IMPACT OF ANGIOSPERMS CANOPY ON SOIL ENRICHMENT IN CHOLISTAN DESERT

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***Abstract*: Soil flora is of immense importance to enhance the edaphic factors of any ecosystem and it is well known that the growth and development of the plants are majorly supported by the availability of nutrients in the soil. The objective of the present investigation was to study the effects of canopies of selected fifteen angiosperm trees in the Baghdad-ul-Jadeed Campus of "The Islamia University of Bahawalpur, Pakistan" a sandy land of the Cholistan desert. For this purpose, the physio-chemical properties of soil and the availability of micro and macro-nutrients present in the soil, under the canopies of selected species were recorded and compared with that of un-canopied and fertile soil. The collected soil samples were sieved, oven-dried, and then analyzed through inductively coupled plasma-optical emission spectroscopy and Kjeldhal's apparatus for the determination of macro and micro-nutrients. The studies showed that the concentrations of macro and micronutrients were high in considerable amounts in the soil samples taken from canopied zones as compared to un-canopied zones. Highest nitrogen contents were observed in *Callistemon viminalis* i.e. 0.8288$\pm$0.0395. Comparing the micro-nutrients of barren and fertile soil, it was demonstrated through results that most of the selected tree species soil samples showed considerable amounts of micronutrients present in them. It was evident that due to the presence of angiosperm trees, the pH of the soil samples changed from extremely alkaline to less alkaline, hence improving its fertility. Results also revealed that the texture of the soil was sandy due to the desert ecosystem which changed to clayey nature due to the presence of studied trees. Amongst 15 canopied soil samples, angiosperms *Tamarix aphylla* exhibited maximum electrical conductivity 5.19$\pm$0.0256 and minimum pH 7.84$\pm$0.043. It was also found that soil under *Moringa oleifera* showed maximum moisture content (i.e. 5.30$\pm$0.002). The overall picture of the recent study indicated that angiosperms have positive impacts on the soil parameters which enhance its fertility.

***Index terms*:** Soil fertility, angiosperms, EC, pH, moisture contents, soil texture, macro, and micro-nutrients.

I. INTRODUCTION

The topmost layer of Earth's crust is soil that supports the entire life existing on Earth. Soil fertility is contributed by certain soil components such as soil water, soil texture soil nutrients, etc. Soil of different types has different effects on plant growth and development (Bossio *et al.,* 2020). Soil quality is of cardinal importance for agricultural production, and soil fertility is gaining high importance in regard to food security, poverty reduction, and environmental management. For the cause of global food security and safe ecological management, soil fertility management is getting more and more interest (Assefa and Tadesse, 2019). (Han, *et al.,* 2021) define soil fertility as the ability of the soil to provide plants with nutrients, water, and oxygen. But soil fertility may also merely be defined as the capacity or the ability of the soil to help in the growth and metabolism of plants and trees (Abakumov *et al.*. 2023). The GDP contribution of Agriculture in any country depends upon the fertility of its soil.

Agriculture is a key economic sector and the main source of income and fulfills the basic needs of the persistent population in Pakistan. Fertile soil is the foundation of a sustainable agricultural system (Abakumov *et al.*, 2023). Soil is often ignored, in the plant-animal-soil continuum, because it does not indicate stress in an obvious way. A soil that is rich in nutrients is termed fertile. The expectation of growing plants as food must include the reality that plants will take nutrients out of the soil (Lehmann *et al.*, 2020). The importance of soil fertility cannot be denied. No fertile soil means, no plants, and no plants mean, no food for us (Nair and Nair, 2019). Soil fertility ensures plants and our survival. For this sake we should help farmers increase soil fertility and improve the productivity on their land in sustainable ways (Katiyar *et al*., 2022). Nowadays the creation of a new biotope on ruined lands is the most focused objective at the global level. Rehabilitation of soil for nutrients is the basic goal of fertilization. Improper fertilization in the past has caused serious controversy, but the basic assumption of fertilization is to replenish the soil. Soils feed the plants which in turn feed the animals that feed us. Fertilization is an important issue because it is required to produce sufficient food for the increasing population from the decreasing cultivated land (Ait Elallem *et al.*, 2021).

