International Journal of Plant & Soil Science

Volume 35, Issue 18, Page 1633-1640, 2023; Article no.IJPSS.103330
ISSN: 2320-7035

An Analysis of the Correlation between Physiochemical Characteristics of Soil and the Morphological Characteristics of *Grewia optiva* Drummond in the Northwestern Himalayan Region

Jyoti Dhiman [a++*], H. P. Sankhyan [a#], Neerja Rana [b†], Parul Sharma [c‡] and Shikha Thakur [a‡]

[a] Department of Tree Improvement and Genetic Resources, College of Forestry, Dr. YS Parmar University of Horticulture and Forestry, Nauni-Solan (HP), 173230, India.
[b] Department of Basic Sciences, College of Forestry, Dr. YS Parmar University of Horticulture and Forestry, Nauni-Solan (HP), 173230, India.
[c] Department of Biotechnology, College of Horticulture, Dr. YS Parmar University of Horticulture and Forestry, Nauni-Solan (HP), 173230, India.

Authors' contributions

This work was carried out in collaboration among all authors. Author JD did the survey, data collection of the manuscript. Author HPS draw the road map for data collection and research of the manuscript. Authors NR, PS and ST member of advisory committee, they provided laboratory guidance for testing soil samples and analysis of collected data of the manuscript. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2023/v35i183436

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/103330

Original Research Article

Received: 18/05/2023
Accepted: 25/07/2023
Published: 05/08/2023

[++]Ph. D. student;
[#]Professor and Head;
[†]Associate Professor;
[‡]Assistant Professor;
**Corresponding author: E-mail: jyotid175@gmail.com;*

ABSTRACT

Continued research on the physiochemical properties of soil is critical for the long-term maintenance of cropping systems, (including trees), in order to harness their economic benefits. The current study was carried out in the Department of Tree Improvement and Genetic Resources, COF, Nauni, Solan (H.P.) during the period 2020-2023 to quantify the impact of soil nutrient variation on the morphological characteristics of *Grewia optiva* Drummond in different districts with variable climate and heterogeneous soils. The impacts on growth parameters (tree height, crown spread, leaf traits) of selected populations of *Grewia optiva* Drummond statistically analyzed using Karl Pearson correlation coefficient. Two composite soil samples representative of the different populations were drawn from the two depths *i.e.,* 0-15 cm (surface layer) and 15-30 cm (subsurface layer). These samples were collected underneath the selected populations of *Grewia optiva* Drummond. The collected soil samples were tested using standard soil methods and results were analysed using OPSTAT software. There was highly positive correlation observed between leaf area and soil N (0.509), leaf area and SOC (0.407), leaf area and soil P (0.728) and leaf area and soil K (0.577). Leaf length showed a highly significant correlation with SOC (0.401), soil N (0.509), soil P (0.710), and soil K (0.592). The tree height (0.385), tree diameter (0.602), crown spread (N-S) (0.629), crown spread (E-W) (0.334), branch nodal length (0.436) and leaf width (0.470) showed a significant positive correlation with soil P. Soil K showed a significant positive correlation with tree height (0.774), tree diameter (0.645), crown spread (N-S) (0.576), crown spread (E-W) (0.314), branch nodal length (0.737) and leaf width (0.592). Soil pH demonstrated highly significant correlation with Leaf width (0.449). The correlation developed between tree morphological and soil characteristics will help in quantify the impact of different soil characteristics on tree and leaf morphometric characteristics. It will further help in identification and selection of superior genotypes of *Grewia optiva* for further propagation to get improved genetic gain and for production of quality planting material.

Keywords: Grewia; yield; fertilization; soil quality; nitrogen; crop production.

1. INTRODUCTION

"Grewia optiva, often known as Biul/Bihul or Bhimal, is a plant belonging to the Tiliaceae family. This species is favoured by mountainous farmers in Uttarakhand, Himachal Pradesh, Nepal, and elsewhere for qualities like as palatability, rapid growth, ease of propagation, and fodder production" [1]. "It supplies fodder during the lean season when there is no alternative to green fodder. It possesses more than 70 (%) potential DM digestibility and 56.7 percent effective degradability, making it a great energy source for ruminants" [2,3]. "*Grewia* is a genus with around 150 species worldwide, 42 of which are located on the Indian subcontinent" [4].

