Fundamental and Applied Agriculture
Vol. 7(2), pp. 112–120: 2022
doi: 10.5455/faa.100144

AGRICULTURE | ORIGINAL ARTICLE

Assessment of soil nutrient status of mandarin orchards in Syangja, Nepal

Asbin B K [1], Krishna Raj Pandey [1*], Bishal Shrestha [2], Keshav Bhattarai [1], Deepak Khatri [1]

[1]Faculty of Agriculture, Agriculture and Forestry University Rampur, Chitwan, Nepal
[2]Department of Horticulture, Agriculture and Forestry University Rampur, Chitwan, Nepal

ARTICLE INFORMATION

Article History
Submitted: 10 Mar 2022
Accepted: 17 Jun 2022
First online: 30 Jun 2022

Academic Editor
M M R Jahangir
mmrjahangir@bau.edu

**Corresponding Author*
Krishna Raj Pandey
krishnapandey2055@gmail.com

ABSTRACT

The research was conducted in Putalibazar, Bhirkot, and Waling municipality and Arjunchaupari rural municipality of Syangja district , Nepal in 2021 to assess the status of the primary nutrients (nitrogen, phosphorus, and potassium), pH, and soil organic matter of the cultivated mandarin orchards located at different altitudes. There were six treatments: three in north-facing namely <900 meter above sea level (masl), 900-1100 masl, and >1100 masl, and three in south-facing namely <900 masl, 900-1100 masl, and >1100 masl. These treatments were replicated 4 times each in Randomized Complete Block Design (RCBD). A total of 72 soil samples were taken from 0 to 30 cm soil depth in 'V' shaped pattern from last week of March to the first week of April. Analysis of soil samples was done in the regional soil testing laboratory Pokhara, Kaski. The altitude range had a considerable effect on soil nutrient status except for phosphorous and potassium availability. Both pH and soil organic matter content were found increasing with the increase in altitude. Soil pH level was found increasing with increase in altitude from 5.62 in <900 masl to 6.70 in altitude >1100 masl in south facing slope. Highest organic matter content (5.76%) was recorded in 900-1100 masl of north facing slope followed by lowest 3.76% in <900 masl in south facing slope. Similarly, highest nitrogen content (0.28%) was recorded in 900-1100 masl of north facing slope followed by lowest (0.18) in >1100 masl in south facing slope. Phosphorus and potassium were found highest in 900-1100 masl of both north and south facing slope. The findings of the research showed that the altitude range of 900-1100 masl and north-facing slope was suitable for mandarin cultivation from the nutrient status point of view.

Keywords: Altitude, fertility, mandarin, soil nutrients, soil parameters, soil testing

Cite this article: BK A, Pandey KR, Shrestha B, Bhattarai K, Khatri D. 2022. Assessment of soil nutrient status of mandarin orchards in Syangja, Nepal. Fundamental and Applied Agriculture 7(2): 112–120. doi: 10.5455/faa.100144

1 Introduction

In the Nepalese context, citrus is considered as one of the most important fruit crops in terms of area coverage, production, and export potential (Kaini, 2019). Citrus contributes about 26.84% of total fresh fruit production in Nepal (MOALD, 2021). The genus citrus includes different species such as sweet orange, mandarin and acid Lime. Among them, Mandarin is the most common citrus fruit grown in Nepal. The mid-hill region (1000 to 1500 m altitude) has a comparative advantage in the cultivation of citrus fruits, especially mandarin and sweet orange (FDD, 2013). Mandarin trees require large quantities of mineral nutrients to attain adequate growth and yield and the requirements for some of the nutrients vary with soil fertility and type (Erner et al., 2005). As the mandarin is grown in hilly areas of Nepal, high rates of soil erosion and nutrient loss have been reported from degraded forest land, grazing lands, and sloping agricultural fields which reduces the fertility decline in citrus orchards (Srivastava and Singh, 2009).

Evaluation of soil fertility for sustainable soil management and crop production has become a major concern for researchers these days. According to Brady and Weil (2002), soil fertility evaluation helps to determine the appropriate nutrient management strategies for the soil under consideration. Among various techniques used for a soil fertility evaluation, Soil testing is the most widely used one and is referred to as an indispensable tool for sustaining productivity through soil fertility maintenance (Havlin et al., 2010). Soil testing assesses the fertility status of soil and provides a basis for formulating fertilizer recommendations in order to increase productivity and maintain soil fertility for crop production on a sustainable basis (Ramulu and Reddy, 2018).

