NUTRIENT STATUS OF *POPULUS DELTOIDES* AND *TERMINALIA ARJUNA* RAISED ON SODIC LAND

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SRIVASTAVA, N. SINGH, B. & BEHL, H. M. 2004. Nutrient status of *Populus deltoides* and *Terminalia arjuna* raised on sodic land. New forest resources are being created on wastelands to increase the forest cover as well as to fulfil the needs of the growing Indian population. Such an attempt was made on a partially reclaimed sodic soil at Lucknow in north India using two potential species of diverse nature and habitat. In this study the fast growing exotic *Populus deltoides* and the slow growing indigenous *Terminalia arjuna* were examined for their nutrient regimes, seasonal variations and degree of nutrient retranslocation during senescence. Leaf and twig samples of each species, collected from May till December from 25 trees having diameters at breast height of 10 to 12 cm, were analysed and simulated. *Populus deltoides* showed higher concentrations of N and K, particularly in leaf component whereas *T. arjuna* had relatively high concentrations of Na, Fe and Mg. Concentrations of P and Ca were almost similar in both species. P, Ca and Mg in both species showed similar seasonal patterns unlike that of N, K, Na and Fe. N, P, K and Fe decreased from spring to winter while Ca, Mg and Na increased during the same period. Foliar nutrient contents were always greater than that in twigs in both species. Most of the nutrients recorded highest concentrations in the rainy season which is the period of maximum nutrient stress when extension growth of leaf is completed. In general the nutrient retranslocation during senescence was greater in *P. deltoides* than in *T. arjuna*.

Key words: Nutrient concentration – sodic soils – seasonal variations – retranslocation

SRIVASTAVA, N. SINGH, B. & BEHL, H. M. 2004. Status nutrien *Populus deltoides* dan *Terminalia arjuna* yang ditanam di tanah sodik. Sumber hutan yang baru kini ditanam di atas tanah tandus bagi meningkatkan litupan hutan serta untuk memenuhi keperluan penduduk India yang semakin bertambah. Usaha ini turut dijalankan terhadap tanih sodik di Lucknow, utara India yang ditebus guna sebahagiannya dengan menggunakan dua spesies yang berbeza tabiat dan habitat. Dalam kajian ini, pokok eksotik yang tumbuh cepat iaitu *Populus deltoides* dan pokok asli yang tumbuh lambat iaitu *Terminalia arjuna* diselidik julat nutriennya, variasi musim dan tahap translokasi semula ketika kesenesenan. Sampel daun dan ranting setiap spesies dikumpul dari bulan Mei hingga Disember daripada 25 batang pokok yang berdiameter pada aras dada sebanyak 10–12 cm lalu dianalisis dan disimulasi. *Populus deltoides* menunjukkan kepekatan N dan K yang lebih tinggi terutamanya dalam komponen daun sementara *T. arjuna* mempunyai kepekatan Na, Fe dan Mg yang agak tinggi. Kepekatan P dan Ca hampir sama dalam kedua-dua spesies. P, Ca dan Mg dalam kedua-dua spesies menunjukkan corak bermusim yang serupa. Ini berbeza dengan N, K, Na dan Fe. Kepekatan N, P, K dan Fe menurun dari musim bunga ke musim sejuk sementara kepekatan Ca, Mg dan Na bertambah pada tempoh tersebut. Dalam kedua-dua spesies, kandungan nutrien daun sentiasa lebih tinggi

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berbanding ranting. Kebanyakan nutrien mencatat kepekatan tertinggi pada musim hujan yang merupakan tempoh tekanan nutrien maksimum apabila pertumbuhan tambahan daun selesai. Secara umumnya, translokasi semula ketika kesenesenan lebih tinggi dalam *P. deltoides* berbanding *T. arjuna*.

Introduction

Foliar analysis is often used to estimate the potential of trees to utilise soil nutrients. However, concentration of foliar nutrients varies considerably with season, site, position of crown and size and age of leaf as well as of trees (Bowen & Nambiar 1984). Leaf nutrients vary with season in response to the growth corresponding to temperature, soil moisture and ionic equilibrium in soil solution. Seasonal variability is often larger than intraspecific variability (Oliveira *et. al.* 1996). Seasonal variations in foliar nutrient levels are considered to be more important than fertiliser trials in estimating the nutrient requirement of a species (Knight 1978). Besides, the patterns of different nutrient elements may differ from one another during the year and a suitable time for their measurements could only be ascertained if the seasonal trend of each element is known.