"Soil consists of definite chemical, physical, mineralogical and biological properties, which provide a medium for plant growth" [5]. " The knowledge of physiochemical properties viz; organic carbon, available Nitrogen (N), Phosphorus (P_2O_5), Potassium (K_2O), pH, electrical conductivity, soil texture and bulk density of soil is also important to determine the available nutrient status in soil and to develop specific fertilizer recommendations" [6]. "The soil organic matter content, electrical conductivity and pH regulates not only macronutrients (N,P,K) but also micronutrinets (Zn, Fe, B and Cu) for better uptake in plants" [7] "The response of trees to increasing atmospheric CO_2 concentrations is often mediated by the availability of nutrients in the soil" [8]. "Whether terrestrial ecosystems, forests, cropland trees are sources or sinks for CO_2 and their growth will ultimately depend on interactions of the C cycle with the cycles of nutrients, especially nitrogen (N) and phosphorus (P)" [9]. "An increased production of exoenzymes has been found in several studies with CO_2 enrichment, and this effect has depended on the availability of N in the soil" [10,11,12]. "Nitrogen (N) is one of the most important biological elements for plants, agricultural crops and forest trees, because it is a component of amino acids, proteins, genetic materials, pigments, and other key organic molecules" [13,14,15]. "N has an irreplaceable role in organ construction, material metabolism, fruit yield, and the quality formation of fruit trees" [16]. "Soil nitrogen (N) deficiencies can affect the photosynthetic N-use efficiency (PNUE), mesophyll conductance (g_m), and leaf N allocation" [17]. "Potassium (K) is used for flowering purpose, it is also required for building of protein, photosynthesis, fruit quality and reduction of diseases" [18]. "Potassium is an activator of dozens of important enzymes, such as protein synthesis, sugar transport, N and C metabolism, and photosynthesis. It plays an important role in the formation of yield and quality improvement" [19,20]. "Potassium has strong mobility in plants and plays an important role in regulating cell osmotic pressure and balancing the cations and anions in the cytoplasm" [21]. "Phosphorus (P) is also an essential plant nutrient for various tree growth functions" [22]. "Plants take up Phosphorus in its inorganic form as phosphate" [23]. Phosphorus limitation decreases the efficiency of plant respiration [24] and night respiration may increase along the N/P ratio. "Therefore, considering the importance of the physiochemical properties of the soil mentioned above, the present study was carried out to perform a correlation and nutritional analysis of the soil under the populations of *Grewia optiva* Drummond in Himachal Pradesh and Uttarakhnad" [25].

2. MATERIALS AND METHODS

2.1 Site Description and Data collection

The present study was carried out in four altitudinal zones *viz*; 400 to 800 m, 801-1200 m, 1201-1600 m and 1601-2000 m above mean sea level (a m s l), of Himachal Pradesh (HP) and Uttarakhand (UK). In each altitudinal zone, five populations (4 from HP and 1 from UK) were selected. The total populations under study were twenty. On each site/population, four trees of 20-30 cm diameter class were marked accordingly. The soil samples were collected during the month of November, when the species was in the seed ripening and fodder lopping stage. Two composite soil samples representative of the different population were drawn from the two depths *i.e.,* 0-15cm (Surface layer) and 15-30cm (subsurface layer). These samples were collected underneath the selected twenty populations of *Grewia optiva* Drummond. Each sample was air dried, grounded with wooden pestle and mortar, sieved through 2 mm sieve and stored in plastic containers. The soil samples were then analysed for morphological (soil colour), physiochemical (bulk density, particle density, porosity, pH, EC), and available nutrient status using standard methods Table 1.

