Nutritional diagnoses of oriental beech trees in damaged Caspian forest sites, using the diagnosis and recommendation integrated system (DRIS)

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Abstract

Oriental beech established in the Hyrcanian forests, is a valuable tree whose habitats are constantly exposed to destructive factors which change the nutritional status of soil and leaves. Analysis of foliar elements is a commonly used method for studying tree nutrient status that indicates site's quality. Foliar analysis of beech (*Fagus orientalis* Lipsky) was carried out in Kojour (Mazandaran) in order to assess the nutritional balance of trees in a damaged forest site (a direct result of livestock grazing and anthropogenic perturbations). Sunny leaves of dominant trees were taken in August and foliar concentration of macroelements, N, P, Ca, K and Mg were measured. The diagnosis and recommendation integrated system (DRIS) analysis was applied for evaluating the nutritional state. The results showed deficiency with K and P in disturbed stands. Nutrient Balance Index (NBI) indicated imbalance in nutrient status. These results suggest the usefulness of DRIS for foliar tissue analysis as an indicator of nutritional status and elemental stress in natural forests.

Keywords

Nutritional Diagnoses; *Fagus orientalis*; DRIS; Nutrient Balance Index; Caspian Forest

Contents

1 Introduction

Tertiary relic Caspian (or Hyrcanian) forests are located in the north of Iran with great diversity of unique, endangered and endemic species which contain 80 tree and 50 shrub species (Mohajer 2007). In these forests, oriental beech (*Fagus orientalis* Lipsky) is an important and dominant wood producing species which takes up about 18% of the area in a range of 700 to 2200 m above mean sea level. The beech forests have been run by a shelter wood system but because of regeneration problems, this system has been unsuccessful (Sagheb Talebi and Schütz 2002). These habitats are constantly exposed to destructive factors such as livestock grazing and anthropogenic perturbations which limit the future productivity of the site, destroy the forest understory (reproduction), hasten soil erosion, and change the nutrient status of soil and leaves. The restoration of tree species diversity and community structure are difficult under such circumstances. Forest restoration must go beyond afforestation, reforestation and even ecological restoration to improve ecological integrity (Calle et al. 2012). Restoration requires strategies that capture resources, increase their retention and improve microclimate (Yates et al. 2000). To adopt the efficient strategy for reforestation after degradation it is necessary to test the soil quality and function. For this purpose, assessing the nutrient status is considered as an important factor. The nutrient status is a critical determinant of plant quality and performance; consequently, nutrients are often monitored in agriculture, forestry, and horticultural practices in order to identify and correct deficiencies and excesses (Haase and Rose 1995). Studies based on analyzing the leaf nutrient content are useful to assess the nutritional condition of plants (Carmo et al. 2002) and as a tool for early-growth diagnosis and management for optimal growth (Specht and Turner 2006).

One of the methods for interpreting nutrient determination is the diagnosis and recommendation integrated system (DRIS) which eliminates the effect of age on the amount of nutrients (Beaufils 1973). This diagnostic technique incorporates both nutrient intensity and nutrient balance based on the computation of nutrient indices in dual ratios which are then compared two by two with DRIS norms which consist on dual ratio between nutrients obtained from a reference population with high yield (Wadt et al. 1998; Reis Junior and Monnerat 2003).

Several studies evaluated the efficiency of DRIS formulas. Pardo et al. (2013) via the DRIS indices found K is the element that most strongly limited production of rubber on the Eastern Plains of Colombia. Huanga et al. (2012) showed DRIS is efficient for evaluating nutritional status of citrus trees established in high pH soils. Rafael et al. (2011) for evaluation of nutritional status of *Theobroma grandiflorum* Willd. ex Spreng. trees applied different DRIS formulas to recognize and suggest the best method for mineral nutrition researches and the monitoring of commercial orchards of the species. Guillemette and DesRochers (2008) used the DRIS norms for detecting nutritional needs of hybrid poplars (*Populus* spp.) of Western Quebec. Nachtigall and Dechen (2007) used the DRIS for diagnosing the nutrient contents of *Malus domestica* Borkh. trees in South Brazil. Rothstein and Lisuzzo (2006) used the DRIS technique for identifying relationships between foliar nutrition of *Abies fraseri* Pursh. trees and their performances. Results showed foliar N, P, and K levels were all positively associated with tree performance. In contrast, Ca, Mg, and Fe levels in foliage were negatively associated with tree quality. Based on the DRIS analysis and in order to determine the status of foliar P in the nursery with low growth and high growth of *Liquidambar styriciflua* L. stands, Coleman et al. (2003) concluded that in the stand of low growth, leaf potassium concentration is lower than normal.