Nutrient requirement of a species is determined by its growth rate on a specific site. A species grown on poor site with low fertility show different nutrient status compared with the same species grown on fertile site, although both sites may experience similar seasonal trend (Drechsel & Zech 1991). On the other hand, when two species of different nutrient demands are grown on a particular site, they may show similar seasonal variations.

Thus, a study of two species, namely, *Populus deltoides* and *Terminalia arjuna* that differ in growth habit, origin and nutrient demands was undertaken to compare the nutrient concentrations in their leaves and twigs. Results were then used to ascertain the range of seasonal fluctuation, stable period of maximum demand, nutrient retranslocation during senescence and the response of trees to low fertility of sodic soils. *Terminalia arjuna* is an indigenous slow-growing species with low nutrient demand while *Populus deltoides* is a fast-growing exotic with high nutrient demand. It is believed that adjustment in nutrient cycling may be one way for these species to tolerate the stress of sodium toxicity.

Materials and methods

A field trial with *P. deltoides* and *T. arjuna* was raised at Banthra, Lucknow in north India (26° 45' N and 80° 53' E). The soil at the site is degraded sodic soil with low fertility and low water permeability. The soil is silty clay loam with pH of 8.5 to 8.7. Electrical conductivity (EC_2) of the soil under trial plantation varied from 0.27 to 0.38 dSm^{-1}. Organic carbon was estimated to be around 0.2%. The bulk density was 1.3 to 1.5 g cm^{-3} in the upper strata of soil (0 to 30 cm). Plantations were established in 1985 in four replicated plots, each of 0.12 ha size comprising 141 plants. Due to inhospitable condition of the soils, saplings were planted in excavated pits of 1 m^3 size filled with a mixture of soil, sand and compost manure (1:1:1) for proper establishment. The plantations were not fertilised subsequently but were irrigated from time to time. The site receives an average annual rainfall of 950 mm of which about 80% occurs in the rainy season from July till September. There was a marked fluctuation in seasonal temperature with a very high summer temperature. The mean temperature declined markedly from summer (May till June) to winter (December till January), with a mean maximum and minimum of 32 and 18 °C respectively.

The plantations were 10 years old when samples of leaves and twigs were collected. Samples of leaves from both of the species were collected in May till December. Twenty five healthy trees with diameters ranging from 10 to 12 cm were marked for sampling in each plantation. The *T. arjuna* trees were 8 to 9 m tall while *P. deltoides* trees were to 11 to 13 m. In order to alleviate leaf age effect, only mature, fully grown green leaves were sampled for analysis. Consequently, no sampling was carried out in March till April, which is a period of leaf emergence for both species.

Leaf samples were analysed for N, P, K, Na, Ca, Mg and Fe. Oven-dried samples were ground in a Willey mill (< 0.1-mm mesh) and dried at 70 °C. N was estimated by micro Kjeldahl method using Kjeltec Auto 1030 Analyser (Model 8903, Tecator AB, Hoganas, Sweden). Ca, Na and K were analysed by flame photometer (Systronic flame photometer, Mediflame, model 127) after digesting 1 g sample in a di-acid mixture of HNO_3 and $HClO_4$ (10:1) following Jackson (1958). P was estimated colorimetrically by the vanadomolybdo phosphoric acid system (Kalra & Manynard 1991). Mg and Fe were measured by atomic absorption spectrophotometer (Perkin Elmer 5100 PC, USA).

Statistical trend analysis for the various nutrient requirement was derived from monthly data using SYSTAT 9.0 SPSS software program.

Results

At the time of sampling, plantations of *P. deltoides* and *T. arjuna* had aboveground biomass of 32 and 11 Mg ha^{-1} respectively. Temporal variations in N, P, K, Ca, Mg, Na and Fe were observed in the foliage and twigs of *P. deltoides* and *T. arjuna*. Trends of each element, their peak levels as well as similarities or differences between the two species are described below.