Various physical, chemical, and biological properties of soil consisting of different components affect its fertility status (Walsh and McDonnell, 2012). Soil physical parameters (such as soil texture, structure, and color) and chemical parameters (such as pH, organic matter content, and concentrations of available macro and micronutrients are the important soil components responsible for determining soil fertility and its productivity (Khattak and Hussain, 2007; Khadka et al., 2016). Therefore, the determination of these properties is a prerequisite in order to assess information about soil fertility. The physical and chemical tests conducted in the laboratory helps in the estimation of the availability of such soil parameters and also provide information regarding the capacity of soil to supply mineral nutrients (Ganorkar et al., 2013).

The nutrient status of orchards is directly related to the orchard health and longevity of the orchard. Due to the diverse scope for mandarin production in Syangja, it would be advantageous to farmers to create direct economic benefits to uplift their livelihood. This research aims to provide the overall primary nutrients, pH, soil organic matter content of the study area along with a comparison of these parameters based on altitude and overall interrelation between these soil parameters. Moreover, this study will assist in developing strategies and policies for concerned stakeholders, especially to prepare and develop programs that will ensure an increase in productivity as well as the quality of mandarin based on the impact of altitude on nutrient status. .

2 Materials and Methods

2.1 Selection of study site

Syangja district lies in Gandaki Province of Nepal at latitude 28°00′38.16″ North and longitude 83°47′48.48″ East. The study was conducted in mandarin growing areas which included ward no. 1, 3 & 12 of Putalibazar municipality, ward no. 2, 3, 4 & 6 of Bhirkot municipality, ward no. 1, 3, 4 & 6 of Waling municipality and ward no. 1, 3, 9 & 10 of Arjunchaupari rural municipality of Syangja district. Soil samples were collected from commercial orchards having more than 100 trees in each municipality. The reason for the selection of these areas was that they fall under the command area of the mandarin super-zone and are the major sites for mandarin cultivation.

2.2 Sampling techniques

The target population of this study was mandarin producers under PMAMP citrus super-zone Syangja. A total of 72 soil samples were taken from the orchard with similar management practices from the depth of 0-30 cm. A single sample was taken from an orchard with a minimum of 100 mandarin trees and a minimum of 5 years old. A single sample was composed of the 5 different locations dug up to 30 cm depth. There were 3 samples within a replication. Collected soil samples from different orchards were sent to soil analysis laboratory for evaluating soil pH, soil organic matter, total nitrogen, available phosphorus, and potassium content of the soil.

2.3 Research design and treatments

A randomized complete block design (RCBD) was conducted for research which included 6 different treatments (Table 1). Each treatment was replicated 4 times and three samples were taken in each replication. As such, a total of 72 soil samples were taken during spring season from last week of March to the first week of April, 2021.

Table 1. Treatments used in the experiment

Sl. No.	Treatments (altitude in meter)
T1	<900 masl North facing
T2	900-1100 masl North facing
T3	>1100 masl North facing
T4	<900 masl South facing
T5	90-1100 masl South facing
T6	>1100 masl South facing

2.4 Parameters

The soil samples taken from the depth of 0 to 30 cm in ‘V’ pattern from different orchards under study were evaluated and compared for various parameters, which were, soil pH, soil organic matter content, total nitrogen, available phosphorus, and available potassium.

