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Soil macronutrient status in different depths after wheat harvest in the paddy-wheat cropping system of Rupandehi District of Nepal

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ABSTRACT
Understanding the soil nutrient content varied with the soil depth is one of the most important aspects of every crop husbandry practice and information about the soil nutrient status of a certain area is very important for nutrient management programs. Considering this, a study was carried out in order to find out the depth-wise status of soil pH, soil organic matter and macronutrients in the paddy-wheat cropping system of the different areas of Rupandehi District of Nepal. The study was undertaken from April, 2019 to May 2019 immediately after the harvesting of the wheat crop. Altogether 108 samples were collected from two soil depths (0-10 cm and 10-20 cm) of randomly selected 54 sampling points by using a soil sampling auger. The soil parameters were determined by analyzing the samples at National Soil Science Research Centre, Khumaltar. The results of the study showed that soil pH values ranged from 6.73 to 8.03, but were non-significantly (p>0.05) affected soil depth. The soil organic matter, Total Nitrogen (N), available phosphorus (P_2O_5) and available potassium (K_2O) in the soil were significantly (p>0.05) affected by soil depth. Higher soil organic matter (2.01±0.06%), Total N (0.10±0.002%), available P_2O_5 (25.56±1.33 mg kg^{-1}) and available K_2O (47.9± 2.11 mg kg^{-1}) were found in 0-10 cm soil depth. Higher concentrations of nutrients in the upper surface may be due to the incorporation of crop residue and supplementation of depleted nutrients by external sources of fertilizers.

Keywords: Cropping system, soil fertility, soil organic matter, soil pH

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INTRODUCTION

Paddy and wheat are important commodities in Nepali farming systems. Paddy is the primary source of livelihood and contributes up to 40-50% of the energy and 23% of the protein in Nepali's daily diet and income for more than two-thirds of farm households (Joshi 2020). It contributes 20% to the Agricultural Gross Domestic Product (AGDP) and >7% to the total GDP of Nepal. Accordingly, the paddy-wheat cropping system is a popularly practiced system in the Southern plains of Nepal. About 0.5 million hectares of land in Nepal is occupied under the paddy-wheat cropping system, which shares 65.8% and 72.1% of the total area and the total production of cereal crops in the country (Khanal et al 2012). Nevertheless, practicing this cropping system produces comparatively a lower yield of paddy and wheat in the Nepali context. The difference between the attainable yield and the potential yield of paddy is between 45-55% in Nepal (Joshi 2020).

Supplement of balanced nutrition is one of the important factors to improve the productivity under paddy-wheat cropping system. Proper information on how total and plant-available soil nutrients vary across the land is necessary for the rational management of soil fertility. Principally, plant nutrient management is governed by the level of nutrients in soil, however, information about soil properties is essential for sustainable agriculture (Tomar et al 2020). To understand the soil fertility status, soil testing before planting of next crop is very essential to know the nutrient availability and fertilizer recommendation. Rupandehi District although is popular for paddy-wheat production, but information on nutrient status is limited. Therefore, in present study we aimed to assess the nutrient status of paddy-wheat growing areas of Rupandehi District Nepal.

MATERIALS AND METHODS

Sites description

A study was conducted at various sites of paddy-wheat growing area of Omsatiya Rural Municipality and Rohini Rural Municipality of Rupandehi district of Nepal. The sites are geographically located at 27.542662°N, 83.491016°E and 27.514097°N, 83.538675°E, respectively. The climate is of sub-tropical type with three distinct seasons: summer, rainy and winter.

Soil sample collection and analysis

The soil samples were collected from the farmers' field during April to May 2019, after the wheat crop harvest. The farms which were adopting long-term (at least 10 years) paddy-wheat cropping systems were selected for the study. As paddy and wheat both are shallow-rooted crops, soil samples were collected from the depths of 0-10 cm and 10-20 cm. A total of 108 soil samples were collected from randomly selected 54 sampling points by using a soil sampling auger.

The collected soil samples were analyzed in the laboratory of the National Soil Science Research Centre, Khumaltar, Lalitpur. Unwanted materials like leaves, plant parts, gravel, and stones were removed from the samples and then samples were dried at room temperature. After drying, samples were ground and sieved through a 2 mm mesh sieve. Soil chemical parameters of the samples were analyzed in the laboratory by using the protocols as shown in Table (1).