The fertility of soil depends upon the physiochemical properties of soil like pH, EC, moisture content, and the availability of macro and micro-nutrients. The pH of a soil is to quantify the soil's acidity, or hydrogen (H^+) ion concentration. Soil pH has immense effects on the availability of many nutrients (Ghazali *et al.*, 2020). The reason is that pH affects both the chemical forms and solubility of nutrient elements. Trace elements such as iron, zinc, and manganese are more available at lower pH than most nutrients, whereas molybdenum and magnesium are more available at higher pH than many other nutrients. The optimum soil pH range for many crops is slightly acidic, between about 5.8 and 7.0, because in that range there is a well-balanced availability of all nutrients (Pahalvi *et al.*, 2021). Likewise, the EC level of the soil water is a good indication of the amount of nutrients present for the crops to absorb. Mapping and monitoring of the EC level are needed to establish its areal extent and also to keep a record of changes in salinity, to formulate properly required and timely management strategies for improvement, reclamation, and rehabilitation of such soils (Hossain *et al.*, 2020). Plants are damagingly affected, both physically and chemically, by excess salts in some soils and by high levels of exchangeable sodium in others (Pahalvi *et al.*, 2021). Similarly, moisture content is useful in a wide range of scientific and technical areas and is expressed as a ratio, which can range from 0 to the value of the materials' porosity at saturation. Differences in water availability between sites of similar topography will be dominated by soil characteristics and their influence on hydrology (Dobrowolski *et al.*, 1990). It can be given on a volumetric or mass (gravimetric) basis. However as far as soil texture is concerned the relational amounts of different particle sizes in a soil specify its texture, i.e. whether it is a clay, loam, sandy loam, or other textural classes (Pepper and Brusseau, 2019). Different soil properties are influenced by texture including drainage, water holding capacity, aeration, susceptibility to erosion, organic matter content, cation exchange capacity (CEC), pH buffering capacity, and soil tilth. It also determines the rate at which water passes out through saturated soil. In soil fertility, coarser soils generally have a lesser ability to hold and retain nutrients than finer soils. However, this ability is reduced as finely textured soils undergo intense leaching in moist environments (Barman and Choudhury, 2020). Hence all these factors are a prime contributor in the enrichment of any soil sample.

Macro & micro elements are required by the plants for their proper growth. One aspect of successful crop production is knowing the nutrients required to grow plants (Kumar *et al.*, 2021). Significant yield also requires the proper knowledge of the quantity to apply, the procedure and time of application, the source of nutrients to use, and how the elements are influenced by edaphic and weather conditions (Toor *et al.*, 2021). Plants require nitrogen for the production of proteins, nucleic acids (DNA and RNA), and chlorophyll (Sun *et al.*, 2020). Potassium is involved in the process of photosynthesis, carbohydrate translocation, and protein synthesis (Sustr *et al.*, 2019). Calcium is required by the plants for regulatory functions. It has a part in cell wall structure and it also stabilizes membranes (Thor, 2019). Magnesium is the fundamental component of chlorophyll, the other green coloring material of plants; hence it is vital for photosynthesis (Koch *et al.*, 2020). Copper was also thought to be involved as an enzyme activator and in chlorophyll formation although its specified role is still unknown. It was also linked to protein synthesis (Mir *et al*., 2021). Zinc is involved in the enzyme systems that regulate various metabolic reactions taking place in plants (Cabot *et al.*, 2019). Manganese helps iron in chlorophyll synthesis (Hauer-Jákli and Tränkner, 2019). Other studies have revealed that Iron promotes the formation of chlorophyll, an enzyme mechanism that operates the respiratory system of cells and all the reactions involving cell division and growth (Mehboob *et al.*, 2022). So the importance of these nutrients can never be denied.

The deficiency of these nutrients can cause certain diseases and damage to plants. Low crop quantity and quality, defective plant morphological structure (small number of xylem vessels), widespread invasion of various diseases and pests, low activation of phyto-siderophores, and lower fertilizer usage efficiency were some of the disorders that arise due to nutrient deficiency (Barbedo, 2019). Researchers found that properties of soil e.g. pH, EC, and texture also affected the rate of availability of nutrients in soil. With an increase in soil pH, the availability of iron, manganese, copper, and zinc decreases, and as far as texture is concerned poorly drained soils usually had poor aeration which resulted in iron, zinc, and manganese deficiencies (Sun *et al*., 2020). Organic carbon and total nitrogen contents were higher in the secondary forest soil as compared to other land cover soils due to the thick canopy cover (Sethy *et al.*, 2020).

However, it was also found the thick canopy cover enhances the nutrient accretion in the soil by decreasing the loss of nutrients through soil erosion and leaching (Majasalmi and Rautiainen, 2020). The effects of long-term burning and cutting of plant biomass on the mineral nutrition of *A. sparsifolia* and associated soils were studied and it was found that burning effects inclined to be restricted to the topsoil but it was evident that the concentration of many micro-and macronutrients was increased (Akash *et al.*, 2022). The effects of canopy cover of *C. decidua* were also studied and it was found that the plant improved the nutrient-deprived sandy soils by enhancing the soil nutrient level (Yasin *et al.*, 2016). In another study, it was also observed that the impact of angiospermic trees helps yield better crops to enhance the macro and micronutrients (Vivanco and Austin, 2019).

In the recent investigation, the impact of 15 angiospermic trees on the macro and micro-nutrients present in the desert soil was studied. It was hypothesised that the presence of these trees would enhance all the above mentioned parameters that are required by the soil to increase its fertility. It was evident from the results that the leaf foliage of these plants enhanced the edaphic factors of soil thus contributing to soil enrichment which is a global concern these days.

II. MATERIALS AND METHODS

2.1 Selected Angiosperms

The angiosperms selected for this study are given below in Table 1.

Table 1. Names and codes of selected trees with their codes for statistical data.

