International Journal of Agricultural Technology 2023 Vol. 19(5):2237-2248
Available online http://www.ijat-aatsea.com
ISSN 2630-0192 (Online)

Soil fertility level and nutrient index for important nutrients in the Macuata province of Fiji Islands

Singh, I. R.[1*], Champathi Gunathilake D. M. C.[2] and Prasad, A.[3]

[1]School of Agriculture Science and Technology, SVKM's NMIMS, Shirpur, Maharashtra, India; [2]Institute for Agro Technology and Rural Sciences, University of Colombo, Sri Lanka; [3]Department of Crop Science, College of Agriculture, Fisheries and Forestry, Fiji National University, Fiji.

Singh, I. R., Champathi Gunathilake, D. M. C. and Prasad, A. (2023). Soil fertility status and nutrient index for important nutrients in Macuata province of Fiji Islands. International Journal of Agricultural Technology 19(5):2237-2248.

Abstract The research investigation determined the soil fertility status and nutrient index values in the Macuata province of Fiji. The results revealed that the soils of the farms of the study area are acidic in reaction with average soil pH of 5.10, have moderate levels of soil organic carbon (2.47%), moderate levels of total nitrogen (0.20%), low levels of available phosphorus (10.63 mg/kg), however, the soils had a high content of exchangeable potassium (0.71 cmol/kg), exchangeable calcium (16.82 cmol/kg) and exchangeable magnesium (8.93 cmol/kg). The soil nutrient index value (NIV) calculated of nitrogen and available phosphorus were recorded as low at 1.65 and 1.28 respectively. The NIV for soil organic carbon was medium with 1.99. The calculated nutrient index value for exchangeable potassium, exchangeable calcium, and exchangeable magnesium content was recorded as high with 2.72, 2.91, and 2.72 values, respectively. Further studies could be carried out to determine the soil's physicochemical properties and other available plant nutrients in the area.

Keywords: Soil properties, Nitrogen, Soil organic matter, Phosphorus, Nutrient index value

Introduction

Soil is a non-renewable and basic resource that plays an important role in sustaining people's life, food security, and many socio-economic benefits. However, due to intensive farming practices, export opportunities, and climate change, the soil is deteriorating and being lost at unprecedented rates around the world. This is especially true for Asia and the Pacific. The soil deterioration occurs due to poor soil quality and fertility, and soil erosion. Successful soil management to protect soil quality depends on understanding how the soil reacts to agricultural practices over time (Gebeyaw, 2015). Sustainable soil productivity primarily depends on the soil's ability to provide essential nutrients for plant growth. Soil fertility is one of the most important factors controlling

* **Corresponding Author:** Singh, I. R.; **Email:** indrarajsingh@gmail.com

crop yields and determining the sustainable productivity of agroecosystems. The attraction of growing high-yielding varieties regardless of soil fertility has resulted in the depletion of soil organic matter and the deterioration of soil quality. Adding appropriate amounts of organic matter and lime can help maintain better and improved physical soil conditions for sustainable crop production (Singh *et al.*, 2014).

Nutrient deficiencies are a major impediment to soil productivity, stability, and sustainability (Bell and Dell, 2008). Although soil properties cannot be measured directly, soil properties that are susceptible to management change can be used as indicators (Andrew *et al.*, 2004). Soil quality is controlled by the physical, chemical, and biological factors of the soil and their interactions (Papendick and Parr, 1992; Sachan and Krishna, 2018). It is important to study the fertility status of cultivated soils to use the information to develop farmers' soil management strategies (Hadole *et al.*, 2019; Ojobor *et al.*, 2021; Gunamantha *et al.*, 2021). Although soil pH is a well-balanced indicator of the availability of plant nutrients in the soil (Singh *et al.*, 2013), however, determining the physicochemical properties and available nutritional status of the soil is important for improving sustainable productivity. Nutrient index methods as fertility indicators (Pramod *et al.*, 2013; Singh *et al*., 2016) are good tools to assess soil fertility. The study provided information on soil fertility levels and nutrient indices for important nutrients in the Macuata province of Fiji.

Materials and methods

Study area

The survey was conducted in Macuata province and the survey area was divided into three subdivisions to determine soil properties. The geographic reference of the study area is between 16°27'10.9" S to 16°22'56.9" E and 179°18'25.4" to 179°24'24.4" E. The average elevation of this area is 34 m above sea level. The climate is tropical, with an average annual temperature of about 24.9 ℃ and annual precipitation of about 2064 mm in the study area. The soils in the study area are acidic in nature, with pH varying between 4.80 and 5.50, with low to moderate organic carbon and low electrical conductivity (0.01 to 0.08 dSm-1).