Table 1. The methods used in the laboratory to analyze the chemical properties of the soil

Parameters	Methods
Soil pH	Potentiometric 1:2 (Jackson 1973)
Soil organic matter (OM)	Walkley and Black (1934)
Total Nitrogen (TN)	Kjeldahl (Bremner and Mulvaney 1982)
Available P_2O_5	Modified Olsen's (Olsen et al 1954)
Available K_2O	Ammonium acetate (Jackson 1967)

Data analysis

The data obtained from the laboratory were analyzed by using one-way Analysis of Variance (ANOVA) using STAR software version 2.0.1. The means were separated using the Least Significant Difference (LSD) Test at 1% or 5% level of significance as described by Gomez and Gomez (1984) and Shrestha (2019). The rating of the soil parameters (very low, low, medium, high, and very high) was based on the rating chart of the Soil Science Division (SSD 2019).

RESULTS

Soil pH

The results of the study showed that the distribution of soil pH was nearly neutral to moderately alkaline in both of the soil depths (Table 2). The pH values were statistically similar ($p>0.05$) for different soil depths. The data range of soil pH value varied from 6.73 to 8.03 with a mean value of 7.45 in 0-10 cm soil depth and from 7.06 to 7.99 with a mean value of 7.46 in 10-20 cm soil depth. In both soil depths, the overall mean value of soil pH was observed slightly towards alkaline (Table 2). The distribution of soil pH in the different soil depths with their median value is presented in Figure (1).

Table 2. Depth-wise variation of soil pH, OM and TN contents in the soils under paddy-wheat cropping system

Soil depth (cm)	pH	SOM (%)	TN (%)
0-10	7.45	2.01	0.10
10-20	7.46	1.65	0.09
Grand mean	7.46	1.83	0.09
F-test	ns	**	**
LSD	0.09	0.18	0.006
SEM	0.03	0.06	0.002
CV%	3.2	26.1	18.1

SOM: Soil Organic matter, TN: Total nitrogen, LSD: Least Significant Difference, SEM: Standard Error of Mean, CV: Coefficient of variation, ** denotes significant at 1% level of significance, ns= non-significant

