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Assessment of Soil Fertility Status Using Nutrient Index Approach in Cassava Farms of Rewa Province, Fiji

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ABSTRACT

Background: Nutrient index methods and fertility indicators can be used to determine the fertility status of soils. The information can be used to develop soil management strategies for farmers.

Methods: The research was conducted in the Rewa district of Fiji, with an aim to assess soil fertility status using the nutrient index approach. A total of 57 cassava-growing farms were selected from three sub-districts of Rewa province for the present investigation and collected soil samples were analyzed in accordance with standard procedures for evaluating chemical parameters and the status of available nutrients in the soil.

Result: The study discovered that the soils of farms are acidic in reaction, have low levels of organic carbon, low to moderate levels of major primary nutrients, however, the soils had a high content of calcium and magnesium. The soil nutrient index value calculated of soil organic carbon and available phosphorus were recorded as low with 1.48 and 1.40 respectively. The NIV for nitrogen and potassium content was medium category values of 1.91 and 1.95, respectively. The nutrient index value calculated for exchangeable calcium and magnesium content was recorded as high with 2.75 and 2.35 values respectively.

Key words: Nutrient assessment, Nutrient index, Primary nutrients, Rewa, Soil fertility.

INTRODUCTION

Sustained and consistent yields are governed by the nutrient supplying capacity of the soil to the growing plants. Soil testing is a vital tool to assess the nutrient supplying capacity of the soil. The deficiency of nutrients has become a major constraint to the productivity, stability and sustainability of soils. The concept of soil health and soil quality has consistently evolved with an increase in understanding of soils and soil quality attributes. The Quality of soil is controlled by physical, chemical and biological components of soil and their interaction (Sachan and Krishna, 2018).

Soil properties cannot be measured directly, but soil properties that are sensitive to changes in the management can be used as indicators. The attraction for growing high-yielding varieties without considering the fertility of soils could result in depletion of soil organic matter reserves and reduce the quality of soils. The addition of appropriate doses of organic matter and lime helps in maintaining better and favorable physical conditions of soils for sustainable farm productivity. Determination of physico-chemical properties and available nutrients status of the soil of an area is vital for improving sustainable productivity. Soil pH is a good indicator balance of plant available nutrients in the soil (Singh *et al*., 2013).

Identifying the state of nutrients in the soil before sowing a crop offers a solid foundation for estimating the crop's nutritional requirements for the desired production level (Amara *et al*., 2017; Theresa *et al*., 2019). Methods such as nutrient index methods and fertility indicators can be used to determine the fertility state of soils. Using the concentrations of organic carbon, available phosphorus and available potassium as measures of soil fertility, (Ravikumar, 2013; Amara *et al*., 2017) used soil nutrient index values as a measure of soil fertility. It is important to investigate the nutrient status of the farmlands so that the information can be used to develop soil management strategies for farmers (Hadole *et al*., 2019, Ojobor *et al*., 2021). In the study area, farmers have been growing crops with less knowledge of the fertility status of their farms. Therefore, if the fertility status of their farms is investigated, the information will guarantee appropriate fertilizer recommendations and uses. Hence, the study helps in understanding the scope of cassava growth in the region evaluating the fertility status of the Rewa district of Fiji.

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MATERIALS AND METHODS

Study area description

The research was conducted in the Rewa province of Fiji, which is comprised of three sub-districts (Rewa, Vutia and Toga), between 2017 and 2018. The study area is located in between 178° 20′ 00″ E and 18° 05′ 00″ S longitude. The area experiences a tropical humid climate having an average annual rainfall of 3000 mm and the temperatures vary from 21°C to 26°C. Soils are acidic, with pH range from 5.1 to 6.6. They contain low to medium organic carbon and low electrical conductivity (0.01 to 0.08 dSm^{-1}) and the texture of soil vary from sandy clay loam to cay loam (Singh *et al*., 2013).