Soil sampling and analysis

Fifty-eight representative surface samples were collected using augers from the topsoil (0–20 cm) of farmland in the villages of Nakama, Nareva and Labasa in Makuata province, keeping in view the variation in soil type, slope, and land use to determine soil properties and primary nutrient level. The soil was completely air-dried, passed through a 2 mm sieve, and placed in an appropriately labeled plastic bag for analysis. The location of the sampling sites is shown in Figure 1. Standard analytical methods as described by Richards (1954) and Jackson (1973) were followed for measuring various soils attributes such as pH, electrical conductivity (EC), organic carbon (OC), and primary and secondary nutrients such as total nitrogen, available phosphorus, potassium, calcium and magnesium at chemistry laboratory, Koronivia Research Station (KRS).

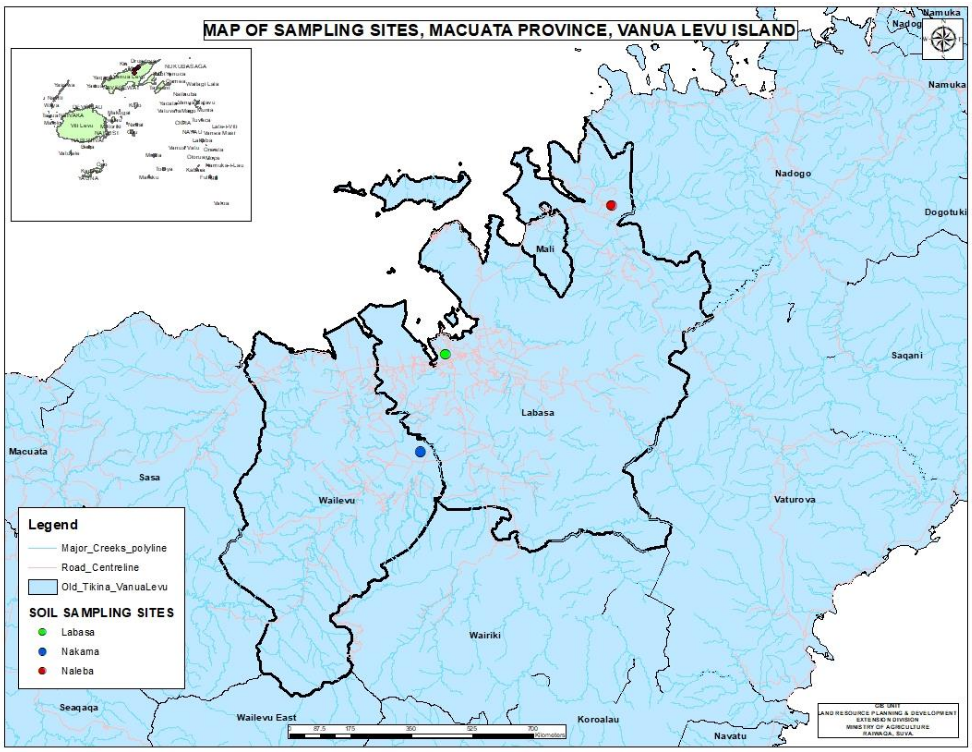

Figure 1. Location map of the study area

The nutrient availability index was calculated based on the fertility rating chart in Table 1 and categorization were done as proposed by Ramamoorthy and Bajaj, 1969 and used by Denis *et al.,* 2017 and Patil *et al.,* 2017 which are discussed below:

$$N.I = \{(1 \times A) + (2 \times B) + (3 \times C)\} / TNS$$

Where A = Number of samples in the low category; B = Number of samples in the medium category; C = Number of samples in the high category, and TNS = Total number of samples.

Table 1. Soil rating chart and their nutrient indices (FMARD, 2012)

Soil properties	Range		
	Low	Medium	High
Soil pH	< 6.0	6.1-6.9	>7.0
	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 (cmol /kg)	<1.5	1.5-4.5	>4.5
Exchangeable magnesium (cmol /kg)	<1.5	1.5-4.5	>4.5

The nutrient index value 1.67 to 2.33 is considered as the medium. An NIV less than 1.67 is considered a low and greater than 2.33 is a 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 SPSS 20 package.