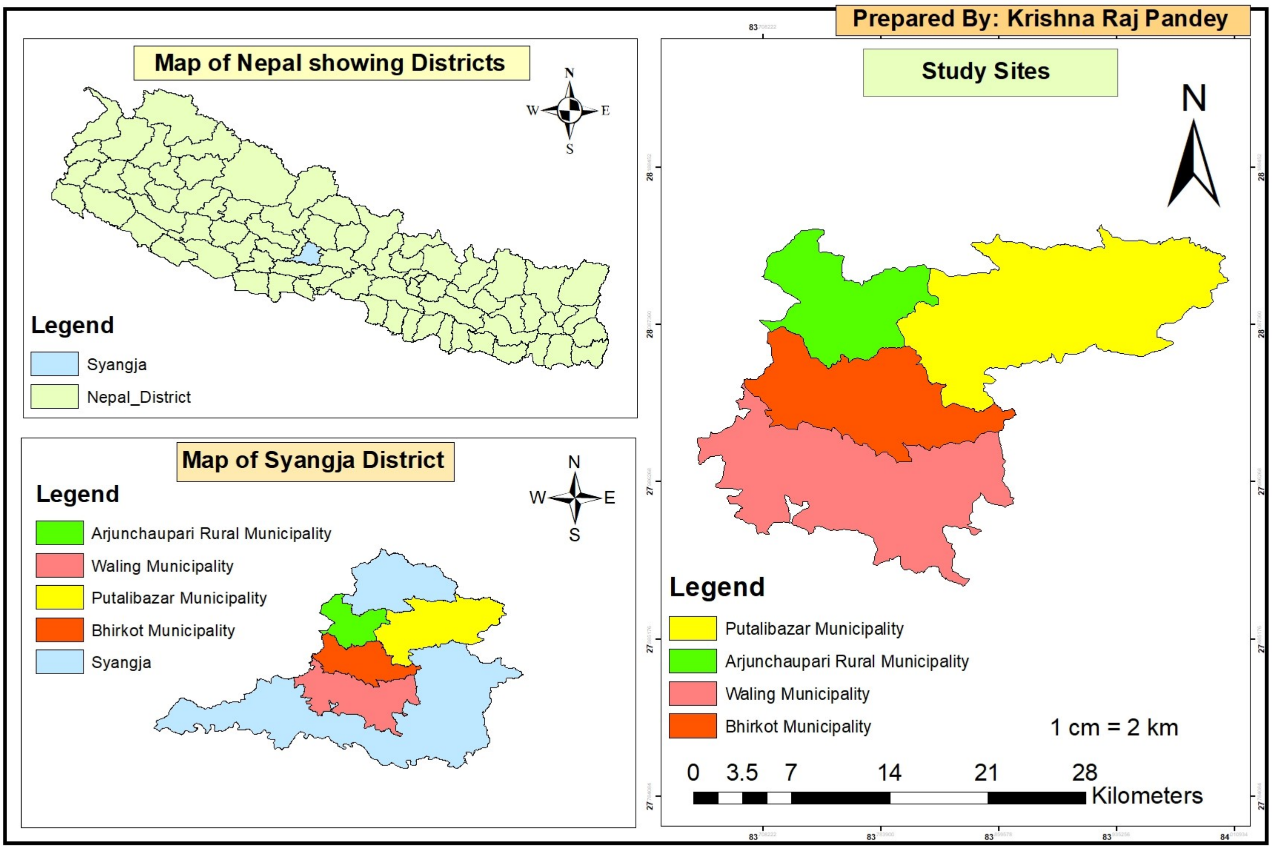

Figure 1. Map of the study area

Table 2. Laboratory analysis techniques for different soil physical and chemical properties

Parameters	Study method
Soil texture	Mechanical analysis method (Day, 2015)
Organic matter (OM)	Walkley – Black method for OM determination (Houba et al., 1989)
Soil pH	Glass-calomel electrode pH meter method (1:2 soil water ratio) (Cottenie et al., 1982)
Total nitrogen	Kjeldahl distillation unit method for Nitrogen (Bremner and Hauck, 2015)
Available phosphorus	Modified Olsen bicarbonate method (Watanabe and Olsen, 1965)
Available potassium	Ammonium acetate extraction method (Pratt, 2016)

Table 3. Rating chart for classification of fertility status of the studied soils according to Soil Science Division, Khumaltar, Lalitpur (2002), and Ward lab laboratories

Nutrient status	SOM (%)	Total N (%)	Available P (mg kg^{-1})	Available K (mg kg^{-1})
Very low	<1	<0.05	0-3	0-40
Low	1-2.5	0.05-0.1	4-9	41-80
Medium	2.5-5	0.1-0.2	10-16	81-120
High	5-10	0.2-0.4	17-30	121-200
Very high	>10	>0.4	>30	>200

2.5 Soil sample collection and preparation

A simple shovel was used for soil samples collection. The soil samples were taken from the orchard having normal bearing trees where general orchard management practices were followed. These subsamples, taken from orchards having more than 100 trees, were then collected in plastic and the standard procedure was followed for obtaining 0.5 kg of the composite sample. The collected soil samples were labeled and brought to the Directorate of Soil testing laboratory, Pokhara, Kaski of Gandaki Province, and was air-dried in shade. The air-dried samples were then grounded and sieved through a 2 mm sieve for chemical analysis.

2.6 Laboratory analysis

The collected soil samples were brought and analyzed at the Directorate of Soil testing laboratory, Pokhara, Kaski of Gandaki Province. Specific laboratory techniques and separate study methods were used for the analysis of different soil parameters in each sample collected from different locations as depicted in Table 2.

2.7 Data presentation

Experimental data of soil organic matter and nitrogen obtained from the study were rated based on the fertility status chart of Soil Science Division, Khumaltar, Lalitpur. Similarly, phosphorus and potassium-related data were recorded in accordance with Ward's lab laboratory rating (Table 3) and data of pH were rated according to Khatri-Chettri (1991) (Table 4).

Table 4. Rating chart for soil reaction rating of the studied soils according to Khatri-Chhetri (1991)

Soil pH value	Soil reaction rating
<6	Acidic
6.0-7.5	Neutral
>7.5	Alkaline

2.8 Statistical analysis

MS-Excel was used for data entry whereas R-studio was used for analyzing data. Data were analyzed using Analysis of Variance (ANOVA). Mean comparison was done with Duncan's Multiple Range Test (DMRT) at 5% probability level when significant differences existed between treatment means. SPSS software was used for correlation analysis of different parameters. Descriptive analysis was also performed.

