Research Journal of Botany

ISSN 1816-4919

Academic Journals Inc.

www.academicjournals.com

OPEN ACCESS Research Journal of Botany

ISSN 1816-4919
DOI: 10.3923/rjb.2016.18.24

Research Article
Assessment of Soil Macronutrient Status of Some Threatened Medicinal Plants of Kashmir Himalaya, India

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Abstract
Background: One of the important ecological factors for the survival of plants is the soil. Fertility of soil is determined by the presence or absence of nutrients which have agronomic importance. Bandipora, a temperate Himalayan district of Kashmir is endowed with rich and unique floristic diversity with a good proportion of plants used locally as ethnomedicine. Although, a number of studies, mainly focused on the enumeration of medicinal plants have been conducted in the region, but so far no such study has been carried out to check the fertility condition of soils where threatened medicinal plants grow luxuriantly. In this backdrop, present study was conducted to ascertain the soil macronutrient status of some sites where locally used threatened medicinal plants of the region grow luxuriantly. **Materials and Methods:** Corresponding soil samples of locally used threatened medicinal plants were collected from three physiographic zones and analysed for properties such as pH, organic carbon, available nitrogen, phosphorus and potassium. **Results:** A total of 23 composite soil samples were collected and categorised into low, medium and high altitude soils. Variations existed in the estimated chemical parameters depending on the environmental conditions (altitude aspect) wherefrom the soil samples were collected. Low land and medium land soils were neutral to slightly alkaline, while those of high land were acidic. All soils were high in organic carbon and medium in available nitrogen, phosphorus and potassium. **Conclusion:** This study generated a useful information concerning chemical properties of corresponding soils of locally used threatened medicinal plants of the region and if this information is put to use in the cultivation of these plants at places of choice, simply by making soil amendments, there is no doubt that the extinction of these precious resources can be checked.

Key words: Soil fertility, medicinal plants of Kashmir, organic matter, available nitrogen, phosphorus, potassium

Received: January 24, 2016 Accepted: April 20, 2016 Published: June 15, 2016

Citation: Parvaiz Ahmad Lone, Ajay Kumar Bhardwaj, Kunwar Wajahat Shah and Fayaz Ahmad Bahar, 2016. Assessment of soil macronutrient status of some threatened medicinal plants of Kashmir Himalaya, India. Res. J. Bot., 11: 18-24.

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Soil is a critically important component of earth's biosphere playing an important role in water flow and retention, solute transport and retention, physical stability and support, retention and cycling of nutrients, buffering and filtering of potential toxic materials and maintenance of biodiversity and habitat[1]. Soil is one of the important ecological factors for the survival of plants since they get nutrients and water supply besides their dependency on anchorage. Not only this, plants in turn indirectly affect their neighbours in many ways and one of the most important is by altering the biotic, physical and chemical characteristics of soils[2]. Climate, another most dominant ecological factor, acting over parent material for a never ending large period of time is responsible for successive changes in soil development. Many morphological, physical, chemical, biochemical and macro and microbiological reactions and processes occur simultaneously and also interactively in soils which not only affect the soils own character slowly and steadily but also influence the immediate environment and the plants it supports and nourishes[3]. The reaction and processes which affect the soils character and their properties are in turn influenced by several natural factors viz., climate, organism, parent material and modified to a great extent by the relief features such as slope and altitude[3].

Soil fertility is an important factor, which determines the growth of plant. Soil fertility is determined by the presence or absence of nutrients i.e., macro and micronutrients[4]. Macronutrients such as nitrogen (N), phosphorus (P) and potassium (K) together make up the trio known as NPK. All these nutrients are accumulated by the plants in their bodies in different concentrations. However, these nutrients are usually lacking from the soil because plants use them in large amounts for growth and survival. Hence, these nutrients are known to govern the fertility of the soils, control the yields of the crops[5] and hence have agronomic importance.

In general, soil constitutes a bank of majority of nutrients essential for plant growth i.e., plants grow by absorbing nutrients from the soil. Their ability to do so depends on the nature of the soil. The various components of soil include mineral matter, soil organic matter or humus, soil water/soil solution, soil atmosphere and biological system. Soil organic matter has long been recognized as an important indicator of soil productivity. It refers to the organic fraction of the soil exclusive of undecayed plant and animal residues and plays a crucial role in maintaining sustainability of cropping systems by improving soil physical (texture, structure, bulk density and water-holding capacity), chemical (nutrient availability, cation exchange capacity, reduced aluminium toxicity and allelopathy) and biological (nitrogen mineralization bacteria, dinitrogen fixation, mycorrhizae fungi and microbial biomass) properties[6]. Soil organic matter is known to adsorb heavy metals from the soils and hence can reduce toxicity of these metals to plants and also reduce their escape to ground water.

