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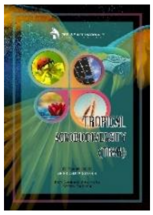

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RESEARCH ARTICLE

AN ASSESSMENT OF SOIL NUTRIENT STATUS UNDER DIFFERENT AGED SWEET ORANGE ORCHARDS IN SINDHULI DISTRICT OF NEPAL

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ABSTRACT

A study was conducted in Sindhuli district to assess the fertility status of different aged sweet orange orchards and their effect upon soil nutrients. Seven different aged sweet orange orchards viz. 1-5 year, 6-10 years, 11-15 years, 16-20 years, 21-25 years, 26-30 years and 30 and above years were taken as treatments and replicated three times in Randomized Complete Block Design. Composite samples were collected in each study site from 45 cm soil depth from each plot. There was significant effect ($p<0.001$) of stand age on soil organic matter, phosphorus and potassium content, whereas significant effect ($p<0.05$) on soil pH and ($p<0.01$) on total nitrogen content. Soil pH was found to be decreasing with orchard age with maximum pH observed in 1-5 years orchard (6.87) and minimum in thirty and above years orchard (5.87). Organic matter and nitrogen were found to be increasing with increasing orchard age. Maximum SOM and nitrogen content were found in 26–30-year orchards with values of (5.99) and (0.28) respectively and minimum in 1-5 years orchards with values of (1.91) and (0.09) respectively. Phosphorus was found maximum in 5-10-year orchards (53.00) and minimum in above 30 years old (17.00). Likewise, maximum available potassium was observed in 6-10 ten-year-old orchards (464.33) and minimum in 1-5 years old group (259.00). And it was revealed that nitrogen (90.47%) is the most limiting nutrient for sweet orange production in each treatment and overall sampled soil.

KEYWORDS

Fertility, Horticultural crop, Nitrogen, Soil, Organic matter

1. INTRODUCTION

Agricultural sector of Nepal provides employment opportunities to around 65% of the total population and contributes about 27% to GDP (MoALD, 2021). Among horticultural crops, fruits play a great role in increasing the share of agriculture in GDP, which contributes about 7% of total AGDP (MoALD, 2018). Fruits constitute an important item of our food and play a significant role in human diet through the supply of essential vitamins and minerals (Prabhakar et al., 2004). Citrus is one of the major fruit crops cultivated in Nepal in terms of production and area coverage. The production of citrus in Nepal is only about 0.22 million tons (NCDP, 2015/16). Citrus being cultivated in about 60 districts of our country contributes 22.37% to total fruit production and shares about 3% of total fruit exports by volume (Dahal et al., 2020).

Sweet orange (*Citrus sinensis* Osbeck) is the second most commonly produced citrus in Nepal. It can be cultivated best at the altitude range of 800 to 1400 masl in the mid-hill region at the optimum temperature of 5 to 35^0 C (MoALD, 2017). Sindhuli is the number one sweet orange (junar) producing district of the country (Adhikari et al., 2012). It is cultivated in the altitude range of 800 to 1300 masl along the Mahabharat range in this district (DADO, 2011). Sindhuli has a total area of 1,325 ha for sweet orange production comprising 730 ha as productive area with production of 9650 Mt and productivity of 13.21 Mt/ha (AKC, Sindhuli, 2077). It has been found to be cultivated for 40 years by the majority of growers who consider junar trees as their ancestor's gift to them. Junar was found to be cultivated as commercial crop as it has developed special identity in Nepali market (Adhikari and Rayamajhi, 2012).

Sindhuli is leading district in junar production and the farming of junar is semi-intensive type (Adhikari et al., 2012). At the present time, people are involved in commercial junar production because of suitable agro-climatic and soil conditions. Junar, being a perennial crop, depletes large amounts of nutrients from the soil and further application of organic manures as well as fertilizers require proper knowledge about nutrient status of soil. Although the farmers have been growing junar for a longer time and the production area is more than 1000 ha under junar super zone, not much work is done regarding the soil testing and fertility analysis. Farmers have been managing their soil and fertilizers without sufficient scientific knowledge by just communicating with each other.