3 Results and Discussion

3.1 Soil chemical properties

The level of nitrogen (N), phosphorus (P), potassium (K) and organic matter (OM), and soil pH are shown in tables and described within subsequent sections. The ANOVA tables are presented in Appendices and the values are rated according to the rating chart of the Directorate of Soil testing laboratory, Pokhara, Kaski, and Ward lab laboratories rating chart.

3.1.1 Soil pH

The pH level in different altitudesof the mandarin orchard is shown in Table 5. The result of the study indicated that the effect of altitude on soil pH was significant ($p < 0.01$).

Table 5. Soil pH in different altitudes of mandarin orchard in Syangja, Nepal

Orchard altitude (masl)	pH
<900 north facing	5.62c
900-1100 north facing	6.33ab
>1100 north facing	6.47ab
<900 south facing	6.51ab
900-1100 south facing	6.22b
>1100 south facing	6.71a
$LSD_{(0.05)}$	0.44**
SEm (±)	0.06
p value	<0.01
CV (%)	4.58
Grand Mean	6.31

Means followed by the same letter (s) in a column are not significantly different at 5% level of significance in DMRT test. SEm: Standard Error of Mean, Coefficient of Variance (CV), ** is significant at $p<0.01$

The lowest soil pH (5.62) was observed at an altitude lower than 900 masl in the north-facing slope whereas the highest soil pH (6.71) was observed at an altitude greater than 1100 masl in the south-facing slope. The lowest pH at an altitude less than 900 masl might be the result of continuous application of chemical fertilizers, especially nitrogenous fertilizers which have an acidifying effect similar to the findings of (Belay et al., 2002). Similar result was found by Sharma et al. (2019) in which they found continuous application of the chemical fertilizer in apple orchard reduced the soil pH due to the application of ammonium fertilizers or urea resulting in high level of H^+ in soil. There was no significant difference in pH level between north and south-facing slopes. Similar results were shown by Tamene et al. (2020) in which they found no relation of soil pH with different slopes. Soil pH level was increased with an increase in altitude which was similar to the result found by

Tasung and Ahmed (2017) where they found soil pH increased numerically with the increase in altitude and decreased numerically with the increase in depth. Prevalence of warm climate which favors the accumulation of H^+ might be the reason behind the decrease in soil pH at a lower altitude as suggested by Zhang et al. (2019). Overall pH of the study area was slightly acidic to nearly neutral. The study found that climate and topography are the two important factors responsible for variation in soil pH in which topography affects soil pH by controlling water flow and by changing the local climate. Soil pH data showed a significant increase with increasing altitude (Table 5).

3.1.2 Organic matter content

The soil organic matter level in different altitudes is shown in Table 6. Soil organic matter content was more in higher altitudes as compared to lower altitudes. In both north and south-facing slopes, organic matter content was found highest at an altitude range of 900-1100 masl.

Table 6. Soil organic matter content in different altitudes of the mandarin orchard in Syangja, Nepal

Orchard altitude (masl)	OM (%)
<900 north facing	4.46bc
900-1100 north facing	5.76ab
>1100 north facing	5.14ab
<900 south facing	3.76c
900-1100 south facing	4.52bc
>1100 south facing	3.99c
$LSD_{(0.05)}$	0.75
SEm (±)	0.10
p value	<0.001
CV (%)	10.73
Grand Mean	4.61

Means followed by the same letter (s) in a column are not significantly different at 5% level of significance in DMRT test. SEm: Standard Error of Mean, Coefficient of Variance (CV).

The highest organic matter content (5.76%) was found at an altitude range of 900-1100 masl in north-facing slope whereas the lowest organic matter content (3.76%) was found at an altitude lesser than 900 masl in the south-facing slope. There was a significant difference in organic matter content between north and south-facing slopes in which north-facing slopes had higher amounts of organic matter content than south facing slopes. This may be due to the insolation difference along with the altitude and difference in soil temperature and soil water thereby affecting the decomposition as reported by (Bangroo et al., 2018). Further, the results of the study indicated that the effect of altitude on soil organic matter was highly significant (p<0.001). Also, the result showed the increase in organic matter content with an increase in altitude which is similar to the result shown by Tasung and Ahmed (2017) in which they found an increase in soil organic carbon stocks with increasing altitude. Similar results were shown by Schawe et al. (2007). Zhang et al. (2021) also demonstrated an increase in organic matter content with an increase in altitude up to 4000m but decreased with an increase in altitude above 4000 m. The low altitude region experiences warmer temperature which accelerates the enzymatic breakdown of the labile soil organic matter pool than in the high altitude with colder temperature.