Results

Nutrient status in farms of Macuata province

The pH of the soil samples varied from 3.5-6.1, 3.7-5.6, and 4.8-5.9 Naleba, Nakama, and Labasa farms respectively (Table 2). The low values of soil pH are due to the intense rainfall and consequent leaching of bases. The electrical conductivity varied from 0.01-0.08, 0.02 - 0.05, and 0.01 - 0.03 dSm-1 in soils of Naleba, Nakama, and Labasa farms respectively. The soil organic carbon content ranged from 1.2-4.3 in Naleba farms and from 1.7-3.7 % in Nakama farms while it ranged from 1.2-3.2% in Labasa farms. The total nitrogen content of soils of Naleba farms ranged from 0.08-0.27 in Naleba farms and from 0.11-0.32 % in Nakama farms while it ranged between 0.17-0.25percent in Labasa farms. These soils are of low to medium levels of total nitrogen status. The available phosphorus content of soils of Naleba farms ranged from 1.0-65.0 mg/kg, and 1.0-49.0 mg/kg in Nakama farms while it ranged between 1.0-4.0 mg/kg in Labasa farms. The highest mean of available phosphorus was recorded in Naleba farms while the lowest was in Labasa farms. The exchangeable potassium was highest in Naleba farms and lowest in Nakama farms. According to rating limits, these soils are of low potassium levels. The available potassium content of soils of Naleba farms ranged from 0.22-1.87 cmol/kg, 0.27-1.59 cmol/kg in Nakama farms while it ranged between 0.25-1.50 cmol/kg in Labasa farms. Mean exchangeable potassium was highest in Naleba and lowest in Nakama farms. The exchangeable calcium of soils of Naleba farms ranged from 7.1-21.6 cmol/kg, 2.5-33.3 cmol/kg in Nakama farms while it ranged between 6.3-37.6 cmol/kg in Labasa farms. The highest mean exchangeable calcium was found in Labasa farms and the lowest in Naleba farms.

The exchangeable magnesium content of soils of Naleba farms ranged from 1.8-37.5 cmol/kg, 1.3-18.0 cmol/kg in Nakama farms whereas it ranged between 1.32-14.1 cmol/kg in Labasa farms. The highest mean exchangeable magnesium was found in Naleba farms and the lowest in Nakama farms.

Nutrient variability in soils of Macuata province

The pH of the soil samples of the Macuata province ranged from 5.0-5.5 with a mean value of 5.1. The result indicated that soils are very low in soil pH and strongly acidic in nature. The organic carbon content of soil samples examined in subdivisions of Labasa ranged between 2.30 and 2.60%, with a mean value of 2.47 %. The total nitrogen content of studied soils ranged between 0.18 and 0.22%, with a mean value of 0.20% (Table 3).

The available phosphorus in soil samples ranged between 3.3 and 14.8 mg/kg, with a mean value of 10.63 mg/kg. These results indicated low values of the available phosphorus in the study area. The exchangeable potassium of the analyzed soil samples of the study area varied from 0.65-0.75 cmol/kg with a mean value of 0.71 cmol/kg. It indicated that the Macuata province contains a sufficient level of available potassium. The exchangeable calcium of the analyzed soil samples varied from 13.8-22.49 cmol/kg with a mean value of 16.82 cmol/kg. The exchangeable magnesium of soils of the analyzed soil samples of Macuata province varied from 7.4-10.9 cmol/kg with a mean value of 8.9 cmol/kg (Table 3).

Nutrient index value (NIV) in Macuata province

The status of nutrient index values in the farms of Macuata province is depicted in Table 4. The NIV for farms in sub-districts in Macuata province was calculated to determine the fertility state of these soils. The NIV calculated for nitrogen and available phosphorus were recorded as low at 1.65 and 1.28 respectively. The NIV calculated for organic carbon content was in the medium category with values of 1.99. The NIV calculated for exchangeable potassium, calcium, and magnesium was recorded as high with 2.72, 2.91, and 2.72 values respectively.

