# Nutrient status of natural and healthy sissoo forest and declining plantation sissoo forest (*Dalbergia sissoo*, Roxb.) in Nepal

**S. P. Sah[1], P. K. Jha[2], N. Lamersdorf[1]**

[1]*Institute of Soil Science and Forest Nutrition, Göttingen University, Göttingen, Germany*
[2]*HMG/DANIDA Tree Improvement Programme, Regional Office, Hetauda, Nepal*

**ABSTRACT**: Sissoo (*Dalbergia sissoo*, Roxb.) is a nitrogen fixing leguminous tree species with natural habitat in the lowland region of Nepal called Terai up to an altitude of 1,000 m. For the last few years, this economically important tree species has been dying rapidly in the plantation forests. On the contrary, its status in the natural forest in riverine areas has been unknown yet. The paper compares the nutrient status of natural and healthy sissoo forest with declining plantation sissoo one. It is evident from this study that both stands do not differ very much with respect to their soil and plant nutrients. Therefore it was concluded that the waterlogging of soil was the main factor responsible for the decline of plantation sissoo forest.

**Keywords**: sissoo forest; *Dalbergia sissoo;* health status; declining plantations; nutrients; soil texture; waterlogging; Nepal

The accelerated rate of deforestation in Nepal in the past has resulted in severe forest degradation in the country. Fortunately, the fast-growing tree species present in the country have become very popular for their plantation to overcome this problem. One of such fast-growing tree species is sissoo (*Dalbergia sissoo,* Roxb.). Sissoo is a nitrogen fixing leguminous multipurpose plant species, occurring along riverbanks in the lowland region of Nepal up to an altitude of 1,000 m. It is an important reforestation species on the plains (known as Terai). This plant species occurs naturally in the riverine sal (*Shorea robusta*, Gaertn.) forest. It springs up on land slips and at other places where fresh soil is exposed but avoids stiff clay and waterlogging. It thrives in sandy-loam soils with good drainage. It is a deciduous tree species, growing to a height of nearly 30 m at favourable sites. This species, due to its fast-growing nature, quality timber, easy propagation, drought resistance etc., has been the most favourable plantation species for the private as well as governmental sector for the last 3 decades. Due to its popularity, it has been planted almost everywhere in local communities such as agricultural fields, canal sides, pond banks, waste-lands etc. The basic reason behind it has been to take hasty benefits from this multipurpose species for fuel wood, fodder and timber because the income from agricultural crops has often been found to be comparatively slower.

Unfortunately, for the past few years (5–6 years), sissoo has been declining rapidly. However, its status in the natural forest has not been investigated and it is still unknown. Therefore, a natural and healthy sissoo forest was also selected in this study. Our field visits to various sites revealed a serious threat to the sissoo plantation in Nepalese Terai. Sissoo trees of varying age are dying. The symptoms are also varied. Parajuli et al. (1999) reported a decline due to the occurrence of fungi such as *Fusarium* sp. and *Gandoderma lucidium* in the roots and stems of diseased sissoo trees. However, pathogens are only the secondary cause of decline, not the primary one (Manion 1981). In a plantation site study Sah et al. (1999) reported the soil texture as the main reason behind this phenomenon. Whatever the primary causes of decline are present, they all ultimately lead to the disruption of nutrient cycles of forest ecosystems. Nutrient distribution data provide useful information in assessing the significance of element physiological processes in the trees that effect their overall growth and vitality. For this purpose, this paper comprises a comparative study of a declining plantation site (Tilkane) and a natural and healthy sissoo site (Hetauda). The objective of this paper is to assess the differences in nutrient distribution of the different components of sissoo forest ecosystems in order to identify possible causal factors involved in sissoo decline at the Tilkane site.

## MATERIAL AND METHODS

### EXPERIMENTAL SITES

The kingdom of Nepal occupies a large part of the Central Himalayas and their foothills. Topographically,