SERIAL NO.	SELECTED TREES	COMMON NAMES	CODES FOR STATITICAL DATA
1	*Dalbergia sissoo* Roxb.	Rosewood	D. sis
2	*Cassia fistula* Linn.	Golden shower	C.fis
3	*Mangifera indica* Linn.	Mango	M. ind
4	*Syzygium cumini* Skeels.	Java plum	S.cum
5	*Tamarix aphylla* Linn.	Athel pine	T.aph
6	*Ficus religiosa* Linn.	Pepal	F.rel
7	*Azadirachta indica A.* Juss.	Neem	A.ind
8	*Albizia lebbeck* Benth.	Lebbek	A.leb
9	*Callistemon viminalis* Curtis.	Bottlebrush	C.vim
10	*Phoenix dactylifera*	Date palm	P.dac
11	*Eucalyptus camaldulensis* Dehnh.	Red gum	E.cam
12	*Moringa oleifera* Linn.	Horse radish	M.ole
13	*Acacia nilotica* Hill.	Babol	A.nil
14	*Acacia ampliceps*	Acacia	A.amp
15	*Pterospermum acerifolium* Linn.	Bayur	P.ace

2.2 *Soil samples*

Soil samples were collected from the vicinity of the Cholistan Institute of Desert Studies, Islamia University, Baghdad-ul-Jadeed, Bahawalpur. The purpose behind, selecting this site is to study and examine the effects of angiospermic canopy covers of different shrubs on the soil fertility parameters and to make some better recommendations than using fertilizers and other chemicals. The samples of un-canopied (barren) soil were also collected from the Cholistan desert near the sampling sites for comparison of soil quality. To compare the soil samples for soil quality a soil sample of an ideal fertile soil was also collected from Govt. Dept. of Agriculture and Soil Research Centre Bahawalpur. All the soil samples were collected at a depth of 6 inches and at a distance of 25cm away from each plant stem during the summer season. Soil samples were then carefully named and taken to the Cholistan Institute of Desert Studies laboratory. Afterward, all the samples were properly sieved and put into labeled containers for further analysis.

2.3 *Preparation of Solutions*

For the titration, 0.1 N solution of HCl was prepared. 9.74 ml of stock hydrochloric acid (10.27 N) was put in a 1 litre volumetric flask and then diluted with distilled water up to the gauge marked at its neck. For nitrogen determination, 35% solution of sodium hydroxide was made (35 g sodium hydroxide in 100 ml of water). 4% Boric acid solution was prepared by taking 4 g of boric acid in 100 ml water. Chemicals and reagents used in the present study for macro and micro-nutrient determination were analytical grade. De-ionized water was used for the preparation of all test samples and standards. Analytical grade chemicals; 69 % nitric acid of BDH, product number 10168Accuemulti standard was used for trace metal analysis. The concentration of standard used was 1000 mg/L (lot number 212045120). Other chemicals used, include MES-04-1, hydrochloric acid 37% (lot No. H0026NA). For pH calculations de-ionized water and standard buffer solutions of pH 4.0, 7.0, and 9.2 were used. Electrical conductivity calculations were carried out using 0.01 N KCl solution which was prepared by dissolving 0.7456 g KCL in 1 litre of distilled water.

2.4 Determination of Nitrogen Contents:

Protein content in soil samples were analyzed by Kjeldhal's apparatus according to AOAC official methods of analysis, method 978.04, which is as follows:

Preparation of sample: 5g of sample was taken, which is finely sieved, in order to obtain a homogenous mixture in the digestion tube. Samples were then dried in oven at 105^{0}C for 5 hours.

Digestion Process: Digestion is a chemical method to decompose the sample by using acid and salt. To each sample, 7g of anhydrous Potassium Sulphate, 5mg selenium powder, 5ml H_2O_2 35%, 7ml of 98% concentrated H_2SO_4 and 2, 3 boilers were added in the digestion tube. Then the digestion tube was shaken properly to wet the sample. Digestion was carried out for 30 minutes at 420^{0}C. Actually, digestion is required to break the all nitrogen bonds to change them into Ammonium ions. Digestion does not depend only on the acid used but also depends on the temperature, which is given during the digestion process.

Cooling: After digestion, the sample was cooled till the temperature reached up to 50 to 60^{0}C.

Distillation: Distillation was carried out by using 35% NaOH solution and 50% water. 4% Boric acid solution was used for distillation which was carried out in an Erlenmeyer flask. During the process of distillation, ammonium ions were converted to ammonia. This was further used for titration. Distillation is the phenomenon in which liquid components are separated on heating till the point of vaporization and cooled samples are collected to obtain a purified form.

Titration: Titration is a quantitative chemical analysis that is used to find out the unknown concentration of an identified analyte. Nitrogen was determined by using 0.2 N solution of HCl. A mixture of bromo-cresol and methyl red was used to check the end point of titration. The indicator gave a purple color at the start, on titrating it became colourless. Further on the addition of one drop of HCl solution, it turned pink.

Calculations: Nitrogen contents were determined by using this formula;

$$N\% = (T - B) \times N \times 1.4 / S$$

N = Normality of acid used 0.1 N

T = Sample titration

B = Blank titration

S = Wt. of sample 1 gram

2.5 Determination of macro and micro nutrients

Soil samples were analyzed for macro and micronutrients through Inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-OES). For this purpose, all the samples were weighed, dried, ground, and put into a crucible. Then the samples were washed for two hours at 500ºC and then cool. After cooling ash was wet with a few drops of water and then 3 to 4 mL HNO_3 (1+1) was added to it. Then the excess HNO_3 was evaporated on a hot plate set at 100^0C. Now place the crucible into furnace and ash again for 1h at 500 ^{0}C. Then the crucible was cooled. After which the ash was dissolved in 10 mL HCL (1+1) and was transferred quantitatively in a volumetric flask, diluted to volume with de-ionized water. The samples were analyzed for micro and macro elements by Inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-OES) by Optima 2000 DV Perkin Elmer.

