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Assessing Variability of Silicon in Relation to Soil Texture using Box Plot in Rice Growing Soils of Jammu Plains

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ABSTRACT: Rice is among the most important food and grain crop in India but it suffers from many insect and pest infestations. Silicon (Si) is beneficial element for silicophilic plant species *viz.*, rice and sugarcane. Rice takes more Si compared to any other primary nutrients from soil. The content of silica in plants is equivalent to or sometimes more than the major nutrients *i.e.* N, P and K supplied through fertilizers. However, there are differences in the parent materials which affect the mineral composition and particle size distribution of the soils which in turn effect the available Si content. In the present study, we investigated the variability between the amount of available Si in rice growing soils of three different districts of Jammu plains with respect to particle size distribution or soil texture. This analysis of the variability of silicon is important for assessing crop production under different soil textural classes. The study aimed to investigate the variability of silicon using a box plot. A total of 140 surface (0-15 cm) soil samples, collected from three different districts from rice-growing soils of Jammu plains were taken for investigation. The region had an interquartile range (IQR) of Si-1, Si-2 and Si-3, which is 173.78 (g kg^{-1}), 241.80 (g kg^{-1}) and 287.33 (g kg^{-1}), respectively. The **maximum variability distribution of silicon was found in sandy clay loam soil followed by sandy loam soils and the lowest distribution was observed in sandy clay texture under all the three extractants. The kurtosis distribution of available Si-1 was found to be positive and that of Si-2 and Si-3 was found to be negative. The skewness distribution in Si-1, Si-2 and Si-3 was found to be positive. But the kurtosis distribution of Si-1 of soil is positive (0.07) and negative kurtosis distribution was found (-0.48 and -0.57) for Si-2 and Si-3 of soil, respectively. The evaluation of silicon (available) distribution in Jammu, this can lead to make advanced plans for making better package and practices for Jammu valley area.**

Keywords: Silicon, rice, soil texture, variability, Jammu plains.

INTRODUCTION

Rice (*Oryza sativa* L.) is the most predominant cereal crop in Southeast Asian countries, particularly India. Rice is grown on approximately 45 million hectares in India, accounting for 32.14 per cent of the total net cultivated area (Anonymous, 2022). Milled rice production and productivity in India are 177.65 million tonnes and 2.89 tonnes ha^{-1}, respectively (Anonymous, 2022). As a typical Si-accumulating plant, rice plants absorb Si from soil solution during their growth, with more than 78 per cent of the absorbed Si being deposited in straw part (Sun *et al*., 2018; Klotzbucher *et al*., 2015). It is estimated that to produce a total grain yield of 5.0 t ha^{-1}, rice crop removes 230-470 kg Si ha^{-1} from the soil (Rodrigues and Datnoff 2005), thus Si may be a yield-limiting element for rice production (Cuong *et al*., 2017) particularly in soils with deficient or low available Si. Moreover, the removal of silicon with rice harvest without sufficient external silicon input back to soil may result in silicon-deficient rice growing soils, which could limit rice production. It should be noted that many soils are inherently silicon deficient as they are highly weathered (Yang *et al.*, 2021).

Silicon may be a key tool to guard crop production against uncertain future growing conditions by improving crop tolerance to abiotic and biotic stressors (Pooniyan *et al*., 2023). Silicon can promote rice growth and reduce the toxicity of heavy metals in rice. Silicon can strengthen plant defense against abiotic stresses (i.e., heavy metals, salinity, and drought) and biotic stresses (i.e., attacks by pests and pathogens), thereby improve the yield and quality of rice (Guntzer *et al.*, 2012).

The stagnating yields of rice is mainly due to imbalanced fertilizer use, soil degradation, types of cropping system practised, lack of suitable genotypes for low moisture adaptability and disease resistance. Besides this, there is another important factor of repeated mono-cropping with rice and many workers are of the view that continuous rice cultivation may result in the shortage of soluble silicon in paddy soil, especially in highly weathered tropical areas (Savant *et al.,* 1997). Other factors affecting silicon availability in soil are soil texture, pH, organic carbon etc. However, controlling factors for distribution of silicon in typical paddy soils of Jammu region remain largely unexplored. Keeping this view, a study was planned to analyse soil available Si content extracted through various extractants and its variability according to soil textural classes in paddy growing soils of Jammu plains.