The objective of the following study was, therefore, to apply the DRIS technology for evaluating the foliar nutritional status of the oriental beech trees in Caspian forests which have been under livestock grazing and destructive anthropogenic activities for years.

2 Material and methods

2.1 Study site

The study site of oriental beech is located in Kojour region (in Mazandaran province) of Caspian forests. Parcel No.5 of the region was chosen due to of having both undisturbed and disturbed stands. The total area of the selected parcel of Kojour region is 1,004 ha, the range of altitude is 1,400 m to 2,350 m and the average volume per hectare is 163 m^3. The dominant tree is *Fagus orientalis*. In this parcel of the region there is a under tension stand (number 2) which is located in the vicinity of the Pool village and has been exposed to livestock grazing and destructive anthropogenic activities for years. In the vicinity of this stand, there is a relatively undisturbed stand (No.10) with no observable livestock and anthropogenic influences and has high potential yield. This stand was chosen as a reference population for obtaining the DRIS norms.

A database was created to separate oriental beech stands into high and low yield populations. During sampling, each stand was previously classified according to the average growing stock per hectare. The descriptive statistical procedure was applied to these values to verify that the populations were adequately separated. Then for establishing the DRIS norms, the database was divided into two groups: high yield population (stand No.10) and low yield population (stand No.2).

2.2 Sampling and laboratory analysis

Since the suitable trees for foliar analysis must be dominant and healthy, non-randomized (selective) sampling was applied. The dominant trees which are relatively uniformly distributed in both stands (undisturbed and disturbed stands) were chosen. The mature sunny leaves at the base of the highest third of the crown were collected. As a rule, foliar analysis is carried out in the period between the beginning of August and mid-September, because in this period the concentration levels of the nutrition elements are more or less constant (Kopinga and Burg 1995), so sampling was carried out before leaf senescence in September. Elemental concentrations of leaf samples were measured by an atomic absorption device for K (potassium), Ca (calcium), Mg (magnesium) and by spectrophotometry for P (phosphorus); and by Kjldal method for N (nitrogen).

2.3 Development of the DRIS norm

For founding the DRIS norms, after calculating the pair of nutrient ratios, the average, the variance and the coefficient of variation of each ratio were calculated.

Since a pair of nutrient ratios has two forms of expression, one of them should be selected. The way for selecting the form of ratio was based on the ratio of variances (V low/V high). The forms which had the highest variance relation were selected as nutrient ratios for calculating the DRIS indices. DRIS indices were measured for nutrients A to Z based on the following equations (Beaufils 1973).

$IA = [f(A/B) + f(A/C) + ... + f(A/Z)]/n$

$IB = [-f(A/B) + f(B/C) + ... + f(B/Z)]/n$

$IC = [-f(A/C) - f(B/C) + ... + f(C/Z)]/n$

$IZ = [-f(A/Z) - f(B/Z) + ... - f(C/Z)]/n$

Where $f(A/B) = [(A/B)/(a/b) - 1]1000/CV$ if $A/B > a/b$

and $f(A/B) = [1 - (a/b)/(A/b)]1000/CV$ if $A/B < a/b$

A/B is the ratio of the concentrations of nutrients A and B in the sample (stand no.2) while a/b is the ratio of the high-yielding population (stand no.10), n is the number of the ratios, and CV is the coefficient of variation associated with each nutrient ratio norm a/b − a/z. The IA shows the nutritional position of nutrient A, i.e., (i) less than zero indicates that nutrient A is deficient; (ii) equal to zero indicates the balance of the nutrient; (iii) greater than zero indicates that nutrient A is excessive. For calculating the Nutritional Balance Index (NBI), the values of the indices were summed. The Nutritional Balance Index average (NBIa) was calculated according to (Serra et al. 2013):

$NBIa = NBI/n$

Where: n is the number of nutrients that participate in the analysis.