2.2 Experimental Design

Total Sites/ Populations	:	20
No. of composite samples of soil from each site/Population	:	2 (at two depth: 0-15cm & 15-30cm)
Total number of soil composite samples /treatments	:	40(20× 2)
Soil Depth	:	0-15 & 15-30cm
Design	:	RBD(Factorial)

2.3 Statistical Analysis

Karl pearson correlation coefficient ($p<0.05$) used to find correlation between physiochemical properties of soil and morphological characteristics of selected population of *Grewia optiva* which had been recorded simultaneously.

3. RESULTS AND DISCUSSION

Karl Pearson's correlation coefficients (at 5% level of significance) for tree and leaf morphometric characteristics (of different populations of *G. optiva*) and physiochemical characteristics of soil were worked out. It was evident from Table 2 and Fig. 1 that leaf area showed a significant positive correlation with soil N (0.509), SOC (0.407), soil P (0.728), and soil K (0.577). Leaf length showed a highly significant correlation with SOC (0.401), soil N (0.509), soil P (0.710), and soil K (0.592). The tree height (0.385), tree diameter (0.602), crown spread (N-S) (0.629), crown spread (E-W) (0.334), branch nodal length (0.436) and leaf width (0.470) showed a significant positive correlation with soil P. Soil K showed a significant positive correlation with tree height (0.774), tree diameter (0.645), crown spread (N-S) (0.576), crown spread (E-W) (0.314), branch nodal length (0.737) and leaf width (0.592). Soil pH showed highly significant correlation with Leaf width (0.449). Similar results recorded in Douglas-fir by Brix and Ebell [31], which revealed that "fertilization with Nitrogen increased basal area increment, stem height, and branch length, leaf area, leaf length-width, the no. of leaves per shoot increased markedly". Wang et al [32] reported "increased specific leaf area (SLA) and leaf area index (LAI) with N fertilization". A study on *Fagus sylvatica* by Meier and Leuschner [33] reported "positive effects on leaf area and LAI in forests with increased in nitrogen availability". In a similar study by Herbert and Fownes [34] "in native *Metrosideros polymorpha* forest showed

Table 1. Soil parameters analyzed with their methods of measurements

Sr.No.	Soil Parameters	Analysis Method Used
1	Soil colour	Munsell soil colour chart
2	pH	Digital pH meter [26].
3	Organic carbon (%)	Chromic acid titration method [27]
4	Available Nitrogen (kg ha^{-1})	Micro Kjeldhal Method [28]
5	Available Phosphorus (kg ha^{-1})	0.5 M sodium bicarbonate ($NaHCO_3$) at 8.5 pH [29]
6	Available K (kg ha^{-1})	Flame photometric method (1N NH_4OAC extractable) [30]
7.	EC (dSm^{-1})	Digital EC meter [26]