N requirement of poplar appears to be relatively high. Foliar N levels in *P. deltoides* declined from summer to winter (Figure 1(a)). However, in *T. arjuna* the concentration of foliar N remained almost stable during summer (May–June) and rainy season (July–September) but eventually decreased in autumn (October–November) (Figure 1(b)). Foliar N in *T. arjuna* peaked once in June and once in September. N levels in twig increased logarithmically in poplar but linearly in *T. arjuna* from summer to winter.

Both species showed almost similar P concentrations as well as seasonal patterns (Figures 1(c) and (d)). There was a sharp decrease of P in foliage and twig in the early monsoon season (July). The percentage of P then increased in late monsoon (September) and in autumn season but decreased again in winter (December).

K concentrations and seasonal variations in the leaves of the two species had contrasting patterns. K concentration in leaves of poplar (Figure 1(e)) was significantly higher compared with *T. arjuna* (Figure 1(f)). K concentration in poplar leaves decreased exponentially from summer to winter, while in *T. arjuna* leaves, it increased exponentially.

Concentrations of Ca in leaves as well as in twigs was nearly similar in both of the species. The temporal pattern had a characteristic quadratic parabolic shape (Figure 1(g) and (h)). Maximum percentage of Ca was observed in September for poplar and in October for *T. arjuna*. Both of the species showed declines in Ca concentrations in winter.

Terminalia arjuna had higher concentration of Na compared with *P. deltoides*. However, there were wide variations among the replicates of both species at each sampling interval (Figures 1(i) and (j)). Na levels in the leaves of both species