Soil fertility is directly affected by the labile soil organic carbon content. The increase in soil organic matter in high altitudes can be due to the decrease of mineralization associated with decreasing soil temperature and increasing soil moisture. The decrease in organic matter at low altitudes may be due to the oxidation of existing soil organic matter, erosion, and also by leaching as dissolved organic carbon (Han et al., 2010). A low amount of organic matter at low altitude may be due to multiple cropping at low altitude regions which removes the crop residue during harvest. High amounts of tillage and harvesting activities at low regions destroy the surface soil structure, thus exacerbating erosion. High soil acidity of the region might be responsible for the accumulation of high organic matter (Kidanemariam et al., 2012). The study showed overall increase in soil organic matter content with an increase in altitude except in the 900-1100 masl range where there is high amount of organic matter content both in north and south-facing slope.

3.1.3 Soil nitrogen

The results of the study indicated that the effect of altitude on soil nitrogen was highly significant (P<0.001). Likewise, organic matter content, soil nitrogen was found highest at an altitude range of 900-1100 masl in both north and south-facing slopes. The highest soil nitrogen (0.28%) was found at an altitude range of 900-1100 masl followed by the lowest soil nitrogen (0.18%) at an altitude greater than 1100 masl in a south-facing slope. Available soil nitrogen was found higher in low altitude than in higher altitude which is similar to the result shown by Tasung and Ahmed (2017). However, high amounts of nitrogen in 900-1100 masl in both north and south-facing slopes may be due to the high application of fertilizers which suggests that application of the fertilizers complements soil organic matter in increasing soil available nitrogen. There was a significant difference in soil nitrogen level between north and south-facing slopes in which north-facing slope had higher level of total soil nitrogen than south facing slopes (Table 7).

Table 7. Total nitrogen in different altitudes of mandarin orchards in Syangja, Nepal

Orchard altitude (masl)	Soil TN (%)
<900 north facing	0.22c
900-1100 north facing	0.28a
>1100 north facing	0.22c
<900 south facing	0.19cd
900-1100 south facing	0.22c
>1100 south facing	0.18d
$LSD_{(0.05)}$	0.03***
SEm (±)	0.004
p value	<0.001
CV (%)	9.42
Grand Mean	0.23

Means followed by the same letter (s) in a column are not significantly different at 5% level of significance in DMRT test. SEm: Standard Error of Mean, Coefficient of Variance (CV), *** is significant at p<0.001

This might be due to the high temperature prevailing in the south-facing slope. Elevation adjusts the microclimate under various hydrothermal conditions which indirectly affects microbial activity influencing the decomposition and transformation of soil organic matter and total nitrogen (Wang et al., 2018). A significant relationship was observed between soil organic matter and total nitrogen stock at a soil depth of 0-60 cm (Zhang et al., 2021).

3.1.4 Soil phosphorus

There was no significant effect of altitude on available phosphorus (Table 8). Phosphorus level was found higher at an altitude range of 900-1100 masl in both north and south-facing slope in which highest phosphorus (139.3) was found in north-facing slope and lowest phosphorus level (80.28) was found at an altitude lower than 900 masl in south-facing slope. There was no difference in Phosphorus level between north and south-facing slope similar to the result of Gong et al. (2008).

3.1.5 Soil potassium

Based on altitude, there was no significant difference found in available potassium (Table 9). The highest potassium (483.47) was found at an altitude range of 900-1100 masl in a north-facing slope and the lowest potassium (378.15) was found at an altitude lesser than 900 masl on the north-facing slope. The low level of potassium at an altitude greater than 1100 masl might be due to might be due to low capacity of soil to hold the nutrients as shown by Tsheringl et al. (2020). Plant available potassium was higher in north-facing slope in comparison to south-facing slope similar to the result shown by Gong et al. (2008). The K given soil is the reflection of the parent materials of the soil, degree of weathering, and amount of K fertilizer added minus losses due to crop removal and erosion and leaching.

Table 8. Available soil phosphorus in different altitudes of mandarin orchards in Syangja, Nepal

Orchard altitude (masl)	Available P (kg ha^{-1})
<900 north facing	94.77
900-1100 north facing	139.28
>1100 north facing	87.04
<900 south facing	80.26
900-1100 south facing	119.54
>1100 south facing	95.02
$LSD_{(0.05)}$	
SEm (±)	
p value	>0.05
CV (%)	63.72
Grand Mean	102.65

Means followed by the same letter (s) or without any letter in a column are not significantly different at 5% level of significance in DMRT test. SEm: Standard Error of Mean, Coefficient of Variance (CV).