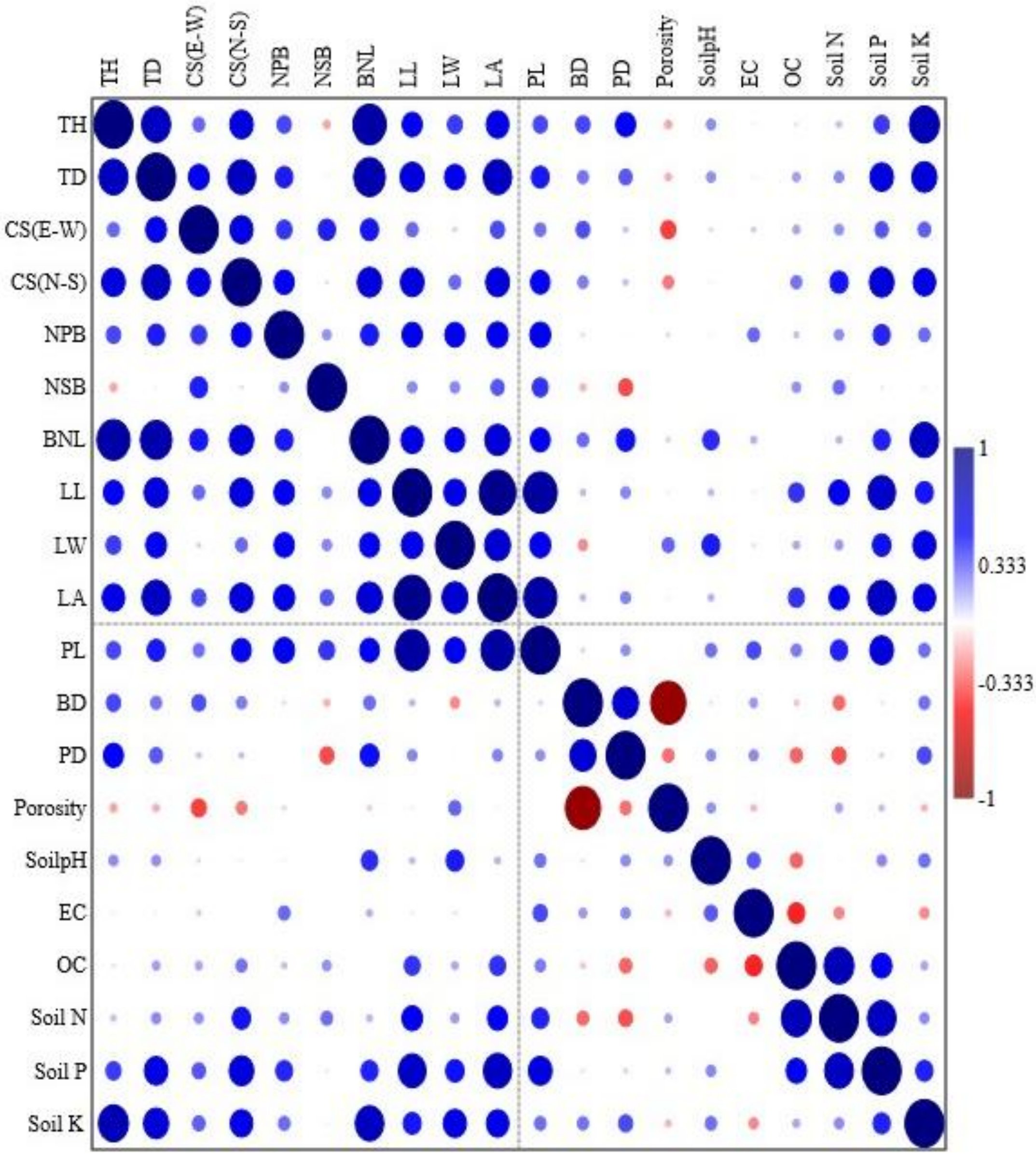

Fig. 1. correlation between physiochemical characteristics of soil and tree and leaf morphometric characteristics of *Grewia optiva* drummond

here TH-tree height, TD-tree diameter, CS-crown spread, NPB-number of primary branches, NSB-number of secondary branches, BNL-branch nodal length, LL-leaf length, LW-leaf width, LA-leaf area, PL-petiole length, BD-bulk density, PD-particle density, EC-electrical conductivity, OC-organic carbon, N-nitrogen, P-phosphorus, K-potassium

Table 2. Correlation between physiochemical characteristics of soil and tree and leaf morphometric characteristics of *Grewia optiva* drummond