The Kashmir Himalaya, being nestled within north-western folds of the Himalaya, harbours a rich floristic diversity of immense scientific interest and enormous economic potential[7]. Although, scientific studies on the floristic diversity in the Kashmir Himalaya have been started about two centuries ago, these studies were mainly focused on the enumeration of medicinal plants. In fact, many far flung areas and difficult terrains in the hinterland are still either least- or totally-unexplored ethnobotanically. Medicinal plants grow at different elevations in different soil types and are used by many communities as herbal remedies for the treatment of various health disorders. In order to meet the ever increasing demand of medicinal plants for indigenous systems of medicine as well as for pharmaceutical industries, medicinal plants need to be commercially cultivated, for which maintenance of soil chemical fertility is a key prerequisite. So far, no such study is carried out on analysis of soil chemical properties of medicinal plants especially those of threatened plants which are facing dire consequences of extinction with the current trend of their exploitation and destruction. Therefore, the aim of the present study was to estimate the various soil properties such as pH, organic carbon, available nitrogen, phosphorus and potassium of corresponding soil samples of threatened medicinal plants and to assess the effect of altitude in these properties. This study will generate a useful information that can be used for the successful cultivation of these plants at places of choice, simply by making some soil amendments.

MATERIALS AND METHODS

Study area: In the present study, Kashmir Himalaya is represented by Bandipora, one of the Northern districts of Kashmir in India (Fig. 1). Bandipora is a newly created district that was carved out from the erstwhile Baramulla district on 02-04-2007. It is mainly hilly and mountainous with stretches of plains and is full of natural beauty with thick forests. The region covers a geographical area of 398 km^2. It lies 34°64'N latitude and 74°96'E longitude and is situated at an average