3 Results

Results indicated the average of growing stock for reference stand (No.10) was 530 m^3 per hectare. The excellent growing stock of natural beech corresponded to 500 m^3 ha^{-1} (Navroodi et al 2000). The average of growing stock for under tension stand (No.2) was 176 m^3 per hectare. The difference in mean growing stock between two stands was statistically significant ($P < 0.05$). This indicates that the sampling proposed for the definition of the DRIS norms was adequate.

The average, standard division and coefficient of variation of all nutrient ratios of the under tension and reference stands and the variance ratio between two stands (high and low yielding) ratio are shown in Table 1.

The following 10 forms of expression which had the highest variance relation (Table 1) were selected as nutrient ratios for calculating the DRIS indices: N/P, N/K, N/Ca, N/Mg, P/K, Ca/P, Mg/P, Ca/K, Mg/K, Ca/Mg.

The DRIS formulas used for calculating indices are:

N index = $[+f(N/P) + f(N/K) + f(N/Ca) + f(N/Mg)]/4$

P index = $[-f(N/P) + f(P/K) - f(Ca/P) - f(Mg/P)]/4$

K index = $[-f(N/K) - f(P/K) - f(Ca/K) - f(Mg/K)]/4$

Ca index = $[-f(N/Ca) + f(Ca/P) + f(Ca/K) + f(Ca/Mg)]/4$

Mg index = $[-f(N/Mg) - f(Ca/Mg) + f(Mg/P) + f(Mg/K)]/4$

The DRIS functions values are shown in table (Table 2) and the values of DRIS indices are shown in table (Table 3). P and K indices are negative and N, Ca and Mg indices are positive. The sum of indices is zero. The arrangement of indices from the lowest to the highest is: K<P<N<Mg<Ca. The values of nutritional balance index and nutritional balance index average (NBI a) are 15.38 and 3.08 respectively.

Table 1. The DRIS norm means, SD, CVs and variance relation for beech trees in under tension and reference populations.

	Under Tension Stand			Reference Stand			
Forms of Expression	**Mean**	**Variance**	**CV (%)**	**Mean**	**Variance**	**CV (%)**	**Variance Relation**
N/P	23.70	10.37	43.65	21.98	9.78	44.50	1.12
P/N	0.05	0.02	43.65	0.06	0.03	50.85	0.59
N/K	7.88	1.51	17.78	6.92	2.79	40.30	0.29
K/N	0.13	0.02	17.26	0.18	0.12	69.19	0.04
N/Ca	15.27	3.20	20.96	16.02	4.84	30.19	0.44
Ca/N	0.07	0.01	22.61	0.07	0.03	46.59	0.22
N/Mg	58.84	8.11	13.79	61.63	24.08	39.08	0.11
Mg/N	0.02	0.01	15.04	0.02	0.02	63.56	0.04
P/K	0.40	0.20	51.08	0.37	0.22	59.98	0.82
K/P	3.05	1.31	42.75	3.61	1.82	50.42	0.52
P/Ca	0.77	0.41	52.69	0.85	0.39	46.33	0.07
Ca/P	1.59	0.68	42.59	1.44	0.65	45.52	1.07
P/Mg	2.96	1.30	44.01	3.23	1.65	51.15	0.62
Mg/P	0.41	0.18	45.02	0.39	0.18	46.54	1.02
K/Ca	1.96	0.41	20.76	2.48	0.64	25.91	0.40
Ca/K	0.53	0.11	20.08	0.43	0.12	27.70	0.79
K/Mg	7.67	1.65	21.50	9.17	2.15	23.45	0.59
Mg/K	0.14	0.03	22.49	0.11	0.02	19.76	1.63
Ca/Mg	3.94	0.64	16.15	3.80	0.76	19.99	0.70
Mg/Ca	0.26	0.04	14.80	0.27	0.05	19.21	0.54

Table 2. The DRIS function values.