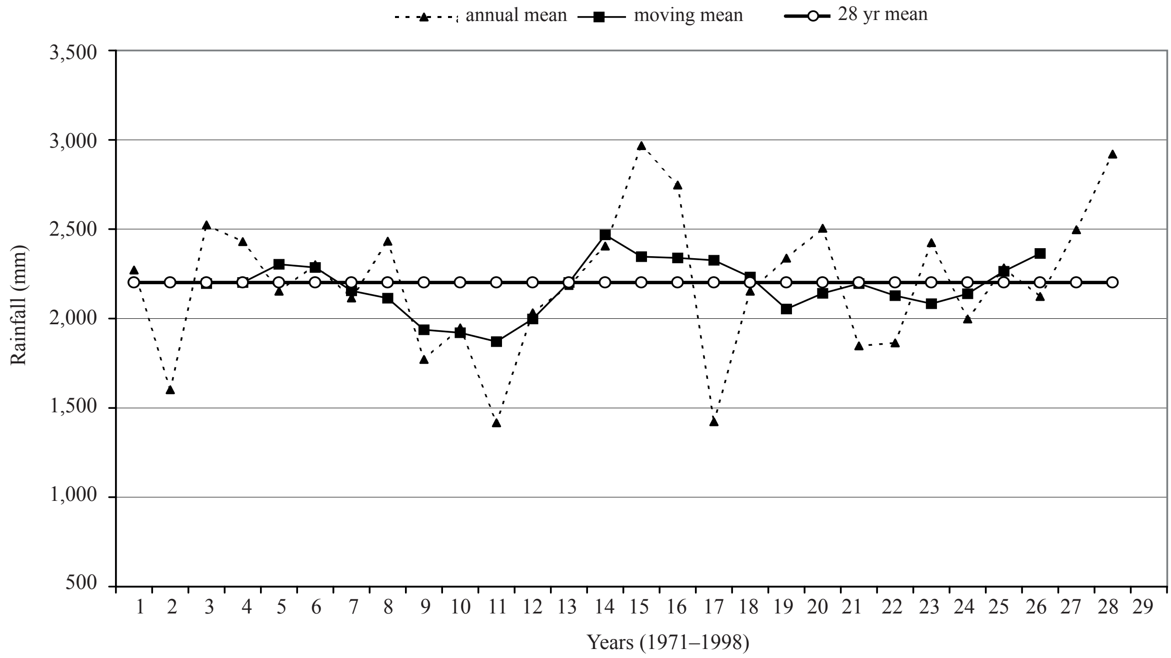


Fig. 1. Annual rainfall variations of Hetauda (source: HMG of Nepal)

Nepal can be divided into 3 main parallel zones: i. Terai, ii. Hills and iii. High Himalayas. Terai is the name (in Nepalese language) given to plains consisting of alluvial depositions. The climate of Terai is subtropical to tropical, mainly attributed to the influence of the monsoon climate.

Two sites, plantation stand (Tilkane) and natural stand (Hetauda), were selected for this study. The Tilkane site is situated close to Royal Chitwan National Park. The Hetauda site lies 60 km east of Tilkane. The trees at Tilkane show declining symptoms whereas the trees at Hetauda are healthy. Both sites have similar climatic characteristics (Figs. 1–3). The average annual rainfall (typical monsoon rainfall) of each site is almost the same (1,200–1,500 mm). The annual minimum and maximum temperatures are also identical at both sites ranging from 5°C to 10°C and 28°C to 35°C, respectively. The soil at the Hetauda site is calcareous and sandy whereas it is clayey and has a high content of raw humus at the Tilkane site. The fine root system at the Tilkane site is superficial and consists mostly of fine roots in the upper soil layer (10 cm depth) whereas at the Hetauda site the root system penetrates to a deeper soil depth of 50 cm.

The visual observation indicated a well drained soil at the Hetauda site whereas the soil of the Tilkane site was found waterlogged.

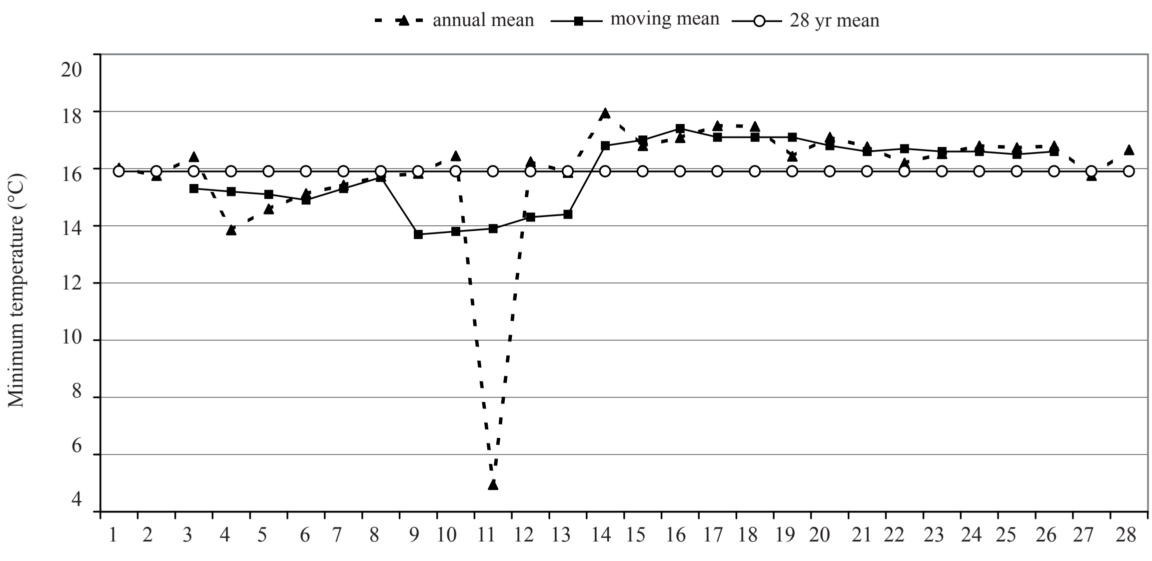


Fig. 2. Annual minimum temperature variations of Hetauda (source: HMG of Nepal)