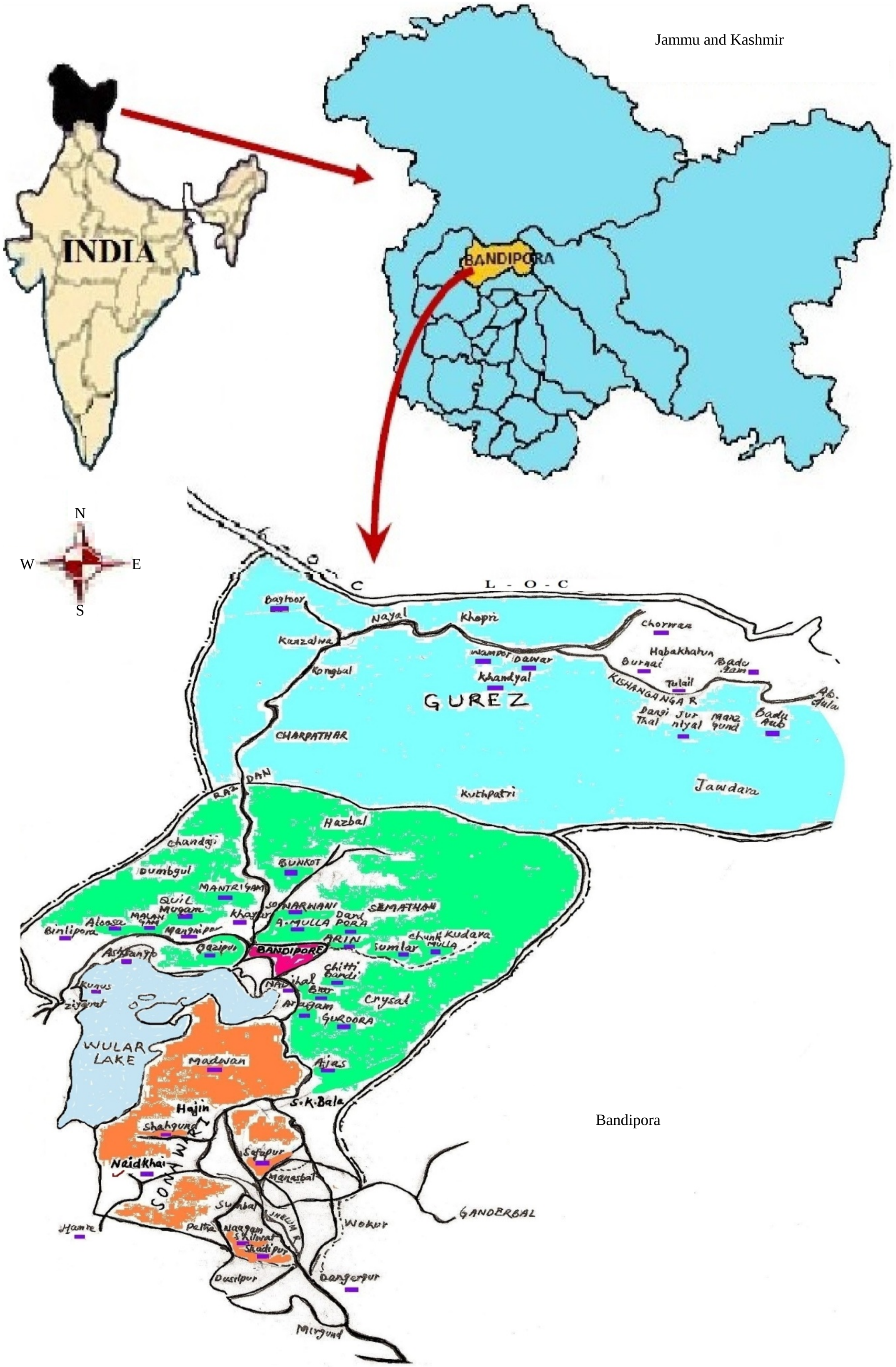

Fig. 1: Map of Bandipora (study area). Geometric co-ordinates are not shown because the area is highly restricted

height of 1701 m AMSL. The district is located on the Northern bank of the Wular Lake the largest fresh water lake in Asia. The total cultivable land in the district is 27028 ha while as the area under forests is about 199396 ha. The district has deciduous vegetation and due to its varied altitude and topography, it has a diverse flora. The climate of the district is moderate and is divided into six seasons of two months each. These include, spring (16 March to 15 May), summer (16 May to 15 July), rainy season (16 July to 15 September), autumn (16 September to 15 November), winter (16 November to 15 January) and ice cold (16 January to 15 March). All these seasons are locally called 'Sont', 'Retkol', 'Waharat', 'Harud', 'Wandh' and 'Shishur' respectively. The hottest months are July and August when the maximum temperature generally rises up to 32°C. The coldest months are January and February, when minimum temperature falls a few degrees below freezing point. The winters are usually harsh due to heavy snowfall and low temperatures.

Methods: During 2012, corresponding soil samples of 23 different threatened medicinal plants[8] of the region were collected from different land use conditions and of different altitudinal ranges. Actually for each sample at least four pits were dug and from each pit a sample was collected. Then all four samples (one sample from each pit) were mixed to retain a composite sample of about 1 kg. To avoid any contamination, soil samples were collected with the help of wooden tools. All composite samples were properly processed in the laboratory and analysed for parameters such as pH, organic carbon, available nitrogen, potassium and phosphorous. Following methods were applied for analysis of such parameters:

- pH by standard pH meter in a 1:2 soil water suspension
- Organic Carbon (OC) by rapid titration method[9]
- Available nitrogen (N) by alkaline permanganate method[10]
- Available phosphorus (P) by Olsen's method[11]
- Available potassium (K) by flame photometry[12]

RESULTS

As a result of field surveys, a total of 23 composite soil samples of 23 different threatened medicinal plants were collected. Following soil classification of Najar *et al*.[13], out of 23 medicinal plant soil samples 4 (17.39%) samples were collected from low land altitudes 1500-1700 m AMSL (Table 1), 3 (13.04%) from medium land altitudes 1701-1800 m AMSL (Table 2) and 16 (69.56%) from high land altitudes 1801 above meters AMSL (Table 3). These soils presented a variation in their analysed chemical properties. The range and average values of various estimated parameters of soils samples are presented in the Table 4.

The various plants of this study have been placed into different threat categories based on the already existing literature[14-19] and personal observations of the authors (when information regarding plant abundance, distribution, localities of their maximum availability, exploitation level and various threats was collected personally from local people especially from plant collectors of the area which was then confirmed with regular field trips).