This kind of poor orchard management practices lead to the declining production. NARDF reported citrus decline to spread throughout Nepal and severely affecting many orchards. Poor orchard management is one of the leading factors for citrus decline (FAO, GON, MOAC, 2011). Intensified farming causes the depletion of soil organic matters whereas imbalanced fertilizer application due to insufficient knowledge about proper orchard management practices and poor nutrient supply leads to decline in soil fertility. Consequently, the growth and development of plants is affected by malnutrition, prevalence of insect pests and diseases ultimately leading to the reduced production and quality of fruits.

Thus, this study is vital for the improvement of nutritional balance of growing media resulting in the optimum crop production and the protection of the environment from contamination by runoff and leaching of excess fertilizers. Furthermore, due to the more nutrient responsive nature of citrus orchards the balanced nutrition programme is mandatory to maintain a sustained productive life of orchards in addition to quality production. Therefore, soil nutrient assessment study is significant.

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2. Methodology

2.1 Selection of study site

The research was conducted in Sindhuli district of Nepal. The research was conducted in different sweet orange orchards of Tinkanya, Golanjor rural municipality-4 of Sindhuli district.

2.2 Research Design

Research was conducted in Randomized Complete Block Design (RCBD) which included 7 different aged sweet orange orchards of 1-5 year, 6-10 years, 11-15 years, 16-20 years, 21-25 years, 26-30 years and 30 and above years as treatments. Each treatment was replicated 3 times comprising of 21 composite samples. For each of composite soil sample, soil was collected from 5 locations within an orchard. To maintain the homogeneity among replications, samples were collected from the orchards having similar nutrient and orchard management practices.

2.3 Sample and Sampling Techniques

Sampling of sweet orange orchards was based on simple random sampling method. Soil sample were collected from seven different aged orchards of 1-5 year, 6-10 years, 11-15 years, 16-20 years, 21-25 years, 26-30 years and 30 and above years as treatments and each of them were replicated three times by using screw auger. Five sub samples were collected randomly from each plot within a replication from 45cm depth from the surface in each plot in a 'Z' pattern. These subsamples were then collected in a plastic bag and standard procedure was followed for obtaining 0.5 kg of composite sample. A total of 21 composite soil samples were collected from 105 soil sampling spots. The collected soil samples were labeled and taken to Soil testing laboratory, Agriculture Knowledge Center, Gorkha and were air dried in shade. The air-dried samples were then sieved through 2mm sieve for carrying out chemical analysis and through 0.2 mm sieve for SOM analysis.

2.4 Data and data types

The study being exploratory type, various sources and techniques of gathering information were used. Mainly, two types of data were collected and analysed for correlating soil nutrient contents in different aged orchards. The study included primary as well as secondary data. The primary data was collected from the analysis of composite soil samples and secondary sources of information were collected from different journals and publications.

2.5 Laboratory analysis

Soil samples collected from each location were analyzed for soil pH, soil organic matter, total nitrogen, available phosphorus and available potassium content of the soil. Soil tests and analysis followed manual for soil and fertilizer analysis 2074/75 published by Soil Management Directorate, Harihar Bhawan Lalitpur. Different soil fertility parameters such as soil pH, organic matter, nitrogen, phosphorous and potassium was analyzed by using Digital pH meter, Walkley – Black method, from Organic matter, Modified Olsen's Method and Ammonium acetate extraction method using flame photometer respectively (Cottenie et al., 1982; Houba et al., 1989; Pratt, 1965; Olsen et al., 1954).

2.6 Data analysis techniques

2.6.1 Characterization of soil nutrient parameters

All Soil physico-chemical data collected from the research were entered into MS Excel and they were rated according to standard ratings for each soil physico-chemical parameter as low, medium and high. So, each unit of soil fertility status were categorized as low, medium, high under standard rating. Soil organic matter content, soil nitrogen, available phosphorus and available potassium were rated according to Shahu, 2015 and analyzed using R-studio and Microsoft Excel. The data were subjected to analysis of variance (ANOVA) appropriate to randomized complete block design technique. When significant difference existed between treatment means, comparison of the means was done using Duncan's Multiple Range Test (DMRT) at 5% probability levels. Correlation analysis were done between different soil nutrient parameters.