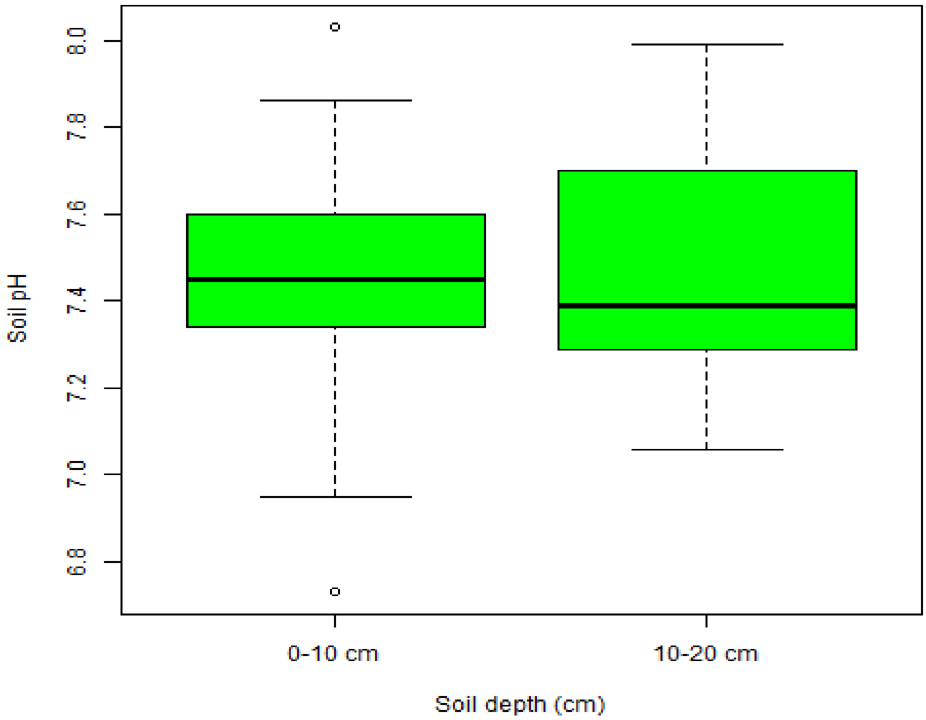

Figure 1. Distribution of soil pH in the different soil depths

Soil organic matter

The soil organic matter (SOM) was found significantly different ($p<0.01$) across soil depths (Table 2) with medium-range values (Figure 2). The range SOM content was varied from 0.98% to 3.80% with a mean value of 2.01% in 0-10 cm soil depth and the range was varied from 0.59% to 3.39% with a mean value of 1.65% in 10-20 cm soil depth. In both soil depths organic matter content was found medium in status and also found higher in upper surface and decreases with increasing the soil depth (Table 2).

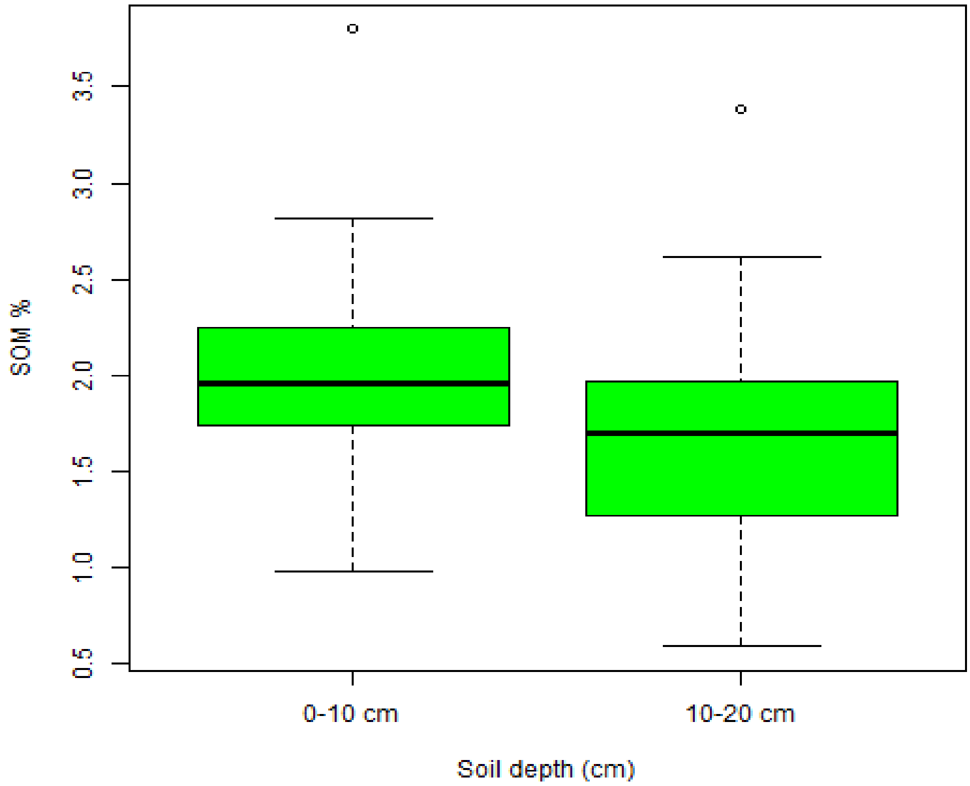

Figure 2. Distribution of SOM in the different soil depths

Total nitrogen

The total nitrogen (TN) content was found significantly different ($p<0.01$) for different soil depth. The TN content was higher in 0-10 cm soil depth and decreased in 10-20 cm depth (Table 2). Likely, distribution of TN in different depths with its median value are presented in Figure 3. The mean value of TN content in soil was 0.10% in 0-10 cm, ranged from 0.06% to 0.13%. However, TN content was significantly lower ($p<0.01$) in 10-20 cm (0.09%) with the range of 0.03% to 0.12%.