Table 9. Available soil potassium in different altitudes of mandarin orchards in Syangja, Nepal

Orchard altitude (masl)	Available K (kg ha^{-1})
<900 north facing	378.15
900-1100 north facing	483.47
>1100 north facing	409.30
<900 south facing	406.60
900-1100 south facing	472.83
>1100 south facing	395.15
$LSD_{(0.05)}$	
SEm (±)	
47.84 p value	>0.05
CV (%)	27.85
Grand Mean	424

Means followed by the same letter (s) or without any letter in a column are not significantly different at 5% level of significance in DMRT test. SEm: Standard Error of Mean, Coefficient of Variance (CV).

3.2 Soil pH *vs.* soil nutrients

3.2.1 Soil pH and SOM

The correlation between soil pH and SOM was negative(r = −0.06). The coefficient of determination (R^2 = 0.0046) indicated that SOM does not contribute significantly to the change in soil pH and the change in soil pH is due to other than SOM. This may be due to the prevalence of acidic to neutral soil in the study area but the presence of alkaline soil would have a positive correlation as shown by Neina (2019) who found a positive effect of soil pH on the dissolution of soil organic matter.

3.2.2 Soil pH and soil nitrogen content

The correlation between soil pH and N was significant (r = −0.124) negatively. The coefficient of determination (R^2 = 0.015) indicated that the soil pH level only contributed 1.5% to the change in soil nitrogen level while the rest effects were due to other factors.

3.2.3 Soil pH and available phosphorus

The soil pH and plant-available phosphorus content had a positive correlation (r = 0.31) with each other. The coefficient of determination (R^2 = 0.10) indicated that the contribution of soil pH to the available phosphorus was 10.13% and the rest of the effects were due to other factors. Soil pH had a significant effect on phosphorus availability.

3.3 Soil pH and available potassium

The correlation between soil pH content and available phosphorus was significant (r = 0.36) positively. The coefficient of determination (R2=0.13 that the contribution of the pH content to the amount of available potassium content was 13.37% and the rest of the effect was due to other factors. Soil pH had a significant effect on plant potassium availability.

3.4 SOM *vs.* soil nutrients

3.4.1 SOM content and soil nitrogen

The soil organic matter and soil nitrogen content had a highly significant positive correlation (r = 0.949**) with each other. The coefficient of determination (R^2 = 0.89) indicated that the contribution of SOM content to the soil nitrogen content was 89.9% and the rest of the effects were due to other factors (Fig. 2). Soil organic matter had a highly significant effect on soil nitrogen level change.

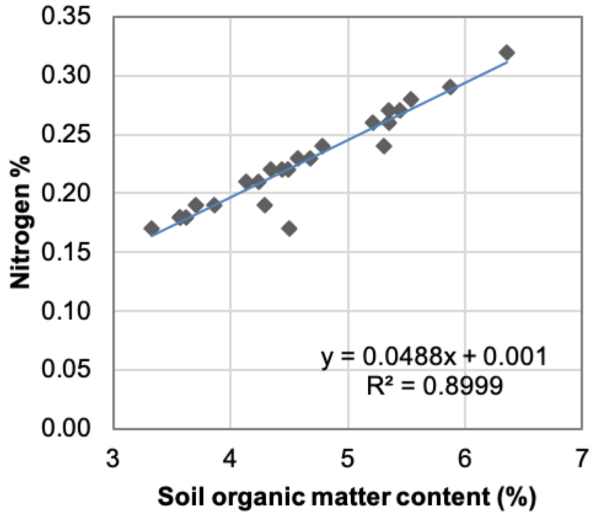

Figure 2. Relationship between SOM content and nitrogen in different altitude's mandarin orchard in Syangja, Nepal

3.4.2 SOM and available phosphorus

The correlation between SOM content and available phosphorus was significant (r = 0.42) positively. The coefficient of determination (R^2 = 0.17) that the contribution of the SOM content to the amount of available phosphorus content was 17.14% and the rest of the effect was due to other factors (Fig. 3). Soil organic matter had a significant effect on plant phosphorus availability.

