminous tropical trees planted on coal mine spoil

ARVIND SINGH

Department of Botany, Banaras Hindu University, Varanasi 221 005, India.  
email: arv\_ind69@yahoo.com; Phone: +91-542-2307147.

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### Abstract

Influence of NPK fertilization on N and P resorption efficiency was studied in nine native tropical tree species planted on coal mine spoil. Of these, *Acacia catechu*, *Albizia lebbek*, *Dalbergia sissoo* and *Pongamia pinnata* were legumes, while *Azadirachta indica*, *Gmelina arborea*, *Phyllanthus emblica*, *Tectona grandis* and *Terminalia bellirica* were nonlegumes. The N and P resorption efficiencies dropped in fertilized plots in all the species. Nonleguminous tree species had exhibited greater efficiency for N resorption than leguminous species. However, no such trend emerged for P resorption between both the groups, as the two nonlegumes *A. indica* and *G. arborea* had resorbed P in the range of leguminous tree species. The study indicates that nutrient enrichment reduces internal cycling of nutrients thus facilitating greater amount of nutrient return to soil which in turn would enhance the reclamation process by allowing the colonization of more species due to increased habitat fertility.

**Keywords:** Leguminous trees, mine spoil, nonleguminous trees, N resorption, P resorption, tropics.

### 1. Introduction

Nutrients in foliage are cycled internally to support the growth of plants. During senescence, nutrients are withdrawn from the senescing leaves through resorption. This is a strategy by plants to conserve nutrients [1] to reduce their dependence on soil nutrient supply [2]. Several resorption studies demonstrate that plants growing on infertile habitats are more efficient in nutrient resorption [3–10]. Contrary reports suggest greater resorption on fertile soils too [11–13]. A few studies, however, claim no relationship between resorption and soil fertility [14–20]. In this study, an attempt has been made to demonstrate relationship between plant nutrient resorption properties and soil nutrient status. The study performed on coal mine spoil which is the overburden material removed during mining and dumped in a haphazard manner. Physically, nutritionally and microbiologically impoverished coal mine spoils present rigorous conditions for both plant and microbial growth [21]. Nitrogen (N) and phosphorus (P) are the two major limiting nutrients in mine spoil [22, 23]. The study was undertaken to assess the degree of internal cycling of N and P in different tree species under fertilized and unfertilized conditions. Greater the internal cycling of nutrients lesser is the nutrient return to soil. This is detrimental to the reclamation of degraded

\*Address for correspondence: S/o Dr K. P. Singh, Old E/2, Jodhpur Colony, Banaras Hindu University, Varanasi 221 005, India.

habitats like mine spoil as it hampers the process of succession by deterring the natural colonization of plant species. The specific objective of the present investigation is to evaluate the impact of NPK fertilization on N and P resorption efficiencies on nine different tropical tree species planted for revegetation of coal mine spoil. The following questions were posed to fulfil the above objective: (i) does fertilization influence N and P resorption efficiencies in tree species?, (ii) does any potential difference exist between legumes and nonlegumes for N and P resorption efficiencies? and (iii) does any relationship exist between leaf nutrient concentrations and nutrient resorption efficiencies?

## 2. Material and methods

### 2.1. Site description

The study was conducted at the Jayant coal mine in the Singrauli Coalfields, India. The Coalfields extends over 2200 km<sup>2</sup> (23°47'–24°12'N; 81°48'–82°52'E at an elevation of 280–519 m above the mean sea level), of which 80 km<sup>2</sup> lies in Uttar Pradesh and the rest in Madhya Pradesh. The climate is tropical monsoonal and the year is divisible into a mild winter (November–February), a hot summer (April–June) and a warm rainy season (July–September). March and October are transitional months. Mean monthly minimum temperature within an annual cycle ranges from 6.4 to 28°C and the mean monthly maximum from 20 to 48°C. The rainfall averages 1069 mm with about 90% precipitation between June and September. The texture of the spoil material was 80% sand, 10% silt, and 10% clay, with 7.4 pH, 0.018% total N and 0.010% total P [24]. Soil cores to a depth of 10 cm consisting of 75% of the particles greater than 2 mm in diameter. The potential natural vegetation in the study area is a tropical dry deciduous forest.