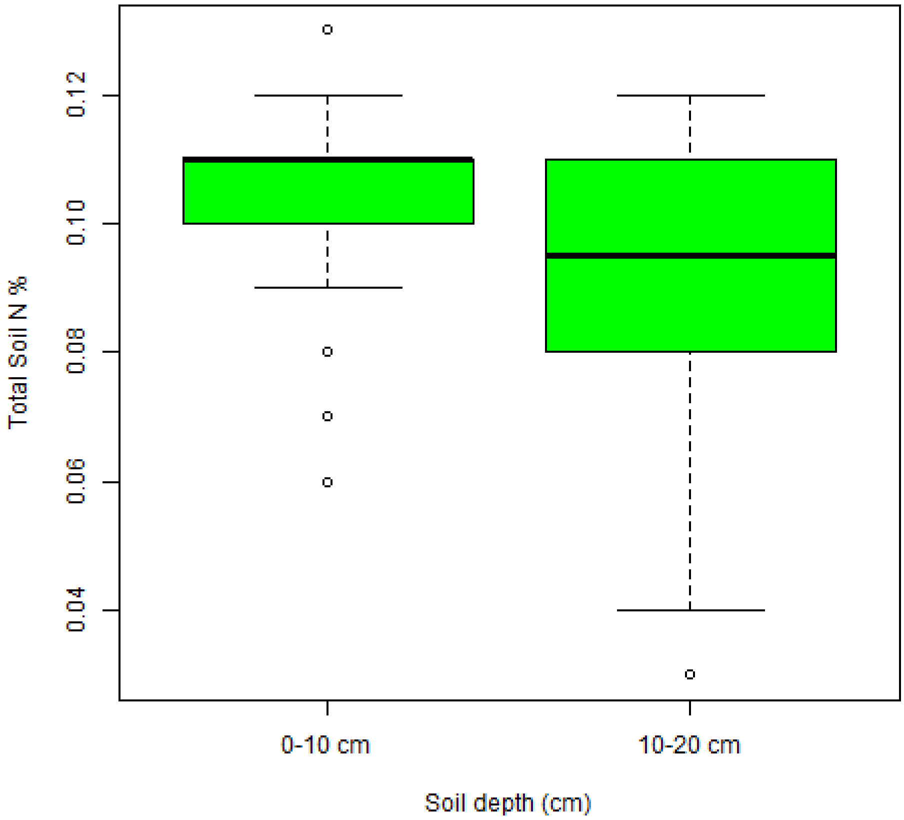

Figure 3. Distribution of TN in the different soil depths

Available Phosphorus

The results showed that mean values of available phosphorus were significantly different ($p<0.001$) for different soil depths (Table 3). The upper surface had higher available phosphorus content compared to the lower surface, with mean values of 25.56 versus 19.36 mg kg^{-1}, respectively. Similarly, the distributions of available phosphorus (Figure 4) showed the median value of available phosphorus content in 0-10 cm soil depth with the range from 8.58 to 79.46 mg kg^{-1}. Similarly, the range available phosphorus content in 10-20 cm was varied from 6.17 to 49.04 mg kg^{-1}. The result indicated that the mean available phosphorus was medium in status in both of the soil depths. In the case of available phosphorus content too, the higher concentration was found on the upper surface in comparison to the lower surface.

Table 3. Depth-wise variation of available phosphorus and potassium in the field under paddy-wheat cropping system

Soil depth (cm)	Available P_2O_5 (mg kg^{-1})	Available K_2O (mg kg^{-1})
0-10	25.56	47.9
10-20	19.36	37.5
Grand mean	22.46	42.7
F-test	***	***
LSD	3.74	5.91
SEM	1.33	2.11
CV%	43.7	3.2

LSD: Least Significant Difference, SEM: Standard Error of Mean, CV: Coefficient of variation, *** denotes significant at 0.1% level of significance