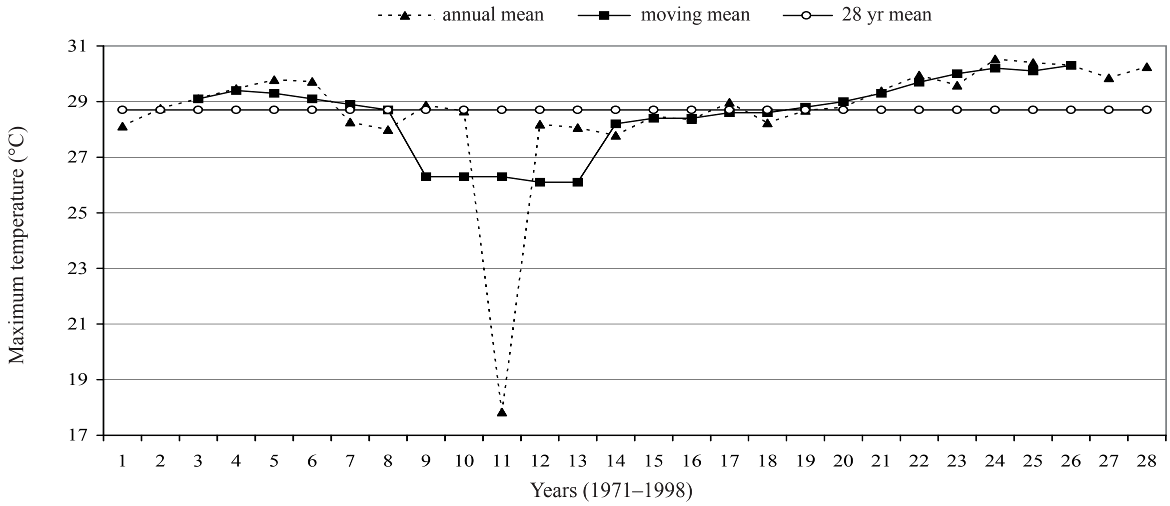


Fig. 3. Annual maximum temperature variations of Hetauda (source: HMG of Nepal)

## SAMPLING AND LABORATORY ANALYSIS

The sampling of soil and plants took place in the month of September, 1999. The following methods of sampling were adopted in this study.

### Soil samples

In each stand, a quadrate of 20 × 20 m was set up and the soil and plant sampling was carried out in the quadrate. The soils from both stands were collected from top (0–5 cm) and subsoil layers (5–50 cm). The samples were extracted from a soil auger. 10 samples from each stand were collected randomly and bulked to 2 samples for the laboratory analysis. The collected soil samples were analysed for their physical and chemical properties. The physical soil properties were moisture content, water holding capacity (WHC), soil density and porosity, soil colour and soil texture. Moisture content was determined by the oven dry weight method. WHC was estimated from the water saturation of soil. For soil density, an iron cylinder (diameter of 20 cm) was used to extract the soil sample, and soil porosity was calculated from the soil density. The soil colour was determined on the Munsell Colours Chart. The soil texture was estimated by the sodium pyrophosphate pre-treatment method (DIN 1993). The cation exchange capacity (CEC) was determined according to MEIWES et al. (1984). 2.5 mg of sieved and dried (40°C) soil was percolated for 4 h with 100 ml 1N $NH_4Cl$. Cations ($Na^+$, $K^+$, $Ca^{2+}$, $Mg^{2+}$ = Mb, basic cations; $H^+$, $Al^{3+}$, $Fe^{3+}$, $Mn^{2+}$ = Ma, acid cations) in the percolate were determined by the AAS technique (Varian Spectra 300A) and the $H^+$ activity by using a glass electrode. Due to the existence of free carbonates in the Hetauda samples (tested by adding HCl to field samples) and the application of $NH_4Cl$ (pH about 4.7) the amount of exchangeable Mb-cations and thus the CEC may be overestimated for that site.

### Plant samples

The different plant parts such as green leaf, leaf litter, bark, stem wood, root etc. were sampled from 3 trees. The sample trees were selected at random in the above-mentioned quadrate. The plant samples were analysed for their different nutrients such as C, N, cations (both Mb and Ma) and anions ($PO_4^-$ and $SO_4^{2-}$). Plant material was digested with $HNO_3$ according to HEINRICHS et al. (1986). 200 mg of dried (60°C) and finely ground plant material was oxidised with 2 ml of $HNO_3$ (65%) at 180°C in a sealed teflon vessel for 10 h, subsequently filtered and transferred to a 100ml volumetric flask. Element analysis was carried out with an ICP-AES instrument (Spectro Analytical Instruments/Kleve).