Samples preparation and laboratory procedures

A total of 57 cassava-growing farms were selected from three sub-districts of Rewa province for the present investigation. Composite soil samples were collected with an auger from topsoils (0-15 cm). After air drying at room temperature at 27°C, collected soil samples were crushed and sieved with a 2 mm mesh, properly labeled and packaged for laboratory analysis. At the Fiji Agricultural Chemistry Laboratory, Koronivia Research Station, standard analytical methods, described by (Richards,1954 and Jackson,1964), were used to measure various soil attributes such as pH, electrical conductivity (EC), organic carbon (OC) and primary and secondary plant nutrients (total nitrogen, available phosphorus, available potassium and calcium and magnesium (Singh *et al*., 2013; Sachan and Krishna, 2018).

Determination of nutrient availability index

The nutrient availability Index was calculated based on the fertility rating chart in Table 1 (FMARD, 2012). An index created by (Parker *et al*., 1951) and refined by (Kumar *et al*., 2013; Amara *et al*., 2017) was used to compare soil fertility levels in the sub-districts of Rewa province of Fiji.

$$\text{Nutrient index} = \frac{\{(1\times A) + (2\times B) + (3\times C)\}}{NS}$$

Where

A = Number of samples in low category.

B = Number of samples in medium category.

C = Number of samples in high category.

NS = Total number of samples.

The nutrient index value 1.67 to 2.33 is considered as medium. The NIV less than 1.67 is considered as low and greater than 2.33 is as high. The NIV is evaluated for pH, OC, Total N, Available P, exchangeable K, Ca and Mg.

Statistical analysis

Descriptive statistics of soil parameters were computed using the Minitab 15 package.

RESULTS AND DISCUSSION

This section describes the soil fertility status of the research area in terms of pH, organic carbon, primary nutrients and secondary nutrients.

Nutrient status in farms of sub-districts of Rewa province

The pH of the soil samples varied from 4.9-7.0, 5.7-6.5 and 5.7 - 6.4 Rewa, Vutia and Toga farms respectively (Table 2). Relatively low values of soil pH are due to the acidic parent material of these soils (Singh *et al*., 2013; Sachan and Krishna, 2018). Soil organic carbon content ranged from 0.8 to 4.3 % in Rewa farms and from 1.6 to 3.3% in Vutia farms, whereas it ranged from 1.0 to 2.8% in Toga farms.

The total nitrogen content of soils of Rewa farms ranged from 0.07-0.53 %,0.13-0.25% in Vutia farms while it ranged between 0.77-0.22% in Toga farms. These soils are of low to medium level of total nitrogen status. The available phosphorus content of soils of Rewa farms ranged from 1.0-95 mg/kg, 1-4 mg/kg in Vutia farms while it ranged between 3.0-23 mg/kg in Toga farms. The highest mean of available phosphorus was recorded in Rewa farms while the lowest was in Toga farms. Exchangeable potassium was highest in Rewa farms and lowest in Vutia farms. According to rating limits, these soils are of low potassium levels. The available potassium content of soils of Rewa farms ranged from 0.07-2.0 cmol/kg, 0.08-0.29 cmol/kg in Vutia farms while it ranged between 0.14-1.23 cmol/kg in Toga farms. Mean exchangeable potassium was highest in Toga and was lowest in Vutia. The Exchangeable calcium content of soils of Rewa farms ranged from 1.98-28.34 cmol/kg, 2.84-10.65 cmol/kg in Vutia farms while it ranged between 10.16-24.58 cmol/kg in Toga farms. The highest mean exchangeable calcium was found in Toga farms and the lowest was in Vutia farms. The Exchangeable magnesium content of soils of Rewa farms ranged from 1.41-9.13 cmol/kg, 1.49-4.16cmol/kg in Vutia farms while it ranged between 3.17-6.37 cmol/kg in Toga farms. Exchangeable magnesium content was highest in Rewa.