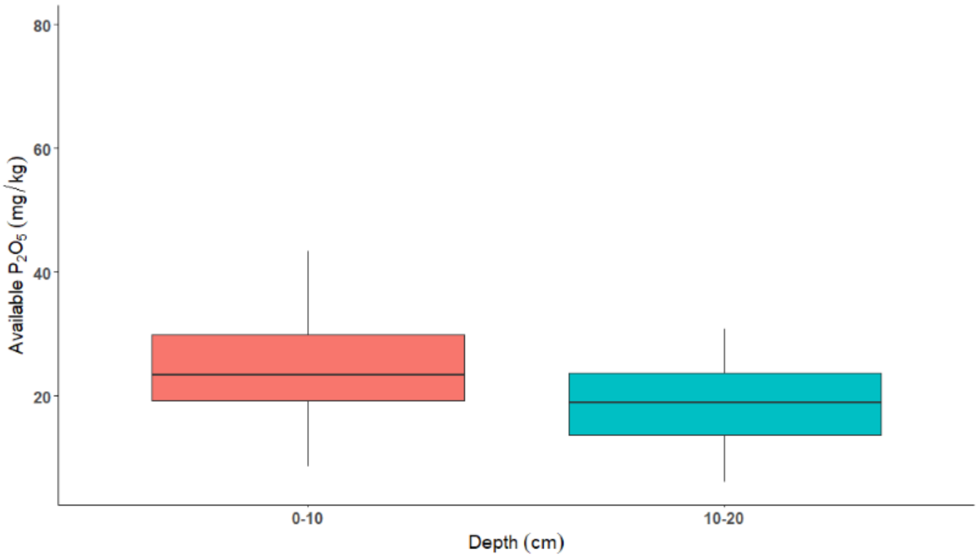

Figure 4. Distribution of available phosphorus in different soil depths

Available potassium

The extractable potassium content was influenced significantly ($p<0.001$) by different soil depths (Table 3). In both soil depths of 0-10 cm and 10-20 cm, low potassium status was found with mean values of 47.9 and 37.5 mg kg^{-1}, respectively. While analyzing the distribution of available potassium within the soil depths, the wider variation in the data was obtained for 0-10 cm (from 15.54 to 92.06 mg kg^{-1}) in comparison to 10-20 cm (Figure 5). Similarly, in case of 10-20 cm soil depth, the extractable potassium ranged from 15.54 to 74.41 mg kg^{-1} (Figure 5).