2.6 PH Determination

Apparatus

The apparatus required for pH determination includes a no. 10 sieve, 4.25-cm3 volumetric scoop for soil to be used, a 50 mL cup, some pipettes with 5mL and 10 mL capacity, a stirring apparatus, a pH meter, some Glassware and dispensing apparatus, and an analytical balance.

Reagents

The reagents required for this process include buffer solutions with pH 10.0, 7.0, and 4.0.

Procedure

5g meshed sample was weighed for SMP buffer determination and put into the cups. 5mL water with the help of a pipette was added to the cup and stirred for 5 seconds. Soil samples were given a 10 minutes stay so that they may stabilize. The pH meter was then calibrated and while stirring the water and soil slurry, the electrode of the pH meter is lowered into the paste. Then the pH is read and recorded. The results are then reported as water pH.

2.7 Electrical Conductivity Determination

The standard test method proposed by the United States Salinity Laboratory Staff 1954, was followed for the determination of EC of selected soil samples, which is given below:

Equipment/apparatus required

To determine the EC of the soil samples we required a conductivity meter, 2-3 beakers, and a suction pump or some filter papers.

Procedure

Saturation extracts were used for EC determination, which was obtained from the soil samples with the help of suction pumps using a negative pressure of 1 atmosphere. Extract temperature was noted and adjusted on the conductivity meter with the help of the knob provided. For each investigation the conductance cell was washed with distilled water and then with extract. Then cell was dipped into the cell making sure that there was no air bubble in it. Conductivity corrected at $25^{/}$C was displayed in mS cm^{-1}or dS m^{-1}.

Formula Used:

$$\text{Dilution Factor (d.f)} = \frac{\text{Vf (total volume of diluted solution)}}{\text{Vi (volume of aliquot taken for dilution)}}$$

2.8 Determination of Moisture Contents

Moisture content was determined by using oven. Soil samples were collected and properly sieved. Then 1 g weighed soil samples of angiosperm trees were taken in oven oven-dried crucible and kept in oven for 5 hours at 105ºC. Moisture content was determined by using the formula:

$$\text{\% of moisture contents} = \frac{\text{Wt. of sample lost after heating}}{\text{Wt. of sample used}} \times 100$$

2.9 Determination of Soil Texture

Soil texture was determined by feel method at Soil and Water Testing/Soil Chemistry laboratories, Agriculture Department Bahawalpur, Government of Punjab. For this purpose, soil is rubbed between the fingers and judged as sandy if it feels gritty. The soil can be categorized as silty if it feels smooth and it can be labeled as clayey feels sticky.

2.10 Statistical Analysis

Results were compiled on Excel sheets and then standard error and deviation were applied, using SPSS software to get more reliable results (Landers 2023). PCA was applied to the data collected from SPSS to determine the principle component relationships in the best possible ways which lessened the intricacy and noise of the data and focused on the most important features (Bro and Smilde, 2014). A cluster dendrogram was also formulated to analyze the results in a more precise way and provide a visual representation of the clustering results, making it easier to understand and interpret the data (Forina *et al.*, 2002).

III. RESULTS

3.1 Results for Nutrient Availability in Soil Samples

Nitrogen, magnesium, calcium, and potassium were investigated as macronutrients in the selected soil samples. For comparison, the nitrogen contents in fertile and un-canopied soil were also calculated. Nitrogen contents were determined by a series of processes, which indicated that the maximum nitrogen observed in fertile soil was 4.0345±0.1385, while it was expressed from the results of un-canopied soil that showed least contents, i.e. 0.07907±0.0067. When the nitrogen contents were calculated in selected angiosperms it was noted that *Callistemon viminalis* exhibited higher values for nitrogen contents i.e. 0.8288±0.0395 while the second and third highest values were shown by *Eucalyptus camaldulensis* and *Ficus religiosa* i.e.0.2893±0.060 and 0.2165±0.0060, respectively. The amount of total nitrogen in the soil of *Azadirachta indica*, *Eucalyptus camaldulensis, Moringa oleifera,* and *Acacia nilotica* were 0.3528±0.0039, 0.2893±0.060, 0.2136±0.0030 and 0.2312±0.0079 respectively. Our results are partially matched with the results of Olowolafe and Alexander (2007) who found that the Eucalyptus tree is suitable for reclamation purposes.