Total N ($N_t$) and C ($C_t$) were determined for both the plant and soil material by a C/N-analyser (CHN-O-Rapide, VarioEL, Elementar, Germany). All given element concentrations are related to the absolute dry weight (dry weight, 105°C).

# RESULTS AND DISCUSSION

## THE CHARACTERISTICS OF SOILS

Our visual observation indicated that the healthy stand of Hetauda, which is of riverine habitat, has the soil with good drainage whereas the diseased stand of Tilkane shows a poor water drainage from the soil. With respect to their physical properties of soil, both stands do not differ very much in general, with the exception of soil texture. Hetauda sissoo stand has sandy soil both in the top layer and in subsoil whereas the Tilkane sissoo stand has black coloured sandy-loam soil with a large amount of organic matter, both in the top and subsoil layers (Table 1). The moisture content, water holding capacity, density and porosity of the soil are identical.

The chemical properties of soils of both stands, however, differ greatly (Table 2). The Hetauda site, having calcareous soils, has a higher soil pH (7.15) whereas the soil of the Tilkane site has a lower pH (5.81). As for the exchangeable cations, Ca content (237.5 $\mu mol_c/g$) in the soil of the Hetauda sissoo stand, as expected, is higher than in the soil of the Tilkane sissoo stand (Ca = 122.3 $\mu mol_c/g$).

Table 1. Physical properties of soils at the Hetauda and Tilkane sissoo forest sites ($n$ = 5; ± standard deviation of the mean)

| Soil depths (cm) | Moisture content (%) | WHC (%) | Density (g/cm$^3$) | Porosity (%) | Colour (Munsel Colour Chart) | Texture |
|---|---|---|---|---|---|---|
| **1. Hetauda (healthy)** | | | | | | |
| 0–5 | 39 (± 5) | 60 (± 5) | 1.43 (± 0.20) | 46.0 | 2.5Y4/2 | Sandy |
| 5–50 | 26 (± 4) | 40 (± 8) | – | – | 10YR3/2 | Sandy |
| **2. Tilkane (declining)** | | | | | | |
| 0–20 | 34 (± 7) | 50 (± 10) | 1.40 (± 0.11) | 47.2 | 7.5YR2.5/1 | Sandy loam |
| 20–50 | 25 (± 4) | 55 (± 11) | – | – | 7.5YR2.5/1 | Sandy loam |

WHC = water holding capacity
2.5Y4/2 = dark grayish brown
7.5YR2.5/1 = black
10YR3/2 = very dark grayish brown

The content of K and Mg is quite high in the stand of Tilkane (K = 1.53 $\mu mol_c$/g and Mg = 44.3 $\mu mol_c$/g) in comparison with the stand of Hetauda (K = 0.72$\mu mol_c$/g and Mg = 6.58 $\mu mol_c$/g) and the Mg content is remarkably high (almost 7 times higher in the soil of Tilkane than in the soil of Hetauda). In addition, the Tilkane site is also richer in N and P than the Hetauda site. It means that in general the soil of Tilkane is richer in nutrients than the soil of Hetauda.

The Tilkane sissoo stand has a high C-content in the soil, i.e. a greater accumulation of organic matter occurs here. In the case of Hetauda, which is calcareous and sandy in nature, shows a low organic matter accumulation, and this is supported by the presence of lower humus content in the soil of the Hetauda site. In the case of Tilkane, the humus content of the subsoil is higher than in the top soil, and this indicates a higher organic matter accumulation in the soil showing a lower mineralisation rate.

C/N ratio in the soil of the Hetauda stand is slightly higher than in the soil of Tilkane stand. Opposite is true of the C/P ratio in the soil, i.e. C/P ratio in the soil of Hetauda site is lower than in the soil of Tilkane. C/N ratio of the Tilkane stand soil indicates a relatively higher N-mineralisation rate than that in the Hetauda stand soil. Opposite is true of the C/P ratio in the soil of the Tilkane stand, showing a relatively higher P-mineralisation rate at this site.

## NUTRIENT CONCENTRATION IN VARIOUS COMPONENTS OF SISSOO TREES

Table 3 shows the nutrient concentration in the different plant parts of sissoo trees of both sites. In both stands, the concentration of nutrients in various components of tress follows the trend of N > Ca > K > Mg and the different tree components according to their nutrient contents follow the trend of green leaf > litter fall > bark > root > wood and such type of trend is similar to a temperate forest (KHANNA, ULRICH 1991). In general, both stands, with few exceptions, show almost similar nutrient allocation and distribution in their different tree components. In both stands, the foliage concentrations of N and P (as well as other mobile nutrients) decrease from green leaf to litter fall. As expected, the Ca-contents of all tree