### 2.2. Experimental design and methods

Nursery-raised 1-year-old individuals of the following nine tree species were planted on fresh mine spoil in July 1993: *Albizia lebeck*, *Acacia catechu*, *Azadirachta indica*, *Dalbergia sissoo*, *Gmelina arborea*, *Phyllanthus emblica*, *Pongamia pinnata*, *Tectona grandis* and *Terminalia bellirica*. In nursery, seedlings were raised using 5 cm top forest soil in polyethylene bags. The seedlings were watered regularly once a fortnight. No nutrient supply was done to seedlings at nursery stage. The seedlings were planted in 20 × 20 m plots with a spacing of 2 × 2 m. Since all the tree species are native and natural components of adjacent tropical dry deciduous forest, they were chosen for revegetation of coal mine spoil. Fertilizer treatment was applied annually in July during 1994–96, and consisted of a full and a half doses of NPK, and a control without fertilizer amendment. Full-dose fertilizer treatment was 60 kg ha<sup>-1</sup> N as urea, 30 kg ha<sup>-1</sup> P as single super-phosphate and 40 kg ha<sup>-1</sup> K as muriate of potash. Urea and single super-phosphate were applied in granular form and muriate of potash in powder form. Three replicate plots were maintained for each treatment. The mature and green leaves were sampled in the first week of September 1996 and senesced leaves were sampled in the first week of December 1996. Senescent 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 middle of the crown in each treatment, i.e. control, half and full doses of NPK treatment for each species from three rep-

licate plots. The samples from five individuals were mixed for each replicate plot and brought to laboratory in polyethylene bags. Blocks of 1 cm<sup>2</sup> were cut, oven-dried at 65°C, weighed and ground. Total N was determined following semi-micro-Kjeldahl procedure [25] and total P was analyzed after tri-acid digestion (a mixture of HClO<sub>4</sub>, HNO<sub>3</sub> and H<sub>2</sub>SO<sub>4</sub> at 1:5:1) following phosphomolybdic acid blue colour method [25]. The nutrient mass was computed as the product obtained by multiplying dry mass (cm<sup>2</sup>) of leaves by their nutrient concentration [9]. Per cent resorption of nutrients was calculated using the formula:  $100 \times (\text{nutrient mass cm}^{-2} \text{ in mature leaf} - \text{nutrient mass cm}^{-2} \text{ in senesced leaf}) \div (\text{nutrient mass cm}^{-2} \text{ in mature leaf})$ .

The relationship between leaf nutrient concentrations and resorption efficiencies was explored through regression analysis. Differences between treatment means were tested for significance through a two-tailed Student's *t*-test.

### 3. Results

#### 3.1. Foliar N and P concentrations in mature leaf

The foliar N concentration in mature leaf was greater in leguminous tree species than in nonleguminous tree species while no clear trend emerged for foliar P concentration. In legumes, the foliar N concentration ranged between 1.95 and 2.19%, whereas it ranged between 1.01 and 1.82% in nonlegumes (Table I). The foliar P concentration in legumes ranged between 0.134 and 0.160%, whereas the same for nonlegumes ranged between 0.103 and 0.165% (Table II).

#### 3.2. Foliar N and P concentrations in senesced leaf

The foliar N concentration in senesced leaf was also greater in leguminous species than in nonleguminous species, whereas the P concentration was greater in nonleguminous species than in leguminous species (Tables I and II). In legumes, the N concentration ranged between 0.97 and 1.30%, and between 0.47 and 0.81% in nonlegumes (Table I). The P concentration in legumes ranged between 0.049 and 0.058% and between 0.067 and 0.084% in nonlegumes (Table II).

#### 3.3. Resorbed N and P pools

No consistent trend emerged for resorbed N and P pools between leguminous and nonleguminous tree species (Tables I and II). In legumes, the resorbed N pool ranged between 48.95 and 107.48 mg cm<sup>-2</sup>, whereas it ranged between 61.25 and 100.75 mg cm<sup>-2</sup> in nonlegumes (Table I). The resorbed P pool in legumes ranged between 3.94 and 10.56 mg cm<sup>-2</sup>, and 4.23 and 8.66 mg cm<sup>-2</sup> in nonlegumes (Table II).