The amount of macro-nutrients (Mg, Ca, and K) in the soil samples was recorded that the soil samples collected from un-canopied area presented very minute amounts of macro-nutrients i.e. 0.0080±0.13, 0.0450±0.09 and 0.0030±0.09 for Mg, Ca, and K respectively. However, the amounts of Mg, Ca, and K present in fertile soil were 0.1980±0.08, 0.4890±0.06, and 1.0340±0.08 correspondingly, which are ideal to fulfill the requirements of any crop grown in that soil. Soil samples taken from selected angiosperm trees i.e. *Dalbergia sissoo, Cassia fistula, Mangifera indica, Syzygium cumini, Tamarix aphylla, Ficus religiosa, Azadirachta indica, Albizia lebbeck, Callistemon viminalis, Phoenix dactylifera, Eucalyptus camaldulensis, Moringa oleifera, Acacia nilotica, Acacia ampliceps, and Pterospermum acerifolium* showed considerable amounts of macro contents. Maximum amounts of nutrients were found in *Mangifera indica* i.e. 1.072 ±0.0099 ppm for Mg, 3.840±0.0478 ppm for Ca and 0.3800±0.0049 ppm for K. Researchers have observed that the mineral contents under the canopy were found to be higher and the soil organic matter was found to be increased from 0.530% in the barren soil to 0.726% under the canopy cover which supporting the recent study (Barbedo 2019).

Micro-contents i.e. Cu, Zn, Mn, Fe, were carried out using ICP and noted that in un-canopied soil only Fe was detected while the fertile soil was comprised of Cu, Zn, Mn, and Fe in considerable amounts i.e. 6.346±0.189, 20.590±0.136, 230.40±0.087 and 1800.98±0.04 respectively. Comparing the micro-nutrients of barren and fertile soil, it was clearly demonstrated through results that most of the selected tree species soil samples showed considerable amounts of micronutrients present in them. Trees like *Moringa oleifera, Acacia nilotica, Acacia ampliceps, Pterospermum acerifolium* showed higher amounts of micro-nutrients.

3.2 Results showing pH values of Soil Samples

While calculating pH for the present study it was found that un-canopied soil showed a highly alkaline nature i.e.8.99±0.08 due to the sandy texture of desert soil, while the fertile soil expressed a slightly alkaline nature 6.50±0.01 due to its fine texture and certain minerals present in it. When the soil of all the angiospermic trees were compared to un-canopied soil it was revealed that varieties showed alkaline nature when their soil samples were investigated for pH. Among fifteen angiosperms *Callistemon viminalis*, commonly known as bottle brush tree indicated maximum alkalinity which is 9.05±0.017, while other species like *Mangifera indica, Phoenix dactylifera, Eucalyptus camaldulensis, Moringa oleifera, Acacia nilotica, Acacia ampliceps, Pterospermum acerifolium, Syzygium cumini, Ficus religiosa, Azadirachta indica, Albizia lebbeck* exhibited pH ranging from 8.1 to 8.9. It was also noted that *Tamarix aphylla* showed minimum pH value which was 7.84±0.043 which expressed that this tree can enhance the soil fertility factor. Based on the aforementioned observations it is concluded that all studied angiosperms are helpful in decreasing the alkalinity of desert except *Moringa oleifera* that has pH similar to the un-canopied area soil. Similar results were expressed in the recent research who investigated that the pH of the soil was lowered under the canopy covers as compared to barren soil (Parveen, *et al*., 2019).

3.3 Results showing Electrical Conductivity of Soil Samples

Electrical conductivity analysis of soil samples revealed that un-canopied, i.e. barren soil showed very low electrical conductance. It was also evident from the calculations that maximum conductance was shown by the fertile soil, i.e.

4.23±0.021 dSm^{-1}. Our findings concluded that *Tmarix aphylla* had maximum EC values, i.e. 5.19±0.0265 dSm^{-1} while the soil under other tree species like *Cassia fistula, Pterospermum acerifolium, Azadirachta indica* and *Syzygium cumini* presented electrical conductivity readings varying from 2.4 to 2.6 $dSm^{-1.}$ Other tree species like Eucalyptus camaldulensis, *Moringa oleifera, Acacia nilotica, Acacia ampliceps, Albizia lebbeck, Callistemon viminalis, Dalbergia sissoo* and *Mangifera indica* exhibited comparatively low EC values that ranged from 1.1 to 1.8 dSm^{-1}.

3.4 Results Showing Moisture Contents in Soil Samples

The hypothesis was supported by the results for moisture contents that angiosperms help regulate the moisture contents of soil. While calculating the moisture contents of soil samples taken, it was observed that very minute moisture contents were calculated in the un-canopied soil, as it does not have any plantation that could increase its moisture content. Maximum moisture contents i.e. 12.03±0.24 were calculated in the fertile soil samples. When the moisture contents were calculated in the selected angiospermic species it was observed that *Moringa oleifera* showed maximum moisture contents i.e. 5.30±0.0002% which revealed that this tree had maximum water holding capacity. It was also observed that second highest moisture contents were found in *Mangifera indica. Syzygium cumini, Cassia fistula, Pheonix dactylifera*, and *Dalbergia sissoo* were also higher in moisture contents than the other trees studied for this purpose.

3.5 Results for Soil Texture

The un-canopied soil expressed a sandy texture due to its habitat, i.e. desert. Fertile soil indicated a soil texture of fine sandy loam soil. Hence it was observed that the loamy character of soil is important for increasing the fertility of soil. A general trend was observed for the texture, in the soil samples of selected trees. It was found that most soil samples showed the same texture, i.e. sandy soil, as all these samples were selected from a desert ecosystem (Cholistan). But some of the tree species like *Dalbergia sissoo, Ficus religiosa, Mangifera indica, Moringa oleifera*, and *Pterospermum acerifolium* showed changed soil textures, i.e. clayey soil, which indicated that these tree varieties have changed the soil texture of persistent soil. While specific literature on the direct influence of angiosperms on soil texture may be limited, the indirect effects of plants on soil texture and structure through root penetration, organic matter deposition, soil aggregation, water, and nutrient cycling, and erosion control are well-documented in soil science and ecology research. The results for soil texture are shown in Table 2.