Table 2. Nutrient status of the soils of different subdivisions of Macuata province, Fiji

Soil property	Farms	Range	Mean	Percent of samples falling within the range		
				High	Medium	Low
pH	Naleba	3.5-6.1	5.0	0	10	90
	Nakama	3.7-5.6	4.8	0	0	100
	Labasa	4.8-5.9	5.5	0	13	87
EC	Naleba	0.01-0.08	0.03	0	0	100
	Nakama	0.02-0.05	0.03	0	0	100
	Labasa	0.01-0.03	0.02	0	0	100
Organic carbon (%)	Naleba	1.2-4.3	2.3	20	40	40
	Nakama	1.7-3.7	2.6	36	45	19
	Labasa	1.2-3.2	2.5	37	26	37
Total nitrogen (%)	Naleba	0.1-0.3	0.20	25	30	45
	Nakama	0.1-0.3	0.22	16	28	56
	Labasa	0.1-0.3	0.18	13	26	61
Available phosphorus (mg/kg)	Naleba	1-65	14.8	20	0	80
	Nakama	1-49	13.8	18	9	73
	Labasa	1-4	3.3	0	0	100
	Naleba	0.22-1.87	0.75	90	10	0
Exchangeable potassium (cmol(+)/kg)	Nakama	0.27-1.59	0.65	63	37	0
	Labasa	0.25-1.50	0.74	62	38	0
	Naleba	7.08-21.61	13.80	100	0	0
Exchangeable calcium (cmol(+)/kg)	Nakama	2.54-13.32	14.18	73	27	0
	Labasa	6.33-37.55	22.49	100	0	0
	Naleba	1.8-37.5	10.9	80	20	0
	Nakama	1.3-18.0	7.4	82	19	19
Exchangeable magnesium (cmol(+)/kg)	Labasa	1.3-14.1	8.5	75	13	12

Discussion

The low values of electrical conductivity might be due to the leaching of soluble salts by frequent and intense rainfall (Singh *et al.*, 2013). The condition of salt enrichment by fertilizer was unfavorable (Roy and Landey, 1962). Higher amounts of plant and animal residues left in soil decompose rapidly in tropical environments, resulting in more chances of accumulation of organic matter in the soil. Moreover, soils are rich in low-activity clays (Singh *et al.*, 2013). A high amount of organic matter provides part of the N requirement of crop plants and enhances the nutrient and water retention capacity of soils (Kavitha and Sujatha, 2015). Although the organic carbon content of the studied soils is high to low nitrogen values might be due to the low mineralization of organic matter in acidic soils. The studied area receives high rainfall (2064 mm) which results in loss of nitrogen due to leaching and denitrification in the soils. Therefore, the soils could retain only a limited quantity of mineralized nitrogen. Similar findings were reported by Radersma and Smit (2011). The low phosphorus status could be ascribed to higher removal than replenishment and fixation of P as iron and aluminum phosphates as these soils are rich in hydrated as well as amorphous oxides of Fe and Al (Curtin *et al.*, 1991). Observed data indicates high exchangeable potassium in the study area, similar findings were also reported by Sachan and Krishna (2018) in the Rewa and Toga region of Fiji. Calcium and Magnesium were found sufficient in the studied area of Macuata province and similar findings were reported by Sachan and Krishna, 2018.

Acidic soils can occur as a result of basic cation leaching or as a result of the constant uptake of bases by crops cultivated on the land. The soil pH values are relatively low due to the acidic parent material of these soils (Singh *et al.*, 2013; Sachan and Krishna, 2018). The soil acidity implied that nutrients are likely to be available or unavailable for crop uptake. Therefore, the application of liming material is recommended to increase the soil pH of the acidic soils. Nitrogen is an essential nutrient for plants and is the most usually deficient of all nutrients (Bhatla and Lal, 2018). These results showed that the nitrogen content in the study area is in the medium range. The data indicated that the soil organic carbon content of the soils of the study area is in the medium range. It is evident that a large portion of soil nitrogen is available in organic form such as decomposed plant parts, and crop and animal residues which are released for plant growth and development through the mineralization process (Singh *et al.*, 2013; Sachan and Krishna, 2018). The range is wide, which may be attributed to variations in soil qualities, such as pH, organic matter content, texture, land use, and other agricultural practices.

Al^{3+} and Fe^{3+} in solution are responsible for the precipitation of phosphate ions as aluminum and iron phosphates, which are insoluble in nature. The very low solubility of phosphorus compounds results in very low concentrations of phosphorus in the solution (Sachan and Krishna, 2018).