#### 3.4. N and P resorption efficiencies

The N resorption efficiency was greater in nonleguminous species than in leguminous species while no consistent trend emerged for P resorption efficiency between legumes and nonlegumes as two nonlegumes *A. indica* and *G. arborea* have resorbed greater amount of





P (Tables I and II). N resorption efficiency ranged between 54.67 and 58.72% in legumes and between 61.25 and 71% in nonlegumes (Table I). The P resorption efficiency ranged between 70.08 and 72.17% in legumes, and between 46.03 and 67.75% in nonlegumes (Table II).

### 3.5. Effect of fertilization on nutrient concentration, resorption and resorption efficiencies

The foliar N and P concentration in mature and senesced leaves increased from control to full NPK treatment in both groups of tree species (Tables I and II). The effect of fertilization on foliar N concentration of mature leaf was greater in nonleguminous species than in leguminous species, while that on foliar P concentration of mature leaf was greater in leguminous species than in nonleguminous ones (Tables I and II).

The resorbed N pool did not show any consistent trend whereas resorbed P pool exhibited increasing trend from control to full NPK treatment in both leguminous and nonleguminous tree species (Tables I and II).

The N and P resorption efficiencies decreased from control to full NPK treatment in both groups of tree species (Tables I and II). The effect of fertilization was not significant on N resorption efficiency in any leguminous species, whereas the same on P resorption efficiency was significant ( $P < 0.05$ ) in all leguminous tree species except *P. pinnata*. The effect of full NPK treatment on N resorption efficiency was significant ( $P < 0.05$ ) in all the nonleguminous species, while that of half NPK treatment was only significant in *P. emblica* and *T. grandis* (Table I). The effect of fertilization on P resorption efficiency was only significant in *A. indica* (Table II).

### 3.6. Relationship between leaf nutrient status and nutrient resorption efficiencies

Negative relationships existed between foliar N concentration and N resorption ( $r^2 = 0.89$ ), and foliar P concentration and P resorption ( $r^2 = 0.89$ ) in the leguminous species. Meanwhile, in the nonleguminous species, positive relationships were established between foliar N concentration and N resorption ( $r^2 = 0.46$ ), and foliar P concentration and P resorption ( $r^2 = 0.57$ ).

Irrespective of species and treatments, no significant relationship between foliar N concentration and N resorption was observed. However, significant positive ( $r^2 = 0.36$ ) relationship existed between foliar P concentration and P resorption.

## 4. Discussion

The study indicates that fertilization decreases N and P resorption efficiencies in all tree species. In fertilized plots, compared to control, the N resorption efficiency decreased from 1.09 to 8.82%, while that of P decreased from 1.69 to 9.71%. This is in conformity with the findings that the nutrient resorption is less efficient in plants of fertilized plots [7, 26]. The reduced N and P resorption efficiencies in fertilized plots demonstrates greater N and P return to soil which would enhance reclamation process due to increased soil fertility. It was observed that plants on fertile soil translocated more N and P out of leaves compared to those on infertile soils; however, resorption efficiency was not affected [20]. In the present study, resorbed N pool was not affected, but the resorbed P pool increased due to fertiliza-

tion. Some studies suggest that when plants in the field are fertilized, nutrient resorption efficiency remains unchanged [12, 16, 27]. Several studies suggest greater nutrient resorption efficiencies in plants of low nutrient status [4–7, 10], while others suggest that plants of greater nutrient status resorb larger proportion of the N and P than plants with low nutrient status [13, 28–30]. It has been argued that plants of low nutrient status should have low resorption efficiency, because most leaf N would be structurally bound and less accessible to hydrolysis and resorption [12]. However, it has been found that the proposed mechanism is correct but the ecological pattern is reversed [10]. It was reported that plants growing on infertile site with low N concentration had high proportion of soluble N [10]. Similarly, many other species have been reported to have a high proportion of soluble N when grown at low N availability [31–33].