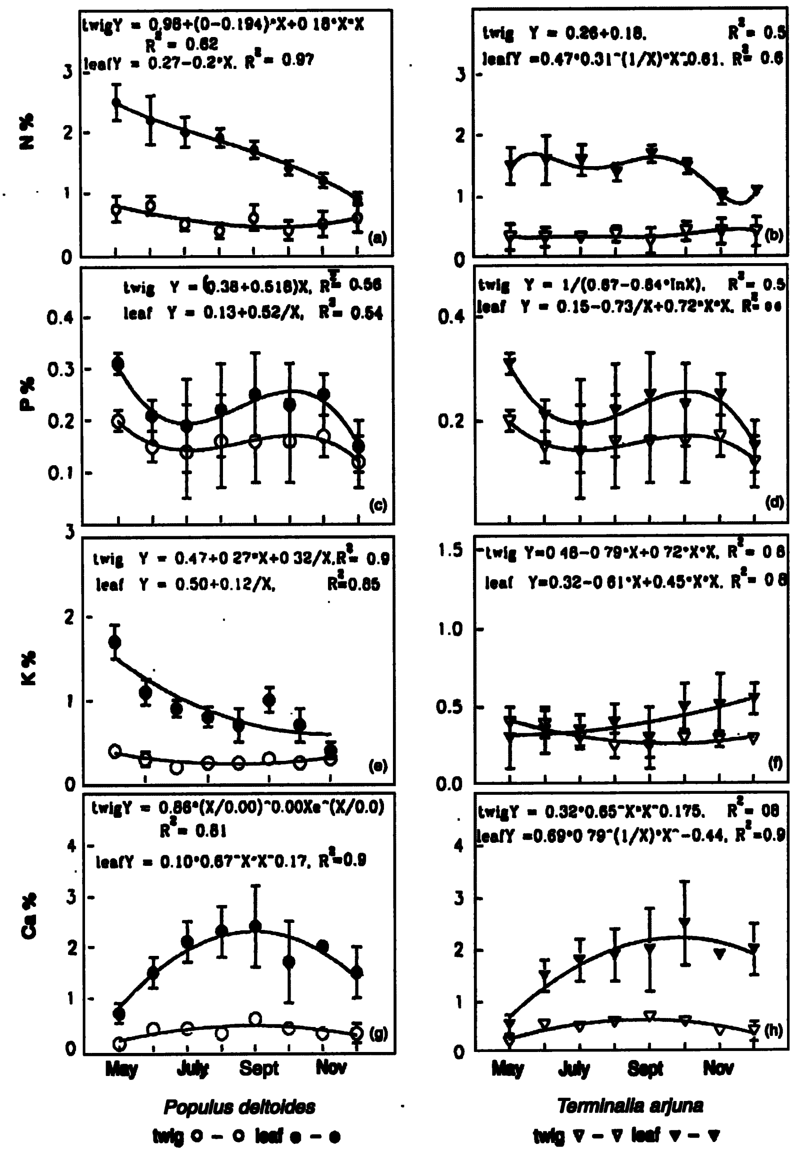

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Figure 1 (continued)

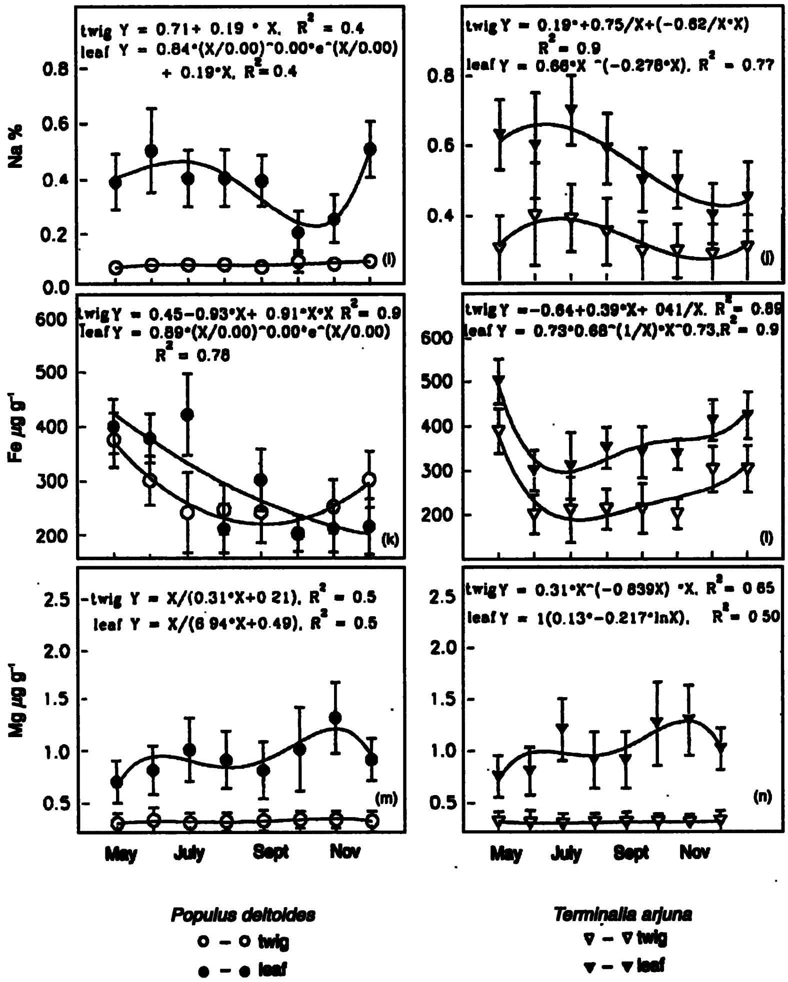

Figure 1 Trend analysis of seasonal variations in nutrient concentration of leaves and twigs of *Populus deltoides* and *Terminalia arjuna* raised on sodic soils in north India

decreased in autumn, but the values increased in winter. The increase in Na concentration in winter was very high in *P. deltoides* but was relatively less pronounced in *T. arjuna*. Na concentrations in twigs of poplar were relatively uniform throughout the entire period of study. In contrast twigs of *T. arjuna* showed Na fluctuations similar to those observed for its leaves.

Fe concentration in poplar leaves decreased exponentially from May till December (Figure 1(k)). On the other hand, Fe concentration in *T. arjuna* decreased in summer and later increased slightly during rainy and winter seasons. Twigs had relatively lower levels of Fe compared with leaves in both poplar and *T. arjuna*. Generally Fe concentrations in both species were lowest in the rainy season (July till September).