Potassium plays a key role in several physiological processes vital to plant growth, from protein synthesis to water balance (Sumithra *et al.*, 2013). The satisfactory conditions might be due to the optimum application of potash and 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). Magnesium ions (Mg^{2+}) are the second most abundant cation plant cells, where they play a variety of roles, including photosynthesis, enzyme catalysis, and nucleic acid synthesis (Khadka *et al.*, 2016). Data indicate the sufficient level of exchangeable calcium and magnesium in the soils of Macuata province in Fiji.

It can be concluded that the soils of Macuata province are low in pH. These soils have moderate levels of organic carbon. Practices such as manure or compost incorporation, crop residue retention, and green manuring are recommended to maintain and improve the level of soil organic carbon. The soils were low in available phosphorus, and moderate in soil organic carbon and nitrogen. However, the soils examined had a high content of potassium, calcium, and magnesium. The research recommends that these soils can be better utilized by adjusting the pH of the soil with the addition of ameliorants and applying optimum doses of primary nutrients using proper application methods. If managed well, studied soils can be used for sugarcane and vegetable production.

This study would help the farmers to determine the application of appropriate doses of plant nutrients through available fertilizers in combination with manures to maximize the yield of crops and to maintain soil physical conditions, at the same time the researchers to explore more areas for further research in this area to identify the ways to restore the soil fertility through sustainable land management practices to mitigate the climate change.

Table 3. Availability of primary nutrients in Macuata province

Farms	Soil pH	Organic carbon (%)	Nitrogen (%)	Phosphorus (mg/kg)	Potassium (cmol/kg)	Calcium (cmol/kg)	Magnesium (cmol/kg)
Naleba	5.00 (L)	2.30 (M)	0.20 (M)	14.80 (L)	0.75 (H)	13.80 (H)	10.90 (H)
Nakama	4.80 (L)	2.60 (M)	0.22 (M)	13.80 (L)	0.65 (H)	14.18 (H)	7.40 (H)
Labasa	5.50 (L)	2.50 (M)	0.18 (M)	3.30 (L)	0.74 (H)	22.49 (H)	8.50 (H)
Mean	5.10	2.47	0.20	10.63	0.71	16.82	8.93

Table 4. Nutrient index value (NIV) in farms of Macuata province

Farms	Organic carbon		Nitrogen		Phosphorus		Potassium		Calcium		Magnesium	
	NIV	Rating	NIV	Rating	NIV	Rating	NIV	Rating	NIV	Rating	NIV	Rating
Naleba	1.80	M	1.80	M	1.40	L	2.90	H	3.00	H	2.80	H
Nakama	2.18	M	1.64	L	1.45	L	2.64	H	2.73	H	2.73	H
Labasa	2.00	M	1.50	L	1.00	L	2.63	H	3.00	H	2.63	H
Mean	1.99		1.65		1.28		2.72		2.91		2.72	

Acknowledgments

The authors are thankful to Fiji National University for providing the necessary facilities. Thanks to the Director of Koronivia Research Station for providing the laboratory facilities for the investigation.

References

Aldon, D., Mbengue, M., Mazars, C. and Galaud, J. P. (2018). Calcium signalling in plant biotic interactions. International Journal of Molecular Sciences, 19:665.

Andrew, S. S., Karlen, D. L. and Cambardella, C. A. (2004). The soil management assessment framework: A quantitative soil quality evaluation method. Soil Science Society American Journal, 68:1945-1962.

Bell, R. W. and Dell, B. (2008). Micronutrients for Sustainable Food, Feed, Fiber and Bio energy Production. IFA, Paris, France (www.fertilizer.org).

Bhatla, S. C. and Lal, M. A. (2018). Plant Mineral Nutrition. In Plant Physiology, Development and Metabolism Springer, Singapore. (pp.37-81). https://doi.org/10.1007/978-981- 13-2023-1_2

Curtin, D; Naidu, R. and Syers, J. K. (1991). Chemical and mineralogical characteristics of some strongly weathered Fijian soils: Fertility implications. Geoderma, 48:363-372.

Denis, M. K. A., Parameshgouda, L. P. Augustine, M. K. and Daniel, H. S. (2017). Assessment of soil fertility status using nutrient index approach. Academia Journal of Agricultural Research, 5:725-735.

FMARD (2012). Literature Review on the Soil Fertility Investigation in Southern Nigeria. Federal Ministry of Agriculture and Rural Development. Edited by Chude V. O., 2nd Ed. 250p.