Approximately half of the N and P contents of leaves is resorbed during senescence and is used to support further plant growth [2, 34]. In the present study, in control treatment, N and P resorption efficiencies varied between 55–71% and 46–72%, respectively. This greater and narrow range of resorption efficiency for both N and P even in younger trees clearly suggests that plants growing on infertile habitats fulfil their nutrient requirements through increased internal cycling of nutrients. Resorption efficiencies of 17–73% for N, and 41–82% for P are reported in six Brazilian rain forest tree species [35]. In evergreen Mediterranean species the N resorption efficiency has been reportedly better (31–82%) and P resorption efficiency was on the lower side (21–71%) [10]. The proportion of nutrients resorbed from senescing leaves ranges from 0–79% for N and 0–90% for P with average value of 52 and 43%, respectively [11]. Overall, N and P resorption efficiencies range from 0 to 80% among species and environmental conditions [2, 36]. Higher N resorption efficiency is, however, reported in deciduous shrubs and trees than in the evergreen ones [34]. All the species in the present investigation were deciduous showing high resorption efficiencies for both N and P. Half or more of the maximum N and P contents of a deciduous leaf is translocated to other plant parts before leaf abscission [11, 15, 28, 37–40]. A greater percentage of N resorption has been reported from leaves of deciduous species than evergreen species [9], which is an ecological need to compensate for shorter life span of leaves and to produce heavy leaf crop annually [41].

In all the five nonleguminous species, the N resorption efficiency was greater than P resorption efficiency. The non-N<sub>2</sub>-fixing species resorb N to a greater extent than P, from senescing leaves [11]. All the four leguminous species generally resorbed less nitrogen than nonlegumes, which may be due to their N<sub>2</sub>-fixing attribute. Plants with N<sub>2</sub>-fixing symbionts have low N resorption efficiency [4, 31, 42–45]. On the other hand, all the leguminous species had high efficiency for P resorption. Several studies suggest a greater P resorption efficiency in N<sub>2</sub>-fixing plants than non-N<sub>2</sub>-fixing plants [11, 31].

The greater N and P resorption efficiencies in *A. indica* and *G. arborea* suggest that fast-growing species have more efficient nutrient resorption. In these two species, probably the actively growing foliage serves as sink for nutrients resorbed out of senescing leaves [13, 46–48].

The negative relationships between foliar N concentration and N resorption, and foliar P concentration and P resorption in leguminous species suggest that with increasing N and P

concentration, N and P resorption efficiencies decrease. Whereas, in non-leguminous species the positive relationships between foliar N concentration and N resorption, and foliar P concentration and P resorption suggests that with increasing N and P concentrations the N and P resorption efficiencies increase. Thus, the leguminous and nonleguminous species behaved in opposite manner in terms of relationship between leaf nutrient status and leaf nutrient resorption.

The N resorption is independent of foliar N status, but P resorption efficiency increased with increasing foliar P concentration. These observations are in contrast to another study where a positive and significant relationship was observed between N concentration and N resorption but none between P concentration and P resorption [11]. In a review study, no relationship was found between leaf nutrient status and leaf nutrient resorption [34].

The positive relationship of leaf N and P concentrations with respective resorption efficiencies, however, is due to the existence of two groups of species among nonlegumes. One group comprises *P. emblica*, *T. grandis* and *T. bellirica* that had low leaf N and P concentrations and low resorption efficiencies, while the other group comprising *A. indica* and *G. arborea* had high N and P concentrations and high resorption efficiencies. Therefore, the shape of relationship would depend on the diversity of species examined.

## 5. Conclusions

It is concluded that N and P resorption efficiency drops with increase in habitat fertility. The leguminous and nonleguminous species potentially differ in terms of N resorption efficiency. The nonlegumes had a higher efficiency for N resorption than legumes. However, no distinct trend emerged for P resorption efficiency between both groups of trees. The study also suggests that fertilization is potentially a sound approach for reclamation of mine spoil, as the fertilized trees leave more N and P in their senesced leaves due to reduced resorption efficiencies than unfertilized trees. The leaf litter with more nutrients ameliorate the spoil fertility thus accelerating the process of succession which culminates into a self-sustaining community.

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