Table 2. Soil characteristics of the Hetauda sissoo stand (calcareous soil) ($n$ = 2)

| | pH ($CaCl_2$) | Exch. cations ($\mu mol_c$/g) | | | | | (mmol/kg) | | | Humus (%) | C/N | C/P |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Na | K | Ca | Mg | Mn | C | N | P | | | |
| **1. Hetauda (healthy site)*** | | | | | | | | | | | | |
| 0–5 cm | 7.15 | 0.47 | 0.72 | 237.5 | 6.58 | 0.60 | 983.7 | 44.8 | 17.8 | 2.00 | 22.0 | 55.26 |
| 5–50 cm | 7.44 | 0.07 | 0.22 | 261.5 | 5.60 | 0.52 | 516.4 | 14.6 | 14.8 | 1.10 | 35.4 | 34.89 |
| **2. Tilkane (declining site)** | | | | | | | | | | | | |
| 0–20 cm | 5.81 (± 0.04) | 0.40 (± 0.14) | 1.53 (± 0.02) | 122.3 (± 0.50) | 44.3 (± 0.50) | 0.13 (± 0.0) | 1,626.1 (± 70.6) | 106.2 (± 3.2) | 22.60 (± 0.14) | 3.35 | 15.31 | 71.95 |
| 0–50 cm | 5.14 (± 0.03) | 0.38 (± 0.19) | 1.75 (± 0.01) | 136.5 (± 3.75) | 39.2 (± 1.30) | 0.40 (± 0.08) | 2,027.6 (± 2.05) | 130.1 (± 0.20) | 24.82 (± 0.22) | 4.20 | 15.59 | 81.70 |

*Only one soil sample analysed

Table 3. Nutrient contents of different components of Hetauda and Tilkane plantation sissoo forests ($n$ = 3, ± SD)

| | C (%) | N | Na | K | Ca | Mg | Mn | Fe | Al | P | S |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (mg/g) | | | | | | | | | |
| **1. Tilkane (declining site)** | | | | | | | | | | | |
| Green leaf | 44.2 (± 1.6) | 30.9 (± 2.1) | 0.12 (± 0.05) | 10.2 (± 2.2) | 24.2 (± 8.3) | 6.1 (± 0.10) | 0.07 (± 0.0) | 0.50 (± 0.10) | 0.90 (± 0.30) | 2.0 (± 0.26) | 2.0 (± 0.10) |
| Litter fall | 45.8 (± 1.1) | 22.3 (± 3.5) | 0.06 (± 0.0) | 2.60 (± 0.04) | 18.2 (± 3.30) | 4.1 (± 0.70) | 0.40 (± 0.40) | 42.5 (± 45.0) | 0.70 (± 0.40) | 1.30 (± 0.20) | 0.70 (± 0.20) |
| Stem wood* | 48.0 | 3.5 | 0.05 | 2.3 | 1.2 | 0.90 | 0.01 | 0.50 | 0.20 | 0.30 | 0.20 |
| Twig wood | 47.7 (± 0.3) | 10.5 (± 0.30) | 0.04 (± 0.01) | 3.4 (± 0.30) | 8.3 (± 0.90) | 2.0 (± 0.20) | 0.02 (± 0.01) | 1.6 (± 1.40) | 0.10 (± 0.01) | 1.2 (± 0.20) | 0.70 (± 0.0) |
| Bark | 38.5 (± 1.8) | 13.8 (± 0.50) | 0.07 (± 0.02) | 2.40 (± 0.70) | 64.5 (± 1.60) | 7.4 (± 0.50) | 0.03 (± 0.01) | 1.5 (± 0.10) | 3.0 (± 1.70) | 0.60 (± 0.0) | 1.3 (± 0.10) |
| Root | 45.3 (± 0.55) | 10.6 (± 1.30) | 0.08 (± 0.01) | 7.3 (± 0.40) | 3.9 (± 0.10) | 2.1 (± 0.20) | 0.04 (± 0.01) | 4.2 (± 1.6) | 3.8 (± 0.90) | 0.90 (± 0.10) | 0.50 (± 0.10) |
| **2. Hetauda (natural and healthy site)** | | | | | | | | | | | |
| Green leaf | 44.6 (± 0.05) | 24.9 (± 0.17) | 0.07 (± 0.01) | 10.9 (± 0.70) | 31.9 (± 2.10) | 4.1 (± 0.10) | 0.05 (± 0.0) | 0.40 (± 0.01) | 0.40 (± 0.01) | 1.4 (± 0.01) | 1.7 (± 0.01) |
| Litter fall | 28.4 (± 3.18) | 12.2 (± 0.60) | 0.20 (± 0.0) | 7.1 (± 0.40) | 40.7 (± 2.40) | 4.4 (± 0.40 | 0.30 (± 0.04) | 13.9 (± 4.40) | 13.2 (± 0.90) | 0.80 (± 0.04) | 1.2 (± 0.10) |
| Stem wood | 40.3 (± 0.74) | 8.3 (± 0.40) | 0.07 (± 0.01) | 5.1 (± 0.20) | 66.4 (± 6.90) | 3.6 (± 0.20) | 0.01 (± 0.0) | 0.20 (± 0.05) | 0.20 (± 0.08) | 0.30 (± 0.05) | 0.90 (± 0.0) |
| Twig wood* | 46.4 | 11.1 | 0.04 | 7.4 | 17.8 | 2.0 | 0.01 | 0.20 | 0.10 | 1.0 | 1.0 |
| Bark | 40.6 (± 0.78) | 45.0 (± 0.90) | 0.06 (± 0.0) | 1.2 (± 0.10) | 92.9 (± 3.90) | 1.8 (± 0.10) | 0.03 (± 0.0) | 0.70 (± 0.10) | 1.2 (± 0.30) | 0.40 (± 0.05) | 1.6 (± 0.10) |
| Root | 40.5 (± 8.54) | 9.3 (± 2.10) | 1.0 (± 0.07) | 6.6 (± 0.70) | 6.4 (± 0.80) | 1.8 (± 0.80) | 0.06 (± 0.03) | 5.8 (± 1.5) | 3.8 (± 3.8) | 0.5 (± 0.10) | 0.6 (± 0.10) |