MATERIAL AND METHODS

A. Study area

The study area comprises of rice growing plains of Jammu, Kathua and Samba districts of Jammu and Kashmir union territory. Jammu district lies between 32º 44' to 59º 99' North latitude and 74º 49'to 59º 99' East longitude. Samba district lies between 32º 33' to 44º 89' North latitude and 75º 07' to 11º 75' East longitude and Kathua district lies between 32º 22' to 9º 88' North latitude and 75º 31' to 31º 40' East longitude. The area of Jammu, Samba and Kathua districts are about 2336, 1002 and 2651 sq. kms, respectively.

B. Soil sampling and their processing

The surface (0-15 cm) soil samples were collected from 140 rice-growing locations distributed randomly across three different districts using global positioning system. The collected soil samples were mixed well, air-dried in the shade, grounded in pestle and mortar, and passed through 2 mm sieve for the analysis of available silicon and soil texture. The processed samples were stored in polythene bags for analysis.

C. Soil analysis

Mechanical analysis of soil was done by hydrometer method using Bouyoucos hydrometer (Bouyoucos, 1962). Soil samples were treated with hydrogen peroxide to destroy the organic matter present in soil. Clay, sand and silt contents were expressed as percent and then the texture class was computed by using textural diagram. Estimation of available silicon was done by different extractants such as Si-1 by 0.01*M* $CaCl_2$, Si-2 by 0.5*M* NH_4OAc and Si-3 by 0.5*M* CH_3COOH (Narayanaswamy and Prakash 2009).

D. Statistical analysis

Statistical parameters such as interquartile range, skewness and kurtosis were determined using python. In descriptive statistics, the interquartile range is a measure of statistical dispersion, which is the spread of the data. The IQR may also be called the midspread, middle 50%, fourth spread, or H-spread. These quartiles, or four rank-ordered even parts via linear interpolation. These quartiles are denoted by Q_1 (also called the lower quartile), Q_2 (the median) and Q_3 (also called the upper quartile). The lower quartile corresponds with the 25th percentile and the upper quartile corresponds with the 75th percentile, so IQR = Q_3-Q_1. The IQR is an example of a trimmed estimator, defined as the 25% trimmed range, which enhances the accuracy of dataset statistics by dropping lower contribution, outlying points. The effects of skewness and kurtosis, define the distribution or variability of silicon on the various types of soil texture and also elaborate statistical variation between three different extractants.

RESULT AND DISCUSSION

A. Descriptive analysis

The descriptive statistical characteristics of silicon are shown in Table 1. The 25 to 75 per cent quartiles of the soil Si-1, Si-2 and Si-3 of Jammu plains varied from 145.73 to 319.50, 185.20 to 427 and 333.67 to 621.00 per cent, respectively with an interquartile range of Si-1, Si-2 and Si-3 being173.78 (g kg^{-1}), 241.80 (g kg^{-1}) and 287.33 (g kg^{-1}). The positive skewness distribution of Si-1, Si-2 and Si-3 content of soil were found which was 0.47, 0.34 and 0.09, respectively. However, the kurtosis distribution of Si-1 of soil is positive (0.07) and negative kurtosis distribution was found (-0.48 and -0.57) for Si-2 and Si-3 content in soil, respectively. Higher variability in silicon content due to various types of extractants was noticed. Similar results were reported by Mahendran *et al*. (2021).

It was noted that the Si-1 content was generally lower than the Si-2 and Si-3 content within each rice growing soils of Jammu Plains. There has been increase in the variability of Si-3 (Fig. 1). The square within the box represents the mean values of all data, the bottom, mid and top line within the box represents the lower quartiles (Q_1), median (Q_2) and upper quartiles (Q_3), respectively; and the bottom and top bars represent lower margin (Q_1-Q1.5IQR) and upper margin (Q_3 = 1.5 IQR), respectively, IQR = Q_3-Q_1. Consistent with previous studies by Hohn *et al.* (2008); Narayanaswamy and Prakash (2009); Meunier *et al.* (2018), the Si-3 and Si-2 content was generally higher than the Si-1 content (Fig 1). However, the three plant available extractants do not necessarily represent the same silicon content. The Si-1 content best represents the dissolved forms including monosilicic acid and polysilicic acid (De Tombeur *et al*., 2020a, 2020b, Yang *et al*., 2021), while the Si-2 and Si-3 content represent monosilicic acid and polysilicic acid as well as Si adsorbed on soil particles (Meunier *et al*., 2018).