Parameters	TH	TD	CS (E-W)	CS (N-S)	NPB	NSB	BNL	LL	LW	LA	PL	BD	PD	Porosity	Soil pH	EC	OC	Soil N	Soil P	Soil K
TH	1																			
TD	0.747**	1																		
CS(E-W)	0.300	0.533**	1																	
CS(N-S)	0.602	0.728	0.588**	1																
NPB	0.362	0.445	0.396	0.512**	1															
NSB	-0.178	0.026	0.442	0.065	0.215	1														
BNL	0.851	0.816	0.460	0.628	0.452	-0.016	1													
LL	0.512	0.623	0.298	0.605	0.522	0.230	0.572	1												
LW	0.383	0.531	0.090	0.294	0.517	0.236	0.513	0.562	1											
LA	0.581	0.732	0.358	0.610	0.541	0.332	0.655	0.944	0.665	1										
PL	0.362	0.456	0.281	0.495	0.534	0.400	0.503	0.867	0.534	0.852	1									
BD	0.361	0.273	0.348	0.257	-0.079	-0.155	0.291	0.136	-0.232	0.138	0.084	1								
PD	0.508	0.328	0.119	0.123	-0.023	-0.357	0.476	0.237	0.024	0.246	0.221	0.669	1							
Porosity	-0.179	-0.165	-0.380	-0.268	0.080	-0.003	-0.103	-0.043	0.307	-0.038	0.013	-0.903	-0.286	1						
SoilpH	0.225	0.221	0.078	0.037	0.028	0.008	0.416	0.135	0.449	0.148	0.282	-0.067	0.229	0.214	1					
EC	0.038	-0.042	0.105	-0.009	0.294	-0.011	0.154	0.046	-0.069	0.003	0.359	0.201	0.229	-0.145	0.328	1				
OC	0.062	0.192	0.178	0.273	0.127	0.217	-0.017	0.401**	0.169	0.407**	0.260	-0.120	-0.310	-0.018	-0.312	-0.433	1			
Soil N	0.129	0.230	0.220	0.464**	0.226	0.291	0.147	0.525**	0.202	0.509**	0.434**	-0.297	-0.350**	0.182	0.018	-0.244	0.770	1		
Soil P	0.385**	0.602**	0.334**	0.629**	0.429**	0.049	0.436**	0.710**	0.470**	0.728**	0.607**	-0.064	0.088	0.130	0.236	0.010	0.522	0.738	1	
Soil K	0.774**	0.645**	0.314**	0.576**	0.289	-0.043	0.737**	0.458**	0.592**	0.577**	0.287	0.277	0.356**	-0.149	0.284	-0.232	0.174	0.229	0.437	1

***5% level of Significance, where TH-tree height, TD-tree diameter, CS-crown spread, NPB-number of primary branches, NSB-number of secondary branches, BNL-branch nodal length, LL-leaf length, LW-leaf width, LA-leaf area, PL-petiole length, BD-bulk density, PD-particle density, EC-electrical conductivity, OC-organic carbon, N-nitrogen, P-phosphorus, K-potassium* that increased available phosphorus promoted an increase in photosynthetic area which led to increased tree growth". A similar study in *Eucalyptus grandis* by Battie-Laclau et al [35] reported that "K and Na applications enhanced tree leaf area by increasing both leaf longevity and the mean area of individual leaves". "The most important role of pH is the control of nutrients solubility in soil. Nutrient availability usually decreases with increasing pH" [36]. "EC values affects uptake of nutrients by the tree. Very high or low EC decreases plants leaf size, leaf water content, leaf net photosynthetic rate (P_n), stomatal conductance (G_s), transpiration rate (T_r)", [37]. "Soil organic carbon is a natural resource for the sustainable development of human society and a key foundation for sustainable forestry development" [38]. "It plays an important role in the formation and conservation of soil structure, soil nutrient cycling and soil biodiversity. Nitrogen is considered to be the most important nutrient, and plants absorb more nitrogen than any other element. Nitrogen is essential in the formation of protein, and protein makes up much of the tissues of most living things. Increase in available phosphorus affected positively leaf area, crown spread, no. of branches and fruit. Phosphorus, is linked to a plant's ability to use and store energy, including the process of photosynthesis. It's also needed to help plants grow and develop normally" [39]. "Potassium is known to affect cell division, cell permeability formation of carbohydrates, translocation of sugars, various enzyme actions and resistance of some plants to certain diseases" [40,41]. It helps strengthen plants' abilities to resist disease and plays an important role in increasing crop yields and overall quality. Potassium also protects the plant when the weather is cold or dry, strengthening its root system and preventing wilt. Available soil Nitrogen (promotes leaf growth), Phosphorus (root, flower, and fruit), and Potassium supports stem and root growth and protein analysis.

4. CONCLUSION

The correlation developed between tree morphological and soil characteristics will help in quantifying the impact of different soil characteristics on tree and leaf morphometric characteristics and help in selection of superior populations, further improvement and fertilizers recommendation dose. This study will help in identification and selection of superior genotypes of *Grewia optiva* for further propagation to get improved genetic gain and for production of quality planting material.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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