components, especially in green leaf and leaf litter, were found markedly higher at the calcareous site of Hetauda (healthy site) compared with the non-calcareous site of Tilkane (declining site). The higher accumulation of Ca and Mg is also evident in the calcareous soil of Hetauda stand leaf litter than in the non-calcareous soil of Tilkane. But in the stemwood, the Ca-content is very high at the Hetauda site, and this is in contrast to a trend in the tem-

Table 4. Foliage nutrient concentrations (%) in some Indian sissoo forests (NEGI et al. 1999)

| | N | P | K | Ca | Mg |
|---|---|---|---|---|---|
| **1. Normal and healthy stands** | | | | | |
| I. Deharadun, U.P. | 4.18 | 0.28 | 2.40 | 2.33 | 0.30 |
| II. Deharadun, UP | 2.34 | 0.11 | 0.58 | 3.17 | 0.30 |
| III. Ramnagar, UP | 2.55 | 0.11 | 0.67 | 0.35 | 0.23 |
| IV. Yadav, Bihar | 2.46 | 0.24 | 0.96 | 2.38 | 0.15 |
| V. Gonda, UP | 2.64 | 0.07 | 0.86 | 2.72 | – |
| Hetauda, Nepal | 2.49 | 0.14 | 1.09 | 3.19 | 0.41 |
| **2. Declining stands** | | | | | |
| I. Gonda, UP | 2.42 | 0.03 | 0.55 | 2.50 | – |
| II. Bihar | 2.96 | 0.02 | 0.36 | 1.38 | 0.27 |
| III. Una, HP | 2.10 | 0.03 | 0.52 | 1.67 | 0.29 |
| IV. Delhi | 2.92 | 0.04 | 0.37 | 1.50 | 0.34 |
| V. Bhiwani, Hariyana | 2.91 | 0.04 | 0.46 | 1.75 | 0.36 |
| VI. Maldevta, Dehara Dun | 1.74 | 0.03 | 0.72 | 0.65 | 0.34 |
| Tilkane, Nepal | 3.09 | 0.20 | 1.02 | 2.42 | 0.61 |

perate forest. However, SHARMA et al. (1988) reported the lowest amount of Ca in the stemwood from 24 years old sissoo plantation site of U.P., India. Both stands do not differ a lot in the Mb-cation content of tree components. In general, the Ma-cation content is very low in their concentrations at both sites. Only the Fe-concentration of leaf litter in both stands is high compared with other Ma-cations, especially at Tilkane (42.5 mg/g), but this value of Fe concentration cannot be acceptable because of its very high standard deviation value. At Hetauda, Al was found to be at a higher concentration in the leaf litter in comparison with Tilkane.

Although the weight of bark accounts for only 10–15% of the aboveground biomass in trees, the bark may contain 70% of total Ca in the aboveground parts of most trees (DAY, MCGINTY 1975). It is also evident in our studies that the bark contains a higher amount of nutrients, especially N and Ca, at both sites. Both sites differ greatly in N-contents of their bark; the concentration in the bark of sissoo stands on the calcareous soil of Hetauda (45.0 mg/g) is higher than that on the non-calcareous soil of Tilkane (13.8 mg/g). Accumulation of Ca in the bark and stemwood of the stand in Hetauda may be attributed to their base rich calcareous soil.

In general, N-content is found to be slightly higher in the declining stand of Tilkane, which could be attributed to the presence of high nitrogen contents of the soil in this stand. Nutrient contents in the roots of both stands are identical.

Table 4 summarises the foliage nutrient contents of some Indian sissoo forests, both declining and healthy (SHARMA et al. 2000). This table shows that the healthy sissoo stands of India show higher foliage nutrient uptake compared with the declining sissoo stands. On the contrary, in our studies the declining stand of Tilkane shows a higher amount of foliage nutrient uptake compared with the healthy sissoo site of Hetauda.