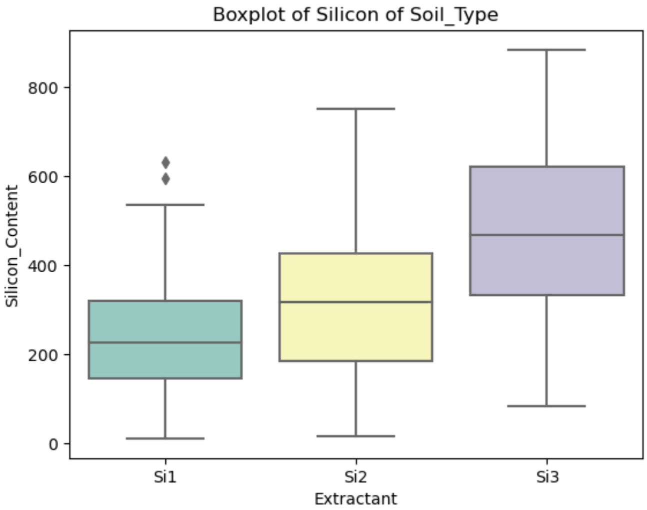

Fig. 1. Variability of plant available silicon content across three different extractants by using Box plot.

Table 1: Descriptive analysis of different silicon extractants in rice-growing soils of Jammu Plains.

Properties	Av.Si ($CaCl_2$)	Av. Si (NH_4OAC)	Av.Si(Acetic acid)
25% (Q_1)	145.73	185.20	333.67
50% (Q_2)	225.20	316.00	466.70
75% (Q_3)	319.50	427.00	621.00
Inter-quartile range	173.78	241.80	287.33
skewness	0.47	0.34	0.09
kurtosis	0.07	-0.48	-0.57

B. Comparison of silicon content with soil textural class

The distribution of available silicon content extracted by three different extractants vary with the soil textural classes in rice growing soils of Jammu Plains. Maximum variability distribution of Si-1 content was found in sandy clay loam soil, followed by sandy loam and then followed by clay loam, loam and lowest Si-1 content variability was noticed in sandy clay soils (Fig. 2).

Whereas in Si-2 content, maximum variability distribution was noticed under sandy clay loam soil, followed by sandy loam, whereas minimum variability was noticed under sandy clay textured soil (Fig. 3).

Maximum distribution of Si-3 content of silicon was found in sandy clay loam soil, followed by sandy loam, and then by clay loam, loam and lowest Si-2 content variability was noticed in sand clay texture soil (Fig. 3). These higher variations of Si-1, Si-2 and Si-3 in sandy clay loam soils might be due to large variations of three fractions of soil *viz.*, sand, silt and clay in sandy clay loam soils. Also amount of available Si in soil is affected by parent material suggesting that the amount of Si could be influenced by the mineral composition and particle size.

Clay content showed a wide distribution of silicon content extracted with 0.01*M* $CaCl_2$, 0.5*M* NH_4OAc, and 0.5*M* CH_3COOH, while the relationship between available Si and sand content was found to be negative and statistically significant for all three extractants. The rise in plant-available silicon with increasing clay concentration in soils of different rice-growing soils is indicated by the positive association between clay content and plant-available Si extracted with 0.01*M* $CaCl_2$, 0.5*M* NH_4OAc, and 0.5*M* CH_3COOH. These results are in accordance to those of Phonde *et al.* (2014).