The data clearly indicates that the pH of low land, medium land and high land medicinal plant soil samples varied from 6.9-7.3, 7.3-7.4 and 5.8-7.2 with mean values of 7.15, 7.33 and 6.31, respectively (Table 4). This means that the soils of low land and medium land were neutral to slightly alkaline, while those of high land were acidic. Organic carbon varied from 8.1-16, 10.8-26 and 17.8-37.2 g kg^{-1} with the mean values of 11.5, 16.4 and 26.7 g kg^{-1} in the low land, medium land and high land soils respectively (Table 4). Hence, all soils had high status of organic carbon. Available nitrogen ranged from 297-410, 311-371 and 280-399 kg ha^{-1} with the mean values of 350.25, 346.33 and 322.12 kg ha^{-1} in low land, medium land and high land soils, respectively (Table 4). Thus

Table 1: Estimated chemical properties of threatened plants collected from low altitude habitats (1500-1700 m AMSL)

Name of the plants	pH	OC (g kg^{-1})	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Threat status
Artemisia absinthium Linn.	7.1	16.0	410	23.0	125	R*
Crataegus songarica K. Koch	7.3	9.0	297	19.6	132	R*
Hyoscyamus niger Linn.	6.9	12.9	394	18.5	133	VU
Prunella vulgaris Linn.	7.3	8.1	300	22.3	131	R*

VU: Vulnerable, OC: Organic carbon, N: Nitrogen, P: Phosphorus, K: Potassium, R*: Rare categories defined based on field observations

Table 2: Estimated chemical properties of threatened plants collected from medium altitude habitats (1701-1800 m AMSL)

Name of the plants	pH	OC (g kg^{-1})	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Threat status
Bunium persicum B. Fedtsch.	7.4	12.6	357	24.8	168	EN
Colchicum luteum Baker.	7.3	10.8	371	23.3	156	VU
Dioscorea deltoidea Wall. ex Kunth	7.3	26.0	311	18.4	151	EN

EN: Endangered, VU: Vulnerable, OC: Organic carbon, N: Nitrogen, P: Phosphorus, K: Potassium

Table 3: Estimated chemical properties of threatened plants collected from high altitude habitats (1801 above m AMSL)

Name of the plants	pH	OC (g kg^{-1})	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Threat status
Aconitum heterophyllum Wall.	5.9	36.5	390	20.6	147	CR
Aconitum violaceum Jacquem. ex Stapf	7.2	37.2	399	19.7	153	VU
Ajuga parviflora Benth.	6.7	28.0	297	18.2	139	R*
Angelica glauca Edgew.	6.4	26.0	302	17.3	138	EN
Arnebia benthamii (Wall. ex G.Don)	6.5	25.6	298	22.0	142	CR
Cypripedium cordigerum D. Don	6.7	20.5	294	20.7	141	R
Inula racemosa Hook.f.	6.2	21.0	282	21.2	139	VU
Jurinea dolomiaea Boiss.	6.9	17.8	282	21.2	138	EN
Notholirion thomsonianum (Royle) Stapf	6.4	25.2	280	18.5	157	R*
Picrorhiza kurrooa Royle	5.8	28.0	398	22.6	156	EN
Podophyllum hexandrum Royle	5.8	32.0	367	18.2	160	EN
Rheum emodi Wall.	6.3	24.8	294	19.2	145	EN
Saussurea costus (Falc.) Lipsch.	6.1	21.0	283	20.2	147	CR
Taxus wallichiana Zucc.	5.9	36.6	392	19.4	141	EN
Trillium govanianum Wall.	6.2	28.8	306	20.3	137	R*
Valeriana jatamansi Jones.	6.1	18.9	290	18.4	138	VU

AMSL: Above mean sea level, CR: Critically endangered, EN: Endangered, K: Potassium, N: Nitrogen, OC: Organic carbon, P: Phosphorus, R: Rare, R*: Rare categories defined based on field observations, VU: Vulnerable

Table 4: Range and average values of estimated chemical parameters of plant soil samples

Soil properties	Low land (04)*	Medium land (03)*	High land (16)*
pH	6.9-7.3 (7.15)	7.3-7.4 (7.33)	5.8-7.2 (6.31)
OC (g kg^{-1})	8.1-16 (11.5)	10.8-26 (16.4)	17.8-37.2 (26.7)
N (kg ha^{-1})	297-410 (350.25)	311-371 (346.33)	280-399 (322.12)
P (kg ha^{-1})	18.5-23 (20.85)	18.4-24.8 (22.16)	17.3-22.6 (19.85)
K (kg ha^{-1})	125-133 (130.25)	151-168 (158.33)	137-160 (144.87)

*Figures in parentheses indicate the number of soil samples, figures in parentheses indicate the average value of various parameters, OC: Organic carbon, N: Nitrogen, P: Phosphorus, K: Potassium

all soils were medium in nitrogen availability. The available phosphorus in low land, medium land and high land altitude soils ranged from 18.5-23, 18.4-24.8 and 17.3-22.6 kg ha^{-1} with the mean values of 20.85, 22.16 and 19.85 kg ha^{-1}, respectively (Table 4). Hence, soils presented medium levels of available phosphorus. Concerning available potassium, it ranged from 125-133, 151-168 and 137-160 kg ha^{-1} with mean values of 130.25, 158.33 and 144.87 kg ha^{-1} in low land, medium land and high land soils, respectively (Table 4). Thus all the soils had also medium status of potassium.