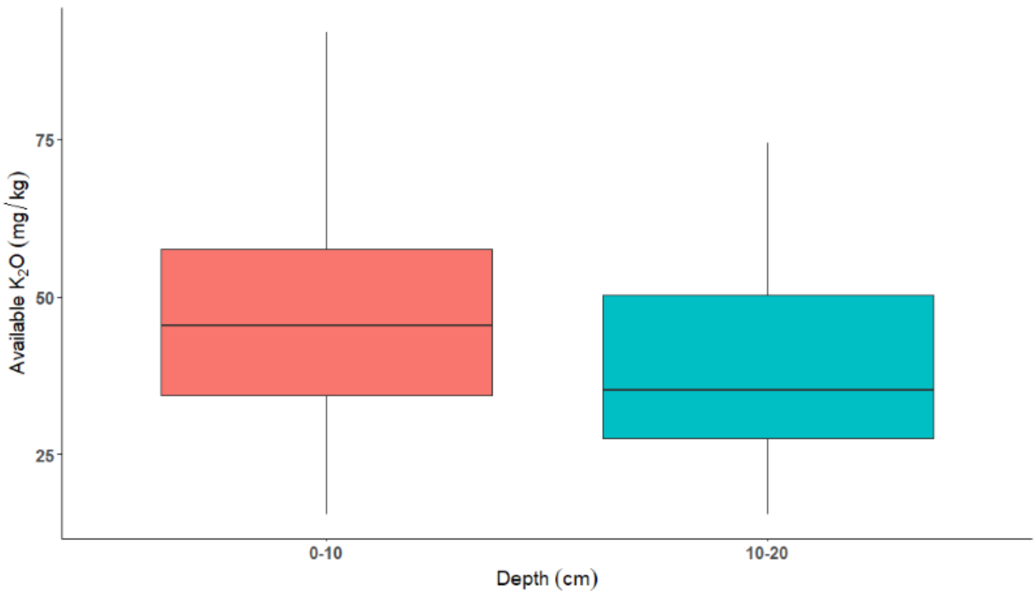

Figure 5. Distribution of available potassium in different soil depths

DISCUSSION

Almost, the similar soil pH was found in both soil depths (Figure 1, Table 2). The pH value in present findings were in slightly disagreement with those of previous studies. Other investigations indicated an increase in soil pH as soil depth rose (Khadka et al 2017, Wani et al 2017). However, in this study the average value of the pH did not show that pattern but was slightly higher range (figure 1, Table 2). It can be generally figured out that variations in crop activity and in leaching of bases due to the higher precipitation could be some of the responsible factors associated with high pH of different depths. We found higher SOM at upper surface than the lower surface, however, soil organic matter content was found medium in status in both of the soil surfaces (Table 2, Figure 2). As the soil organic matter plays vital role in agriculture, the farmers of this area need to adopt the practices for organic matter improvement in their soils. The reasons of higher soil organic matter content in upper surface might be associated with the differences in temperature and moisture between these two depths. With increase in temperature, microbial activities especially the activities of decomposing microorganisms increases. Increased microbial activities accelerate the accumulations of organic matter in the soil (insert reference). Additionally, with the increase in moisture, the total plant production and decomposition in top soil increases (PASSeL, 2022), which could increase the soil organic matter in upper surface as have been occurred in the present study (Figure 2). The result of the study was in agreement with the reports of several studies in case of organic matter content. Khadka et al (2017), Amgain et al (2020) and Giri et al (2022) also reported that the organic matter was decreased in order with increasing the soil depth.

In case of nitrogen content in the soil, higher total nitrogen in upper surface may be associated with the influence of crop activity, and depleted nitrogen content is supplemented by the external addition of N-fertilizers during crop cultivation under paddy-wheat system (Figure 3). The findings is in agreement with previous studies such as Bhat et al (2017, Khadka et al (2017), Ganai et al (2018), Khanday et al (2018), Amgain et al (2020). Mean Nitrogen status of our study area was medium. Therefore, farmers need to apply 75% of recommended nitrogenous fertilizer for sustainable soil fertility maintenance and economic production as have been suggested by Khadka et al (2017).

Similarly, available phosphorus was also obtained higher in the upper depth in the study (Figure 4). A higher amount of organic matter and microbial presence in the upper depth could be responsible for this result. Similar results were reported by other authors too such as Kumar et al (2014, Bhat et al (2017, Khadka et al (2017, Amgain et al (2020). Moreover, available phosphorus was found medium in both soil depths. Thus it is suggested that farmers need to apply at least 60% of the recommended dose of phosphorus for the sustainability of soil fertility.

Although lower concentrations of potassium were obtained in both soil depths, the upper depth had higher potassium content than the lower depth (Figure 5). The application of potassium fertilizer during crop cultivation, release of liable potassium from organic residues could have contributed to the higher available potassium content in the upper depth in comparison to the lower depth of the soil of the paddy-wheat cropping areas in Rupandehi district. Similar results of decreasing potassium levels with increasing soil depths were also reported by Bhat et al (2017), Khadka et al (2017), Khanday et al (2018) and Amgain et al. (2020). The lower potassium in both soil depths might be due to the imbalanced use of fertilizer. In most of the cases, the Nepali farmers mainly focus on nitrogenous fertilizers and low emphasis on the use of potassium fertilizers, hence not enough to replenish the plant uptake potassium in soil. For maintaining the soil fertility, balanced fertilizer should be applied.

CONCLUSION

The study concluded that soils of paddy-wheat cropping areas of Rupandehi district were nearly neutral to moderately alkaline in reaction. The soil pH was not altered by soil depth. The soil organic matter, total nitrogen, available phosphorus and exchangeable potassium were decreased with increasing the soil depth. The organic matter, total nitrogen and phosphorus were medium in status and the exchangeable potassium was low in status in both soil depths. The study recommended applying macronutrients in the soil under the paddy-wheat cropping system of Rupandehi district. The findings of the study would help to guide the required practices for sustainable soil fertility management.

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Authors' Contributions

RA: Designed and implemented the experiment and prepare the manuscript. DK: Assisted to find out the sampling points of the study areas and contributed to important role during laboratory work. SJ: Assisted during laboratory work.

Conflicts of Interest

The authors have no relevant financial or non-financial interests to disclose.

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