Table 2. Texture of selected soil samples with representative research plants

S. No	SOIL SAMPLES	SOIL TEXTURE	S. No	SOIL SAMPLES	SOIL TEXTURE
1	Un-canopied	Sandy soil	**10**	*Albizia lebbeck*	Sandy soil
2	Fertile	Fine sandy loam	**11**	*Callistemon viminalis*	Sandy soil
3	*Dalbergia sissoo*	Clayey soil	**12**	*Phoenix dactylifera*	Sandy soil
4	*Cassia fistula*	Sandy soil	**13**	*Eucalyptus camaldulensis*	Sandy soil
5	*Mangifera indica*	Clayey soil	**14**	*Moringa oleifera*	Clayey soil
6	*Syzygium cumini*	Sandy soil	**15**	*Acacia nilotica*	Sandy soil
7	*Tamarix aphylla*	Sandy soil	**16**	*Acacia ampliceps*	Sandy soil
8	*Ficus religiosa*	Clayey soil	**17**	*Pterospermum acerifolium*	Clayey soil

9	*Azadirachta indica*	Sandy soil				

IV. DISCUSSION

The results in the factors affecting soil parameters of canopied soil are shown by means of a stalked bar graph shown in Fig. 1. This bar graph clearly explains the comparative analysis of the enhancement of soil fertility parameters by selected angiospemic trees. The overall trends in the Fig. 1 indicate that all the tree species selected for the present study have shown certain improvements in enhancing the edaphic factors towards fertility. Noureen *et al.* (2008) have also expressed the improvement of soil properties of Cholistan desert by the plantation of *Calligonum polygonoides* Linn. Similar results were observed by Adeboye *et al.* (2011) who assessed the soil quality by using soil organic carbon and total nitrogen and microbial properties in tropical agro-ecosystems.