ƒ (N/P)	**ƒ (N/K)**	**ƒ (N/Ca)**	**ƒ (N/Mg)**	**ƒ (P/K)**
1/76	3/34	-1/62	1/20	1/35
ƒ (Ca/P)	**ƒ (Mg/P)**	**ƒ (Ca/K)**	**ƒ (Mg/K)**	**ƒ (Ca/Mg)**
2/29	1/10	8/39	13/80	1/84

Table 3. The values of DRIS indices.

DRIS Indices	Values
I_N	1.2
I_P	-0.95
I_K	-6.74
I_{Ca}	3.53
I_{Mg}	2.96

4 Discussion

The DRIS indices revealed that K is the most limiting nutrient for growth, but there is also a deficiency in P. The relative limitations of these elements would be the limiting factor in oriental beech growth. The amount of K index has greater distance from point zero than P index, so K limits the growth more than P. Ca is the nutrient with the highest positive imbalance, N is in excess and Mg is slightly in excess.

Based on the results NBIa is 3.08. NBIa is the mean of all DRIS indices which indicates the average of the deviations of each dual ratio relative to the reference value (Serra et al. 2013). Between the five indices, the absolute values of I_K (6.74) and I_{Ca} (3.53) are greater than NBIa, so I_K shows the nutrient status of highest deficiency ($I_K < 0$). In turn, Ca indicates the highest excess in nutrient position ($I_{Ca} > 0$). Since it has been proved that *Fagus orientalis* needs a large level of K for growth, K deficiency is a major factor limiting growth in the studied population.

The connection between foliar nutrition and soil nutrition is very important but complex. For example, foliar P, Ca, Mg and Fe were connected with nutrient concentrations of soil but there is no connection between foliar N, K, Mn, Cu and soil contents (Wu et al. 2007), so it can be assumed the excess of Ca is due to soil type which is calcimorph.

In addition to the DRIS indices, NBI is the other factor which is efficient to diagnose the tree nutrient position (Silveira et al. 2005). Based on the results, NBI is 15.38. This high deviation from zero shows the great imbalance in nutritional status.

The imbalance in DRIS indices may be as a result of the damage of livestock grazing and anthropogenic perturbations which has led to tree thinning, soil compacting and erosion, water flowing and increment of weeds. All of these destructive conditions have caused the trees to be out of the reach of mobile elements like K. Although in this situation, the activity of grasses has increased and deficiency of N has been compensated but it is not a substitute for K deficiency, so nutritional status imbalance and low fertility of habitat are the results of these situations.

Based on results it can be assumed that foliar analysis along with the DRIS analysis can provide the useful information to show the nutritional balance. This agrees with recent reports (Rafael et al. 2011; Huanga et al. 2012; Pardo et al. 2013), showing the value of DRIS analysis for assessing the nutritional status of trees.

5 Conclusions

In this study for diagnosing nutritional imbalance in a damaged site, DRIS indices were used. Because of being highly sensitive to nutrient imbalances and not being influenced by leaf age, DRIS analysis is very efficient. The other strength of DRIS is that results are easily interpreted. Results indicated K and P are deficient but K is the most imbalanced so it is the element that most strongly limits production. It can be the result of livestock grazing and anthropogenic perturbations in the under tension stand that remove nutrients from the soil. Livestock grazing thus has a paramount impact on the long term sustainability of this site. The accessibility of N, P, and K in soil determines the rate of photosynthetic. The improvement of the nutrient cycle after livestock invasion depends on the rate of trees restoration (Foster and Bhatti 2006). So for restoring the study site, some proper management of livestock should be adopted and for regeneration in degraded area it has been recommended to plant beech seedlings after planting and establishing seedlings of some pioneer species like *Acer velutinum* Boiss. and *Alnus subcordata* C.A. Meyer. (Gorji Bahri et al. 2009).

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