DISCUSSION

High land soils had low pH (Acidic nature) probably because of leaching of bases due to higher rainfall besides release of organic acids by the slight decomposition of organic matter[3,20-23]. Whereas, the medium land soils were alkaline because of their calcareous nature. Soil organic matter is a store house of all essential plant nutrients besides organic carbon[24]. Organic carbon content of the soils showed an increasing trend from low land soils, medium land soils to high land soils. Comparatively more organic carbon content was recorded in high altitude soils[25] probably due to accumulation of higher amounts of organic matter because of wet conditions which favour luxurious plant growth and low temperature that decreases the rate of organic matter decomposition[3,13,22,23,26,27]. Low organic carbon content of low and medium land soils was probably because of high temperature and good aeration which are responsible for the increased rate of oxidation of organic matter[28]. According to Ekeke and Okokwu[29], the lower organic carbon content of low land soils can be attributed to low plant cover, as vegetation removal (due to anthropogenic factors such as collection of fuel wood, encroachment by agriculture and tree falling for construction) reduces the soil organic matter and affects the soil structure and function[30]. Notwithstanding this, the application of high amounts of mineral fertilizers might also accelerate mineralization process and therefore diminish organic carbon[31]. In comparison to medium and high land soils, available nitrogen was more in low land soils because in low land areas there is comparatively high temperature that triggers higher mineralization rates of organic nitrogen releasing more available nitrogen. The high level of available phosphorus reported in medium land soils was perhaps due to the calcareous nature of these soils. Moreover, the biggest reserves of phosphorus in soils are considered to be the rocks and other deposits, such as primary minerals including apatite, hydroxyapatite (hydroxyapatite is the mineral that forms bones and teeth) and oxyapatite. Next to medium land soils, low land soils had also sound levels of available phosphorus and the reason for this could be the regular applications of phosphorus fertilizers[32]. The medium status of potassium in all soils was probably due to the presence of illite and micaceous minerals[33-36]. Illite plays a key role in the supply of potassium and it can be used as a criterion to determine the potassium availability status of soils[30].

CONCLUSION

Based on present investigation, it is concluded that variations existed in the estimated chemical parameters depending on the environmental conditions (mainly altitude) wherefrom the studied soil samples were collected. In comparison to low land and medium land soils, higher altitude soils were found more suitable for the growth of plants, as there is accumulation of sufficient organic matter with subsequent increase in soil moisture due to more precipitation in the form of rain and snow. Available nitrogen (N) content, being a key element in plant growth was comparatively higher in low land soils because in such soils there is comparatively low plant cover and hence high temperature that triggers higher mineralization rates of organic nitrogen releasing more available nitrogen. Useful information concerning soil chemical properties generated in this study can be wisely exploited for successful cultivation of threatened medicinal plants at places of choice simply by making soil amendments.

SIGNIFICANT STATEMENTS

Soil is one of the natural resource upon which the plants depend for their nutrients, water and anchorage. Medicinal plants grow on different soil types and are locally used as herbal remedies against various health disorders. In order to meet the ever increasing demand of medicinal plants for indigenous systems of medicine as well as for pharmaceutical industries, medicinal plants need to be commercially cultivated, for which maintenance of soil chemical fertility is a key prerequisite. So far, no such study has been done to analyse the fertility condition of soils of medicinal plants facing consequences of extinction with the current trend of their exploitation and destruction. In this backdrop, present study was conducted to estimate the soil macronutrient status of threatened medicinal plants. Thus a useful information about fertility status of soils is obtained and if this information is utilized in the cultivation of these plants at places of choice, simply by making soil amendments, there is no doubt that the extinction of these precious resources can be checked. Besides the work of this type will widely serve as an asset for the welfare of present and future generations because it will not only meet the primary health care needs of the local people but also can boost the income of the local people.

ACKNOWLEDGMENTS

We acknowledge the help and guidance provided by Head, Division of Soil Sciences, Faculty of Agriculture, North Campus, Wadura Sopore, Sher-e-Kashmir University of Agricultural Sciences and Technology (SKUAST), Kashmir. We are also thankful to the Department of Science and Technology, New Delhi for providing financial assistance for this study.

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