Gebeyaw, T. Y. (2015). Assessment of Micronutrient Status in Different Land Use Soils in Maybar Lake Watershed of Albuko District, South Wello Zone, North Ethiopia, American Journal of Environmental Protection, 3:30-36.

Gunamantha, I. M., Sudiana, I. K., Sastrawidana, D. K., Suryaputra, I. N. G. A. and Oviantari, M. V. (2021). The evaluation of soil fertility status of open space in campus area and their suitability for tropical fruits production. Journal of Soil Science and Environmental Management, 12:78- 85.

Hadole, S. S., Katkar, R. N. Sarap, P. A. Lakhe, S. R. and Muhammed, S. K. (2019). Status of molybdenum in soils of Palghar district of Maharashtra. Indian Journal of Agricultural Research, 53:737-740.

Jackson, M. L. (1973). Soil Chemical Analysis. 1st Edn., Prentice Hall of India Pvt. Ltd., New Delhi, India.

Kavitha, C. and Sujatha, M. P. (2015). Evaluation of soil fertility status in various agro ecosystems of Thrissur district, Kerala, India. International Journal of Agriculture and Crop Sciences, 8:328-338.

Khadka, D., Lamichhane, S., Khan, S., Joshi, S. and Pant, B. B. (2016). Assessment of soil fertility status of Agriculture Research Station, Belachapi, Dhanusha, Nepal. Journal of Maize Research and Development, 2:43-57.

Ojobor, S. A., Egbuchua, C. N. and Onoriasakpovwa, R. A. (2021). Assessment of soil fertility status using nutrient index approach of Ovu Sub-Clan, Delta State, Nigeria. Agricultural Science Digest, 41:282-288.

Papendick, R. I. and Parr, J. (1992). Soil quality- the key to sustainable agriculture, Am, J. Altern. Agric. 7:2-3. Resource, Martin Capewell, Agriculture Solution LIC.

Patil, S, Kumar, K. S. and Srinivasamurthy, C. A. (2017). Soil fertility status and nutrient index for primary nutrients in Western Ghats and Coastal Karnataka under different agro-ecological systems. Asian Journal of Soil Science, 12:314-319.

Pramod, K., Ashok K., Pardeep K., Ravindra K., Yogesh K. and Sumit, R. (2013). Soil fertility status in some soils of Muzaffarnagar District of Uttar Pradesh, India, along with Ganga canal command area. African Journal of Agricultural Research, 8:1209-1217.

Radersma, S. and Smit, A. L. (2011). Assessing denitrification and N leaching in a field with organic amendments, NJAS - Wageningen Journal of Life Sciences, 58:21-29.

Ramamoorthy, B. and Bajaj, M. P. (1969). Soil fertility map of India. Ferti. News, 14:25.

Richards, L. A. (Ed.) (1954) Diagnosis and improvement of saline and alkali soils Agricultural Handbook No.60, United States Department of Agriculture. U. S. Govt. Printing Office, Washington, D.C.

Roy, B. B. and Landey, R. I. (1962). Studies on red and lateritic soils of Mond watershed area of Raigarh district. Indian Journal of Agricultural Sciences, 32:294-302.

Sachan, H. K. and Krishna, D. (2018). Nutrient status and their relationship with soil properties of dalo [Colocasia esculenta (L.) Schott] growing areas of Rewa district in Fiji. Indian Journal of Agricultural Research, 52:696- 699.

Singh G, Sharma, M. Jatinder, M. and Singh, G. (2016). Assessment of Soil Fertility Status under Different Cropping Sequences in District Kapurthala. J. of Krishi Vigyan, 5:1-9.

Singh, I. R., Nath, P. Goswami, S. N. and Tuitubou, I. (2014). Effect of lime and phosphorus on growth and yield attributes of capsicum on soils of Koronivia, Fiji. Fiji Agricultural Journal, 54:24-29.

Singh, I. R., Sharma, A. C. and Goswami, S. N. (2013). Nutrient status and their availability in relation to properties of soils of Koronivia, Fiji, Fiji Agricultural Journal, 53:1-6.

Sumithra, R., Thushyanthy, M. and Srivaratharasan, T. (2013). Assessment of soil loss and nutrient depletion due to cassava harvesting: A case study from low input traditional agriculture. International Soil and Water Conservation Research, 1:72-79.

(Received: 26 October 2022, Revised: 20 June 2023, Accepted: 3 July 2023)