## CLIMATE ANALYSIS AND ITS POSSIBLE RELATION TO THE SISSOO DECLINE

Figs. 1–3 show diagrams of the annual temperature and rainfall data of Hetauda, close to our research sites. The summer season (Monsoon time) receives 95% of the total annual rainfall and the winter is dry and has a negligible amount of rainfall. The monthly variations of temperature and rainfall in winter and summer were great but their annual fluctuations were much smaller.

The moving mean method was used to eliminate annual variations of temperature and rainfall. The figures comprise 5-year moving mean values, annual mean and time series of annual rainfall and temperature. It is evident from these figures that in general the rainfall did not fluctuate very much and remained annually constant for the last 28 years. With respect to the temperature, the maximum temperature seems to have increased in recent years from 29°C to 30°C. It can be considered as the effect of global warming. The minimum temperature, however, has also shown a decreasing trend in recent years due to the unusual occurrence of foggy weather in winter seasons for the past 4–5 years. Therefore it can be concluded that a slight change in climate has taken place, which is considered to be the effect of global warming. The question arises what the effect of slight change in climate on sissoo forests or on forests in general could be like? Our field survey indicated that the slight change in climate has occurred in recent years and the sissoo decline has also started in recent years. In addition, in recent years (3–5 years) there has been a frequent and prolonged occurrence of foggy weather during the winter in the Terai. Such occurrence of fog in winter may increase the amount of air pollutants in the forest and may affect the forest adversely.

Therefore we recommend to carry out future researches into the long-term monitoring and assessment of air pollution around the different regions of Terai and correlate them with sissoo forest ecosystems. For this purpose, forest nutrient cycling study of several sissoo stands may serve as a tool for identification of the impacts of climate change, hydrology and other abiotic factors on the forests (SCHULZE et al. 1989; SMITH 1990). DOKIYA et al. (1992) reported the high atmospheric deposition of air pollutants even at high-elevation mountains of Nepal. Therefore, the air pollutant deposition cannot be completely ignored.

## CONCLUSIONS

A sissoo decline is often attributed to the infection of roots on clayey soils by the fungus *Fusarium* sp. The mechanism behind this has been assumed to be caused by the colonisation of vascular bundles of roots by the above-mentioned fungi, which hinders the flow of water to the crown. As a result, wilting takes place in terminal branches and the leaves turn yellow, wilt and in extreme cases trees they are killed (BAKSHI et al. 1976). The primary causal factors involved in the root infection by *Fusarium* sp. are mostly assigned to the absence of $O_2$ in the root zone due to prolonged water presence, especially in the rainy season, when the water table rises and can ascend up to the tap root. It has been reported that the water table may rise up to only 2–3 m depth of soil in the lowland and when the tap root comes in contact with the water table, it becomes more susceptible to the above-mentioned fungus. The experience that sissoo thrives on loosely textured soils but suffers adversely from root diseases in stiff clayey soils has been widely accepted. The success of the species on loosely-textured soils appears to be proper soil aeration and good drainage which leads to the healthy growth of roots (BAKSHI 1954, 1957; BAGCHEE 1945).

The healthy stand of Hetauda, which is riverine in habitat, has the loosely-textured soil (sandy soil) with good drainage. Soil density and porosity are also suitable to the sissoo growth. This stand has been found fully healthy. The declining stand of Tilkane shows the identical soil properties as Hetauda but differs in poor water drainage from the soil. Our study indicates that the soil and plant nutrient allocation and distribution do not vary greatly at the two sites.

As mentioned above, however, they differ mainly in the soil water drainage, and it can be assumed in our study that the waterlogging could play a significant role in the sissoo decline of the Tilkane stand. The Hetauda stand, growing as a natural stand, does not show any symptoms of decline. Therefore, based on our studies it can be concluded that only the loosely textured soils with good drainage are suitable for the appropriate sissoo trees growth.

Our study has also recorded a change in temperatures over the last 28 years in the region of research sites. Hence we also conclude that, in addition to the soil factor, changed climatic characteristics of the lowland region of Nepal could also be involved in such decline. Therefore further researches on the interactions between sissoo growth and climatic parameters have to continue on a long-term basis.

In order to assess the primary causal factors involved in the sissoo decline, several sissoo stands have to be studied in future. Permanent research plots should be established for a long-term study. Monitoring of abiotic factors such as atmospheric deposition, climatic data, soil factor, etc. as well as biotic factors such as pathogens should be carried out to find out the possible causal factors.