Nutrient variability in the Rewa province

The pH of the soil is an important chemical parameter because it contributes to the availability of essential plant nutrients (Gunamantha *et al*., 2021; Khadka *et al*., 2016). The pH of the soil samples of the Rewa province ranged from 5.87 to 6.00 with a mean value of 5.94 (Table 3). This shows a low acidic soil reaction (pH). Acidic soils can occur as a result of basic cation leaching or as a result of constant uptake by crops cultivated on the land. The soil pH values are relatively low due to the acidic parent material of these soils (Kahdka *et al*., 2016; Sachan and Krishna, 2018). The soil acidity implied that nutrients are likely to be available or unavailable for crop uptake. Therefore, agricultural lime should be incorporated to increase the soil pH of the very acidic and moderately acidic sites. After microbes decompose organic matter, it becomes a significant source of essential nutrients for plants. It provides nutrients to plants, improves soil structure, increases water infiltration and retention, feeds soil microflora and fauna and aids in the retention and cycling of applied fertilizer (Amara *et al*., 2017; Theresa *et al*., 2019). The organic carbon content of soil samples examined in Rewa province ranged between 1.00

and 2.40 %, with a mean value of 1.80 %. (Table 3). This shows the low status of organic carbon. Due to the fact that the majority of soil nitrogen is available in organic form like degraded plant parts, litter, crop and animal residues that are gradually released for plant growth and development via the mineralization process, this relation was observed (Singh *et al*.,2013; Sachan and Krishna, 2018). Nitrogen is an essential nutrient for plants and is the most usually deficient of all nutrients (Kathpalia and Bhatla, 2018). The total nitrogen content of soils studied in Rewa province ranged between 0.13 and 0.20 %, with a mean value of 0.17 % (Table 3). This indicates the medium status of nitrogen. Energy transformations and metabolic activities in plants rely on phosphorus (Sumithra *et al*.,2013; Kathpalia and Bhatla,2018). The available phosphorus in soil samples from Rewa province ranged between 2.4 and 21.1 mg/kg,

Table 1: Soil rating chart and their nutrients indices.

Soil properties	Range		
	Low	Medium	High
Soil pH	5.5-6.0	6.1-6.9	7.1-8.5
	Moderately acidic	Slightly acidic	Slightly alkaline
Organic carbon (%)	2.0	2.0-3.0	>3.0
Total nitrogen (%)	<0.15	0.15-0.20	>0.20
Available phosphorus (mg/kg)	<15	15-25	>25
Exchangeable potassium (cmol/kg)	<0.2	0.2-0.4	>0.4
Exchangeable calcium (coml/kg)	<1.5	1.5-4.5	>4.5
Exchangeable magnesium (cmol/kg)	<1.5	1.5-4.5	>4.5

Source: FMARD (2012).

Table 2: Nutrient status of the soils of different sub-districts of Rewa province.

Farms	Range	Mean	Percent of sample falling within range		
			High	Medium	Low
pH			7.0-8.5	6.0-7.0	5.5-6.0
Rewa	4.9-7.0	5.87	3	33	64
Vutia	5.7-6.5	6	0	43	57
Toga	5.7-6.4	5.96	0	36	64
Organic carbon (%)					
Rewa	0.8-4.3	2	13	26	62
Vutia	1.6-3.3	2.4	0	57	43
Toga	1-2.8	1	0	36	64
Total nitrogen (%)					
Rewa	.07-0.53	0.2	41	36	23
Vutia	0.13-0.25	0.18	29	43	29
Toga	0.07-0.22	0.13	18	18	64
Available phosphorus (mg/kg)					
Rewa	1.0-95	21.1	28	0	72
Vutia	1.0-4.0	2.4	0	0	100
Toga	3.0-23.0	15.1	64	9	27
Exchangeable potassium (cmol(+)/kg)					
Rewa	0.07-2.0	0.43	49	23	28
Vutia	0.08-0.29	0.16	0	29	71
Toga	0.14-1.23	0.62	64	9	27
Exchangeable calcium (coml(+)/kg)					
Rewa	1.98-28.34	10.85	85	13	3
Vutia	2.84-10.65	6.09	43	57	0
Toga	10.16-24.58	17.27	100	0	0
Exchangeable magnesium (cmol(+)/kg)					
Rewa	1.41-9.13	5.09	59	36	5
Vutia	1.49-4.16	3	0	86	14
Toga	3.17-6.37	5.04	64	36	0

Table 3: Nutrient availability in Rewa province.