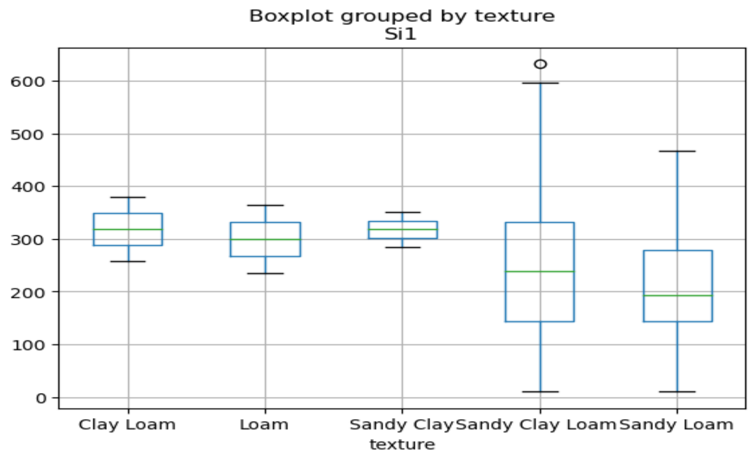

Fig. 2. Variability of silicon content extracted by 0.01M $CaCl_2$ in different soil textures.

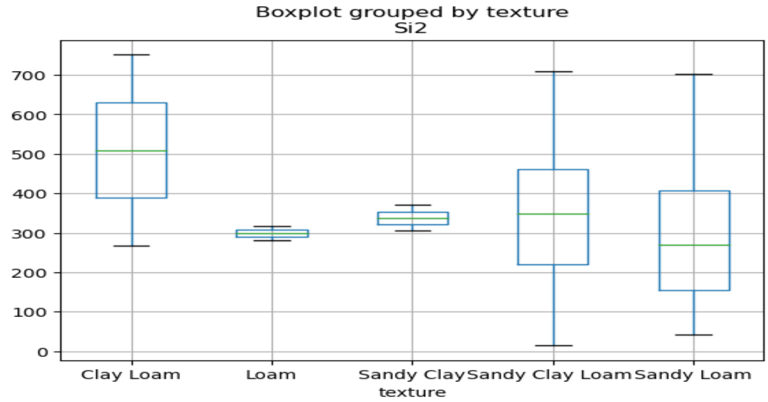

Fig. 3. Variability of silicon content extracted by 0.5M NH_4OAc in different soil textures.

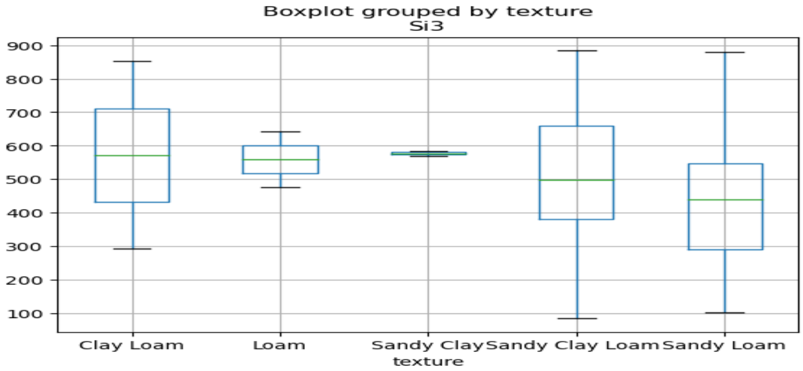

Fig. 4. Variability of silicon content extracted by 0.5M CH_3COOHin different soil textures.

CONCLUSIONS

The distribution of available Si content was related to soil texture in rice growing soils of Jammu plains and maximum distribution was noticed in sandy clay loam soil for all the three extractants followed by sandy loam soils and minimum distribution was seen under sandy clay texture. Negative correlation was found between the amounts of the coarse-sand fraction and the amounts of available Si extracted with three extractants in the soil using whole soil samples whereas silt and clay fraction of soil showed positive correlation with Si-1, Si-2 and Si-3 content of soil.

FUTURE SCOPE

The most prevalent element in the lithosphere, silicon, is still not included in the list of essential elements. Si plays a crucial part in spurring plant growth and development, as has been discovered. It is crucial for controlling the plants' general physiological and metabolic properties. Although it is regarded as a non-essential element, it is known to occur at a rate of about 30%, with the majority of its occurrence occurring as mineral salts in rocks. It is thought to be a versatile or quasi-element in the earth's crust that plants may effectively absorb and move towards aerial areas via the transpiration phenomenon.

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Conflict of interest. None.

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