Temporal variations of Mg were also similar in the two species (Figures 1(m) and (n)). Both of the species showed bimodal peaks in Mg concentrations of leaf during summer and autumn periods.

Discussion

This study showed that major nutrient elements in leaf and twig had different concentrations during various periods of the year. Consequently one time sampling in a particular month or season was unable to provide adequate information about the nutrient status of the trees. These variations correspond to growth period of leaf in the tree. It was generally found that concentrations of most foliar nutrients decreased at the termination of growing season at the end of winter due to variable degrees of retranslocation prior to senescence. This trend, particularly that of N, P and K, has been reported for other trees such as *Prunus, Acer, Betula* and several hardwood tree species (Lea *et al.* 1979). Since the plantations were grown on sodic soils, poplar leaves, especially, accumulated Na in the dormant season (winter), whereas in the active growing season, Na concentration was reduced due to increase in weight and surface area of leaf which remained constant after maturity.

The nutrients in this study showed varying trends during the entire growth period. The dormant season showed decreases for some elements but increases for others. Therefore, the best time to characterise the nutrients seems to be in the rainy months when the trees are under partial stress due to high growth rate and less availability of nutrients. Maximum growth rate in the season correlates with maximum nutrient demand. However, water logging or soil saturation in sodic soil impedes the optimum uptake of nutrients due to biological stress particularly root respiration. During rainy season the extension growth is completed. Thus, many workers collect leaf samples for nutrient analysis at the beginning or in the middle of rainy season (Drechsel & Zech 1991).

This study showed that nutrient retranslocations were greater in poplar than *T. arjuna*. This can be attributed to the faster growth of the former and, thus, its higher nutrient requirements. Although we excluded the juvenile leaves in our samples, age effect could not be neutralised completely even after taking leaves of similar size and weight.

Ca is a non-mobile element and its concentration should not decrease at the termination of the growing season. However, this study showed the contrast and reasons for this could be due to stress and low solubility of Ca in sodic soils. Foliar nutrient concentrations are directly related to ionic equilibrium in the soil-root interphase. Sodic soils at high pH with low Ca/Na ratio create nutritional imbalance and engender adverse physiological effects on plants (Maas & Hoffman 1977). During rainy season, Na concentration in soil solutions becomes diluted and availability of Ca to the plants increases. On the other hand, in winter the soil is dry and Ca is precipitated in insoluble forms, thus becoming less available to the plants. Under this situation availability of Na increases in soil. Therefore, a low Ca/Na ratio is generally noticed in uptake solutions (Grieve & Mass 1988). This phenomenon may have evolved to a greater extent in *P. deltoides* which is more susceptible to Na toxicity compared with *T. arjuna*.

It is concluded that foliar analysis alone is unable to fully explain nutritional relations and disorders in forest plantations. Nutrient requirement of trees can be assessed from the nutrient uptake and nutrient use efficiency of the species, periodical monitoring of soil nutrients and bioassays. Foliar analysis alone can provide some indications about the nutrient deficiency or toxicity of the soil as well as the nutrient requirements of the species. The fast growth of *P. deltoides* indicates a relatively high concentration in foliage nutrient. Although the observed values did not appear to be limiting for plant growth, biomass production in poplar was low at this site compared with well drained fertile soils (Tandon *et al.* 1991). Exchangeable sodium in the sodic soils determines the dynamics of nutrient uptake and thereby, plant productivity. *Terminalia arjuna* is a relatively slow growing species but has been shown to have better tolerance for soil sodicity. This has been confirmed in sodicity studies with pot culture experiments (Singh *et al.* 1992). Results of our study concur with this finding. The two species studied here did not have a uniform pattern for concentrations of N, K, Fe and Na in their leaves and twigs. However, the patterns for P, Ca and Mg were similar. High nutrient requirement of the fast growing *P. deltoides* on this degraded soil site was accomplished by an internal adjustment in the fluxes of nutrient cycling. Such type of tight nutrient cycling tends to restrict the nutrient return from plant to soil through litterfall leading to a relatively high degree of nutrient retranslocation during senescence. In contrast, *T. arjuna* recycled the nutrients more efficiently through litterfall.

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