Farms	Soil pH	Organic carbon (%)	Nitrogen (%)	Phosphorus (mg/kg)	Potassium (cmol/kg)	Calcium (cmol/kg)	Magnesium (cmol/kg)
Rewa	5.87 (L)	2.0 (L)	0.20 (M)	21.10 (M)	0.43 (H)	10.85 (H)	5.09 (H)
Vutia	6.00 (L)	2.40 (M)	0.18 (M)	2.40 (L)	0.16 (L)	6.09 (H)	3.00 (M)
Toga	5.96 (L)	1.00 (L)	0.13 (L)	15.10 (M)	0.62 (H)	17.27 (H)	5.04 (H)
Mean	5.94	1.8	0.17	12.87	0.40	11.40	4.37

Table 4: Status of nutrient index value (NIV) in the farms of sub-districts of Rewa province.

Farms	Organic carbon		Nitrogen		Phosphorus		Potassium		Calcium		Magnesium	
	NIV	Rating	NIV	Rating	NIV	Rating	NIV	Rating	NIV	Rating	NIV	Rating
Rewa	1.51	L	2.18	M	1.56	L	2.21	M	2.82	H	2.54	H
Vutia	1.57	L	2.00	M	1.00	L	1.29	L	2.43	H	1.86	M
Toga	1.36	L	1.55	L	1.64	L	2.36	H	3.00	H	2.64	H
Mean	1.48		1.91		1.40		1.95		2.75		2.35	

with a mean value of 12.87 mg/kg (Table 3). This indicates the low status of the available phosphorus. The range is wide, which may be attributed to variations in soil qualities, such as pH, organic matter content, texture, land use and various agronomic and management practices. Less Ca^{2+} and more Al^{3+} and Fe+3 in solution could be responsible for the precipitation of phosphate ions as aluminum and iron phosphates, which are insoluble. The very low solubility of phosphorus compounds results in very low concentrations of phosphorus in solution (Singh *et al.,* 2013; Sachan and Krishna, 2018).

There are no major plant components that contain potassium, but the mineral plays a key role in several physiological processes vital to plant growth, from protein synthesis to water balance (Sumithra *et al*., 2013). The available Potassium of the analyzed soil samples of Rewa province varied from 0.16-0.62 cmol/kg with a mean value of 0.40 cmol/kg (Table 3). This indicates the medium status of the available potassium. The satisfactory conditions of extractable potassium in the farm might be due to the optimum application of potash as well as less loss of potassium ions from the soil (Khadka *et al*., 2016). Calcium is a critical regulator of plant responses to endogenous stimuli and biotic and abiotic stress signals (Aldon *et al*., 2018). The exchangeable calcium of the analyzed soil samples of Rewa province varied from 6.09-17.27 cmol/kg with a mean value of 11.40 cmol/kg (Table 3). Magnesium ions (Mg^{2+}) are the second most abundant cation in live plant cells, where they play a variety of roles, including photosynthesis, enzyme catalysis and nucleic acid synthesis (Tanoi and Kobayashi, 2015; Khadka *et al*., 2020). The exchangeable magnesium of soils of the analyzed soil samples of Rewa province varied from 3.00-5.09 cmol/kg with a mean value of 4.37 cmol/kg (Table 3). This indicates the medium status of the exchangeable magnesium.

Nutrient index value (NIV) in Rewa province

The nutrient index value (NIV) is a measure of the soil's capacity to supply nutrients to plants (Amara *et al*., 2017). The status of nutrient index values in the farms of Rewa province has been depicted in Table 4.

The NIV for farms in sub-districts in Rewa province was calculated in order to determine the fertility state of these soils. The NIV calculated for organic carbon and available phosphorus were recorded as low with 1.48 and 1.40 respectively. The NIV calculated for nitrogen and potassium content was the medium category with values of 1.91 and 1.95, respectively. The NIV calculated for exchangeable calcium and magnesium content was recorded as high with 2.75 and 2.35 values respectively.

CONCLUSION

The research discovered that Rewa farms soils are low in pH. These soils have low levels of organic carbon. Given the depleted state of soil organic matter, practices such as manure or compost incorporation, crop residue retention and green manuring might all be recommended to improve it. The majority of soils had low to moderate levels of primary major nutrients. However, the soils examined had a high content of calcium and magnesium. The research recommends that these soils be better utilized by adjusting the pH of the soil by the addition of ameliorants, applying adequate primary nutrients through proper application methods and planting improved cassava varieties that thrive in the desired pH range.

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