Table 1: Standard ratings for soil parameters

Soil Physio-chemical parameters	Low	Medium	High
OM content (%)	<=2.5	2.51-5.0	>=5
Nitrogen (%)	<=0.10	0.11-0.20	>0.20
Phosphorus(kg/ha)	<=30	30.1-55	>55
Potassium(kg/ha)	<=110	110.1-280	>280

Source: (Shahu, 2015)

2.6.2 Determination of most limiting nutrient

Standard Soil Rating only helps to characterize the soil but it may not be an accordance with the exact sweet orange requirement. Therefore, the obtained soil parameters data are compared with the optimum range of sweet orange orchards requirement in order to find which nutrient is the most limiting factor for the development of sweet orange.

Table 2: Optimum soil test value for sweet orange

Soil Parameters	Optimum Range
Soil Ph	5.5-7.5
Available Nitrogen (mg/kg)	86.7-122.4
Available Phosphorus (mg/kg)	5.9-17.8
Available potassium (mg/kg)	173.4-403.2

Source: (Shrivastava & Singh, 2004)

3. Result and Discussions

3.1 Soil chemical properties

3.1.1 Soil pH

According to rating chart for soil reaction rating of the studied soils according to Khatri-Chhetri, majority of sampled soil was found to have neutral pH (Khatri-Chhetri, 1991). Maximum soil pH was observed in one to five years old orchard (6.87) followed by six to ten years old orchard (6.60), eleven to fifteen years old orchard (6.53), sixteen to twenty years old orchard (6.57), twenty-one to twenty-five years old orchard (6.40), twenty-six to thirty years old orchard (6.03), and the least pH was found in thirty years and above years old stand (5.87). The soil pH decreases with the increasing age of parks resulting in increased acidity (Setala, et al., 2016). Some researchers also had similar findings and suggested that pH value gradually decreases with increasing age of plants which may be due to ion absorption by the root system that occurs through the release of H^+ (Hinsinger and Jaillard, 1993). Similarly, deposition of organic acid, leaching of bases with water, organic matters accumulation and respiration of soil microorganisms also lead to increase in soil acidity (Yin et al., 2021).

Table 3: Age-wise effect of sweet orange orchards on soil pH of Junar Superzone, Tinkanya, Sindhuli (2021)

Age of sweet orange orchards (years)	pH
1 to 5	6.87[a]
6 to 10	6.60[a]
11 to 15	6.53[ab]
16 to 20	6.57[ab]
21 to 25	6.40[abc]
26 to 30	6.03[bc]
30 and above	5.87[c]
SEm (±)	0.09
F-probability	*
LSD	0.52
CV, %	4.54
Grand mean	6.41

Note: The treatment mean followed by common letter (s) are not significantly different from each other based on Duncan Multiple Range Test at 5% level of significance, * is significant at P<0.05

3.1.2 Soil organic matter

According to standard ratings for soil parameters put forward, the majority of sampled soils was found to have medium soil organic matter content (Shahu, 2015). Maximum soil organic matter was observed in twenty-six to thirty years old orchard (5.99) followed by thirty and above years old orchard (5.90), twenty-one to twenty-five years old orchard (4,46), sixteen to twenty years old orchard (4.36), eleven to fifty years old orchard (4.10) six to ten years old orchard (3.07), and the least organic matter content was found in one to five years old orchard (1.91). It was observed that Soil organic matter increases with increasing age of sweet orange orchard. A group researcher had similar results with this study that soil organic matter content increases with the age of parks (Setala, et al., 2016). Research conducted in China also demonstrated increasing organic matter content with increasing age of forests (Daping, et al., 2017). A group researcher also concluded that soil organic matter content per ha increased with increasing plant age of *Alnus nepalensis* (Sharma et al., 1985). Soil organic matter mainly accumulates from the accumulation of litters. Low organic matter in this study in younger orchard age may be due to high absorption, development of canopy and less accumulation of litter and short turnover time of soil nutrients due to high density of orchards whereas, increasing trends of organic matter in mature orchards may be due to decreased growth of trees, low density of trees and return of soil nutrients (Zhang et al., 2020).