## SUMMARY

Sissoo (*Dalbergia sissoo*, Roxb.) is a nitrogen fixing leguminous multipurpose tree species and its natural habitat is the lowland region (called Terai) of Nepal up to an altitude of 1,000 m. Sissoo tree species, due to its fast-growing nature, quality timber, easy propagation, drought resistance, etc. has become the most favourable plantation species for the private as well as governmental sector for the last 3 decades in the region. Unfortunately, in the last few years, this tree species has been dying rapidly in plantation forests. Its status, however, in the natural forest is still unknown. Therefore, one natural sissoo forest stand has been selected. The natural sissoo forest occurs along the river bank (known as "riverine" species) in the lowland. The present paper compares the nutrient status of natural and healthy sissoo forest with declining plantation sissoo forest. It is evident from our study that both stands do not differ very much with respect to their soil and plant nutrients. They differ mainly in their soil pH, soil texture, soil water drainage. The healthy stand of Hetauda is situated on the calcareous sandy soil (pH > 7.1) whereas the declining stand of Tilkane is on the non-calcareous and relatively acidic (pH < 5.9) sandy-loam soil with a high content of humus in the soil. Furthermore, the soil of Hetauda is well drained and Tilkane has the severely waterlogged soil. Therefore this study has concluded the waterlogging to be the main responsible factor involved in the decline of sissoo stand at the Tilkane site. Furthermore, climatic conditions such as an increase in temperature and occurrence of unusual foggy weather during the winter in the lowland have also been observed in this study and this change in climatic characteristics could also play a role in such decline and this needs further researches.

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# Podmínky a stav výživy zdravých přirozených sissoových lesů a chřadnoucích uměle založených sissoových porostů (*Dalbergia sissoo*, Roxb.) v Nepálu

**S. P. Sah[1], P. K. Jha[2], N. Lamersdorf[1]**

[1]*Ústav půdoznalectví a výživy lesa, Univerzita v Göttingenu, Německo*

[2]*Program HMG/DANIDA pro šlechtění dřevin, regionální pracoviště, Hetauda, Nepál*

**ABSTRAKT**: Sissoo (*Dalbergia sissoo*, Roxb.) je dusík fixující leguminózní víceúčelová dřevina stromovitého růstu, jejímž přirozeným stanovištěm je dolní (nížinný) region Nepálu s nadmořskou výškou do 1 000 m, nazývaný Terai. V posledních letech uměle založené porosty sissoo, dřeviny se širokým hospodářským spektrem, rychle chřadnou a odumírají. Informace o stavu této dřeviny v přirozených sissoových lesích dosud chybějí. Příspěvek srovnává podmínky a stav výživy ve zdravých sissoových lesích a v chřadnoucích sissoových porostech uměle založených. Z výsledků studie vyplývá, že mezi zkoumanými porosty nebyl významný rozdíl ani v obsahu živin v půdě, ani v obsahu živin v biomase rostlinných orgánů stromů. Autoři vyslovují na základě výsledků studie závěr, že hlavní příčinou chřadnutí uměle založeného sissoového porostu je zamokření půdního profilu.

**Klíčová slova**: sissoo lesy; *Dalbergia sissoo*; zdravotní stav; chřadnutí uměle založených porostů; živiny; textura; zamokření; Nepál

Sissoo (*Dalbergia sissoo*, Roxb.) je dusík fixující leguminózní víceúčelová dřevina stromovitého růstu, jejímž přirozeným stanovištěm je dolní (nížinný) region Nepálu (s nadmořskou výškou do 1 000 m), pojmenovaný Terai. Strom sissoo se vzhledem ke svému rychlému růstu, kvalitě dřeva, snadnému rozšiřování, odolnosti vůči suchu a dalším vhodným vlastnostem stal v tomto regionu v uplynulých třiceti letech nejoblíbenější dřevinou jak v soukromém, tak ve státním sektoru. Bohužel v posledních několika letech uměle založené porosty sissoo rychle chřadnou a odumírají. Informace o stavu této dřeviny v přirozených lesích chybějí. Proto byl k získání nových poznatků vybrán přirozený sissoový porost nacházející se v říčním pobřežním pásmu. Mezi zkoumanými porosty nebyl významný rozdíl ani v obsahu živin v půdě, ani v obsahu živin v biomase. Porosty se lišily zejména v pH půdy, v textuře půdy a ve vodním režimu půdního profilu. Porost s dobrým zdravotním stavem se nacházel na lokalitě Hetauda na vápenité písčité půdě (pH větší než 7,0), zatímco nevápenitá půda pod chřadnoucím porostem v lokalitě Tilkane byla relativně kyselá (pH pod 5,9), písčito-hlinitá, s velkým obsahem humusu. Kromě toho Hetauda měla půdu propustnou s dobrým odváděním vody z půdního profilu, zatímco na lokalitě Tilkane byly půdy hůře propustné, s nedostatečně odvodňovaným půdním profilem. Na závěr studie autoři konstatují, že hlavní příčinou chřadnutí sissoového porostu na lokalitě Tilkane bylo zamokření půdy. Z dalších faktorů mohou přicházet v úvahu klimatické změny, jakými jsou v této oblasti zvyšování teploty vzduchu a výskyt mimořádně mlhavého zimního počasí.

*Corresponding author:*

Ph.D. Shambhu Prasad Sah, Department of Forest Ecology, University of Helsinki, PL BOX 27, Latokartanonkaari 7, FIN-00014 Helsingin Yliopisto, Helsinki, Finland
tel.: + 358 9 191 581 26, fax: + 358 9 191 581 00, e-mail: sambhu.sah@helsinki.fi