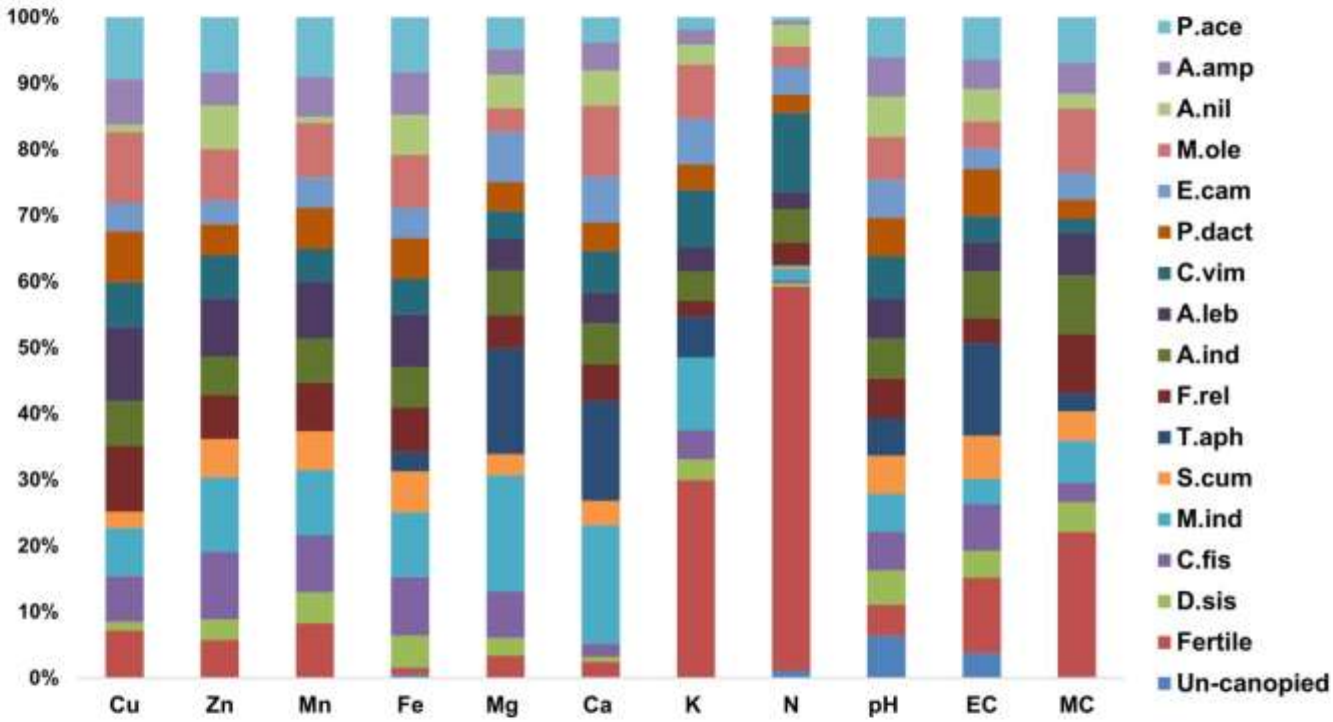


Fig.1 Stalked bar graph showing the impact of selected trees on soil parameters

It is evident from the Fig. 1 that *Callistemon viminalis* showed higher values for nitrogen contents in the soil samples. Similarly, trees like *Mangifera indica*, *Syzygium cumini*, *Moringa oleifera*, and *Tamarix aphylla* have also increased the availability of nutrients in the soil, which would serve to elevate any crop production. Our findings partially matched with various researchers like Kushwaha *et al.* (2021) who determined the impact of *Eucalyptus saligna* and *Albizia falcataria* on soil nutrient supply and limitation and also showed high fertility status These results are in agreement with the previous researches who found five species of Acacia were grown in a field where salinity fluctuated from 4-25 dS m^{-1}. After three years of development, *A. ampliceps* and *A. nilotica* showed markedly higher growth as compared to other species inspected. Complete soil analysis was carried out, at the end of the experiment, which expressed that the soils on which Acacia species were grown, their nitrogen contents were increased to some extent (Wang, *et al*., 2022).

It can also be observed from Fig. 1 that the pH of the barren soil sample taken from the desert, showed a higher alkaline nature but the presence of angiospermic tree tends to decrease the pH of soil samples. Among the selected trees *Tamarix aphylla* was found to be most effective in enhancing soil fertility in the present study. Based on another study, it was found that the differences in soil physical and chemical properties are present among various land use systems and soil types. These variations in soil properties can be attributed to factors such as the accumulation of organic matter from leaf litter, regular tillage practices, crop residue management during harvesting, and the application of organic manures. To ensure sustainable agricultural productivity and maintain environmental and ecological balance, it is advisable to adopt suitable and integrated land management strategies tailored to different land use systems. This approach should involve incorporating trees and vegetation to preserve the environment and promote ecological equilibrium (Parveen *et al*., 2019). Another research conducted by Augusto *et al*., (2015) showed that different chemical properties, such as soil pH, can also be considerably altered by different taxonomic groups of tree species. Thus the comparative study of the previous studies and this research endorsed the fact that the pH of soil in canopy covers lowers as compared to barren land.

The trends of moisture contents from Fig. 1 indicated that the angiospermic tree increased the moisture contents found in the desert soil. The findings of the present study were in agreement with Karim *et al.*, (2009) who found the effect of canopy cover of different shrubs on different physio-chemical parameters of soil. Their research indicated that moisture content was increased under the canopy covers when compared to unfertile soil. The moisture content of soil plays a crucial role in various ecological processes, including nutrient cycling, plant growth, and overall ecosystem functioning. In forest ecosystems, the presence of canopy covers can significantly influence soil moisture levels due to interception and redistribution of precipitation, reduced evaporation rates, and altered microclimate conditions (Dhyani *et al.* 2018). Research supports the idea that the presence of canopy covers in forest ecosystems can result in high moisture levels in the soil. This is primarily due to canopy interception, microclimate modifications, and their subsequent impacts on soil properties and nutrient cycling. The increased soil moisture content under canopy covers can influence plant community dynamics, fostering diverse and moisture-dependent species (Rodríguez *et al.* 2023).

Correlation analysis

The results obtained from the parameters considered in the present study were also analyzed for their correlations with each other. Their correlation analysis is summarized in Table 3.

	Cu	Zn	Mn	Fe	Mg	Ca	K	N	pH	EC
Cu	1									
Zn	0.7	1								
Mn	0.85	0.82	1							
Fe	0.59	0.84	0.66	1						
Mg	-0.07	0.18	0.05	0.29	1					
Ca	0.08	0.19	0.07	0.31	0.87	1				
K	0.19	0.14	0.29	-0.31	0.14	0.15	1			
N	0.13	0.01	0.19	-0.48	-0.17	-0.18	0.92	1		
pH	0.15	0.07	-0.16	0.3	-0.14	0.13	-0.6	-0.61	1	
EC	-0.22	-0.28	-0.16	-0.37	0.33	0.16	0.42	0.43	-0.53	1

If we talk about the correlation of these soil parameters, it is evident from Fig. 2 that Cu has a very good correlation with Zn and Fe availability however it shows negative values for EC and Mg. A similar observation was obtained by Krishna *et al.,* (2005) during their experimentation on heavy metal distribution and contamination in the soil of Thane-Belapur Industrial Developmental Area, Mumbai. Similarly, Zn showed a very healthy correlation with Mn and Fe, but it is also showing a negative value for EC. Results have also revealed that Mn has also inverse relationship with pH and EC as shown in Fig. 2. This inverse relationship of Mn with pH and EC was also observed in another investigation (Sangwan and Singh 1993; Madzin *et al.* 2015). Fe also shows a negative correlation with K and N availability and the EC values. Fig. 2 also shows that K and N have a very strong correlation which also supports our hypothesis. It is also obvious from Fig. 2 that EC has a negative correlation with the availability of micronutrients and pH. However, the values for macronutrients show a positive correlation with EC.

PCA Analysis

The results obtained in this study were analyzed through PCA analysis. Table 3 shows the output of PCA statistics from the research carried out.