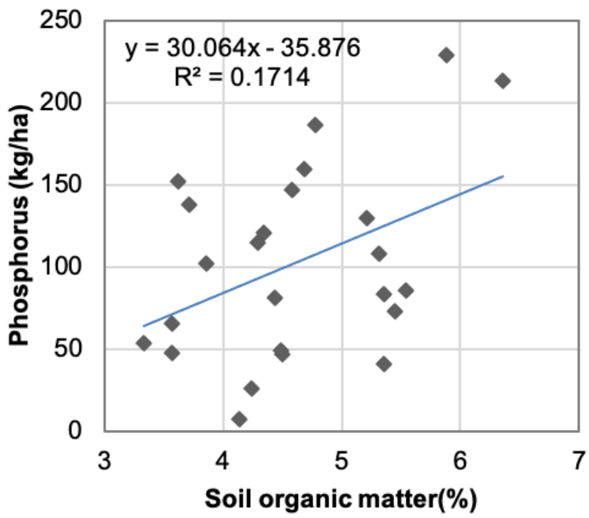

Figure 3. Relationship between SOM content and available phosphorus in different altitude's mandarin orchard in Syangja, Nepal

4 Conclusion

The study site had pH ranging from acidic to nearly neutral, soil organic matter (SOM) and nitrogen ranging from medium to high, and phosphorus and potassium ranging from medium to very high. Both soil organic matter and nitrogen were found lower in the south-facing slope in comparison to the north-facing slope. The altitude had a considerable effect on soil nutrient status except for phosphorus and potassium availability. Both pH and soil organic matter were found to increase with the increase in altitude whereas no significant differences were found in available phosphorus and potassium with change in altitude. Soil organic matter, nitrogen, phosphorus, and potassium all were found highest in the altitude range of 900-1100 masl of both north and south-facing slope in comparison to less than 900 masl and greater than 1100 masl. A significant association was found between the soil organic matter and nitrogen content at the study area. Altitude range containing high nutrients and better soil organic matter (900-1100 masl) might be suitable for mandarin cultivation. Further, timely test of the soil nutrient status of the mandarin orchards and application of the fertilizers based on the soil test results rather than based on blanket recommendations should be conducted by farmers. Future studies should be directed to compare the nutrient status between north and south facing slope. Similarly, for the overall improvement of mandarin orchards under consideration, nutrient status of the other micro-nutrients should also be assessed.

Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

References

Bangroo SA, Itoo H, Mubarak T, Malik AR. 2018. Soil organic carbon and total nitrogen in temperate apple orchards of south Kashmir. International Journal od Ecology and Environmental Science 44:287–292.

Belay A, Claassens A, Wehner F. 2002. Effect of direct nitrogen and potassium and residual phosphorus fertilizers on soil chemical properties, microbial components and maize yield under long-term crop rotation. Biology and Fertility of Soils 35:420–427. doi: 10.1007/s00374-002-0489-x.

Brady NC, Weil RR. 2002. The Nature and Properties of Soils, 13th Edition. Agroforestry Systems 54:249–249. doi: 10.1023/a:1016012810895.

Bremner JM, Hauck RD. 2015. Nitrogen in Agricultural Soils. In: Advances in Methodology for Research on Nitrogen Transformations in Soils. American Society of Agronomy, Crop Science Society of America, Soil Science Society of America. doi: 10.2134/agronmonogr22.c13.

Cottenie A, Verloo M, Kiekens L, Velghe G, Camerlynck R. 1982. Chemical analysis of plants and soils. Laboratory of Analytical and Agrochemistry, State University of Gent, Belgium.

Day PR. 2015. Particle fractionation and particle-size analysis. In: Agronomy Monographs. American Society of Agronomy, Soil Science Society of America. p. 545–567. doi: 10.2134/agronmonogr9.1.c43.

Erner Y, Astzi B, Tagaru E, Hamou M. 2005. Potassium affects Citrus tree performance. The Volcani Center, Institute of Horticulture. Department of Fruit Trees, Israel.

FDD. 2013. Annual Report and Statistical Information. Fruit Development Directorate (FDD), Kirtipur, Nepal.

Ganorkar RP, Chinchmalatpure PG, Ganorkar RP. 2013. Physicochemical assessment of soil in Rajura Bazar in Amravati district of Maharastra (India). International Journal of Chemical, Environmental and Pharmaceutical Research 4:46–49.

Gong X, Brueck H, Giese K, Zhang L, Sattelmacher B, Lin S. 2008. Slope aspect has effects on productivity and species composition of hilly grassland in the Xilin River Basin, Inner Mongolia, China. Journal of Arid Environments 72:483–493. doi: 10.1016/j.jaridenv.2007.07.001.

Han X, Tsunekawa A, Tsubo M, Li S. 2010. Effects of land-cover type and topography on soil organic carbon storage on Northern Loess Plateau, China. Acta Agriculturae Scandinavica, Section B - Plant Soil Science 60:326–334. doi: 10.1080/09064710902988672.

Havlin HL, Beaton JD, Tisdale SL, Nelson WL. 2010. Soil Fertility and Fertilizers- an introduction to nutrient management. 7th edn. PHI Learning Private Limited, New Delhi.

Houba VJG, Van der Lee JJ, Novozamsky I, Walinga I. 1989. Soil and Plant Analysis, Part 5. Soil Science Society of America.

Kaini BR. 2019. Can Nepal export citrus fruits? My Republica. https://myrepublica.nagariknetwork.com/news/can-nepal-export-citrus-fruits/?, Accessed on 09 Dec 2021.

Khadka D, Lamichhane S, Khan S, Joshi S, Pant BB. 2016. Assessment of soil fertility status of Agriculture Research Station, Belachapi, Dhanusha, Nepal. Journal of Maize Research and Development 2:43–57. doi: 10.3126/jmrd.v2i1.16214.

Khattak RA, Hussain Z. 2007. Evaluation of soil fertility status and nutrition of orchards. Soil and Environment 26:22–32.

Kidanemariam A, Gebrekidan H, Mamo T, Kibret K. 2012. Impact of Altitude and Land Use Type on Some Physical and Chemical Properties of Acidic Soils in Tsegede Highlands, Northern Ethiopia. Open Journal of Soil Science 02:223–233. doi: 10.4236/ojss.2012.23027.

MOALD. 2021. Statistical Information. https://www.moald.gov.np/wp-content/uploads/2022/04/STATISTICAL-INFORMATION-ON-NEPALESE-AGRICULTURE-2076-77-2019-20.pdf, Accessed on 22 November 2021.

Neina D. 2019. The role of soil pH in plant nutrition and soil remediation. Applied and Environmental Soil Science 2019:1–9. doi: 10.1155/2019/5794869.

Pratt PF. 2016. Potassium. In: Agronomy Monographs. American Society of Agronomy, Soil Science Society of America. doi: 10.2134/agronmonogr9.2.c20.

Ramulu CH, Reddy PRR. 2018. Soil fertility status of regional agricultural research station, Warangal (Telangana). Journal of Pharmacognosy and Phytochemistry 7:1852–1856.

Schawe M, Glatzel S, Gerold G. 2007. Soil development along an altitudinal transect in a Bolivian tropical montane rainforest: Podzolization vs. hydromorphy. CATENA 69:83–90. doi: 10.1016/j.catena.2006.04.023.

Sharma P, Singh M, Bhardwaj SK. 2019. Effect of Management Practices on Soil Nutrient Status of Apple Orchards in Kullu District of Himachal Pradesh. International Journal of Economic Plants 6:150–155.

Srivastava AK, Singh S. 2009. Citrus decline: Soil fertility and plant nutrition. Journal of Plant Nutrition 32:197–245. doi: 10.1080/01904160802592706.

Tamene GM, Adiss HK, Alemu MY. 2020. Effect of Slope Aspect and Land Use Types on Selected Soil Physicochemical Properties in North Western Ethiopian Highlands. Applied and Environmental Soil Science 2020:1–8. doi: 10.1155/2020/8463259.

Tasung A, Ahmed N. 2017. Effect of different land use system and altitude on soil organic carbon and soil fertility of Siang river basin in Arunachal Pradesh, India. Journal of Crop and Weed 13:126–134.

Tsheringl K, Zangpo Y, Chofil P, Phuntsho T, Dorji U. 2020. Assessment of soil nutrients status of mandarin orchards in dagana. Bhutanese Journal of Agriculture 2:73–86.

Walsh E, McDonnell KP. 2012. The influence of added organic matter on soil physical, chemical, and biological properties: a small-scale and short-time experiment using straw. Archives of Agronomy and Soil Science 58:S201–S205. doi: 10.1080/03650340.2012.697999.

Wang S, Adhikari K, Wang Q, Jin X, Li H. 2018. Role of environmental variables in the spatial distribution of soil carbon (C), nitrogen (N), and C:N ratio from the northeastern coastal agroecosystems in China. Ecological Indicators 84:263–272. doi: 10.1016/j.ecolind.2017.08.046.

Watanabe FS, Olsen SR. 1965. Test of an ascorbic acid method for determining phosphorus in water and $NaHCO_3$ extracts from soil. Soil Science Society of America Journal 29:677–678. doi: 10.2136/sssaj1965.03615995002900060025x.

Zhang Y, Ai J, Sun Q, Li Z, Hou L, Song L, Tang G, Li L, Shao G. 2021. Soil organic carbon and total nitrogen stocks as affected by vegetation types and altitude across the mountainous regions in the Yunnan Province, southwestern China. CATENA 196:104872. doi: 10.1016/j.catena.2020.104872.

Zhang YY, Wu W, Liu H. 2019. Factors affecting variations of soil pH in different horizons in hilly regions. PLOS ONE 14:e0218563. doi: 10.1371/journal.pone.0218563.

The Official Journal of the **Farm to Fork Foundation**
ISSN: 2518–2021 (print)
ISSN: 2415–4474 (electronic)
http://www.f2ffoundation.org/faa