PC Statistics	Standard Deviation	Proportion of Variance	Cumulative Proportion
Comp.1	1.871935	0.350414	0.350414
Comp.2	1.711171	0.292811	0.643225
Comp.3	1.428031	0.203927	0.847152
Comp.4	0.818832	0.067049	0.914201
Comp.5	0.683811	0.04676	0.96096

It is shown in Table 3 that the first two components explained 64.3 % of the overall variability. Hence a PCA plot was constructed to show the correlation of component 1 and component 2 with all the other variables, which is shown in Fig. 2.

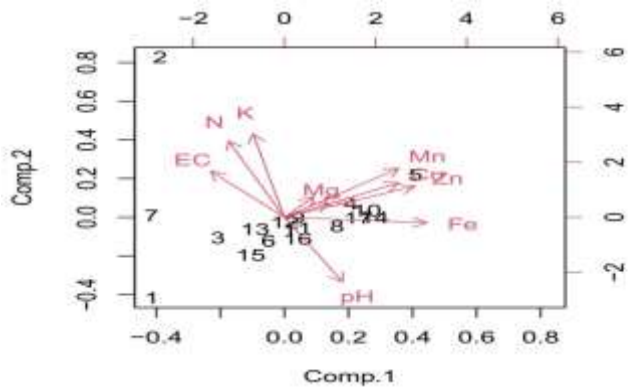
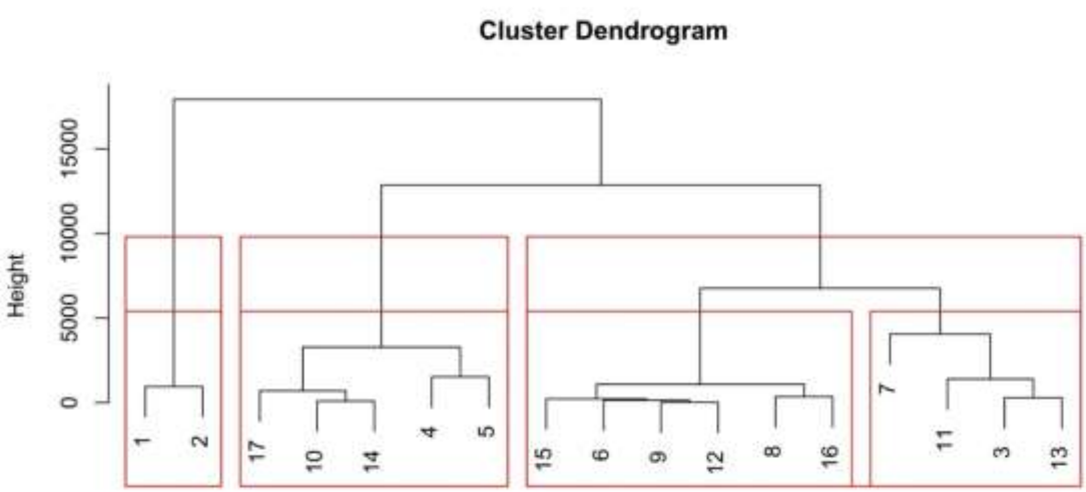


Fig. 2 PCA Plot

The output from the PCA plot revealed that the parameters were quite dense on the right side of the plot. It was also shown that variables like Mg, Mn, Ca, Zn, and Fe showed a positive correlation to both components. Similarly, the variables i.e. EC, N, and K showed a positive correlation with component 2 only. pH was the only variable that showed a negative correlation with component 1. Results were analyzed similarly by Hogberg *et al.*, 2003 during their experimentation on contrasting effects of nitrogen availability on plant carbon supply.

Cluster dendrogram

The trends shown by the selected trees are also shown in Fig. 3 as a cluster diagram to study comparative patterns. This dendrogram shows a hierarchal relationship between selected trees. The trees exhibiting similar impacts on fertility parameters were grouped in a similar cluster.



The whole dendrogram plotted could be distributed into three different clusters. Among these three clusters *Albizia lebbeck*, *Pterospermum acerifolium*, *Moringa oleifera*, *Cassia fistula*, and *Mangifera indica* are all found to be in one cluster, which indicates that the properties shown by these plants have similar impact on fertility parameters. Likewise, *Acacia nilotica*, *Syzygium cumini*, *Azadirachta indica*, *Phoenix dactylifera*, *Ficus religiosa* and *Acacia ampliceps* were placed in the same cluster for showing same properties. Third cluster comprises of *Tamarix aphylla, Callistemon viminalis, Dalbergia sissoo,* and *Eucalyptus camaldulensis.*

V. CONCLUSIONS:

This series of work is conducted to check whether angiosperms are healthy for soil fertility and soil physio-chemical properties or not and it is finally concluded that angiosperms have certain positive impacts on soil properties that enhance its fertility but there are some trees that couldn't prove to be helpful in certain areas. As the selected angiosperms have shown results that have supported the hypothesis selected for this study, so now the plantation of angiosperms should be used as a bio-tool to enhance soil properties. An overall review of this study suggests that angiosperms increase soil fertility of any soil and such tree species are also helpful in enhancing soil physical and chemical properties which bring about fertility of the very soil. Steps should be taken to appreciate the plantation of angiosperms to regulate soil fertility and then to use fertilizers for this process, as it is more favorable for our ecosystem and environment. Further work should be done to investigate the impact of other angiosperms on soil fertility and soil properties that improve soil fertility.

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