Table 4: Age-wise effect of sweet orange orchards on soil organic matter content of (Junar Superzone et al., 2021)

Age of sweet orange orchards (years)	SOM (%)
1 to 5	1.91[d]
6 to 10	3.07[c]
11 to 15	4.10[bc]
16 to 20	4.36[b]
21 to 25	4.46[b]
26 to 30	5.99[a]
30 and above	5.90[a]
SEm (±)	0.32
F-probability	***
LSD	1.14
CV, %	14.96
Grand mean	4.25

Note: The treatment mean followed by common letter (s) are not significantly different from each other based on Duncan Multiple Range Test at 5% level of significance, *** is significant at P<0.001; SOM, Soil Organic Matter.

3.1.3 Soil nitrogen

According to standard ratings for soil parameters put forward by Shahu, 2015, the majority of sampled soils is found to have medium soil total nitrogen content. Maximum soil nitrogen content was observed in twenty-six to thirty years old orchard (0.28) followed by thirty and above years old orchard (0.25), twenty-one to twenty-five years old orchard (0.22), sixteen to twenty years old orchard (0.21), eleven to fifty years old orchard (0.19) six to ten years old orchard (0.14), and the least soil nitrogen content was found in one to five years old stand (0.09). There is a positive correlation between soil organic matter content and total nitrogen percentage of soil also observed that nitrogen is directly related with SOM content (Mengel and Kirkby, 1996). Some researchers had similar results with this study that soil total nitrogen content increases with the age of parks (Setala, et al., 2016). Research conducted in China also demonstrated increasing soil total nitrogen content with increasing age of forests (Daping, et al., 2017). In other study, researchers also concluded that soil total nitrogen content per ha increased with increasing plant age of *Alnus nepalensis* (Sharma et al., 1985).

Table 5: Age-wise effect of sweet orange orchards on soil nitrogen content of (Junar Superzone et al., 2021)

Age of sweet orange orchards (years)	Nitrogen (%)
1 to 5	0.09[d]
6 to 10	0.14[cd]
11 to 15	0.19[bc]
16 to 20	0.21[abc]
21 to 25	0.22[ab]
26 to 30	0.28[a]
30 and above	0.25[ab]
SEm (±)	0.02
F-probability	**
LSD	0.06
CV, %	19.67
Grand mean	0.20

Note: The treatment mean followed by common letters are not significantly different from each other based on Duncan Multiple Range Test at 5% level of significance, ** is significant at P<0.01.

3.1.4 Available phosphorus

According to standard ratings for soil parameters put forward by Shahu, 2015, the majority of sampled soils is found to have medium available phosphorus content. Maximum available phosphorus was observed in six to ten years old orchard (53.00) followed by one to five years old orchard (52.33), eleven to fifteen years old orchard (39.00), sixteen to twenty years old orchard (38.33), twenty to twenty-five years old orchard (37.67) twenty-five to thirty years old orchard (27.00), and the least available phosphorus content was found in thirty and above years old stand (17.00). In this experiment, soil available phosphorus first increased then went on decreasing with the increasing age of orchard, which is found to be almost consistent with changing trend of soil pH. Similar results were put forward by (Yin et al., 2021). The phosphorus availability increases with increasing pH which may be due to increasing solubility of iron phosphate and aluminium salt with increasing pH, also soil phosphorus is affected by soil organic matter contents and total nitrogen contents (Jones and Darrah, 1994).

Table 6: Age-wise effect of sweet orange orchards on soil phosphorus content of Junar Superzone, Tinkanya, Sindhuli (2021)

Age of sweet orange orchards (years)	Phosphorus ($kgha^{-1}$)
1 to 5	52.33[a]
6 to 10	53.00[a]
11 to 15	39.00[b]
16 to 20	38.33[b]
21 to 25	37.67[b]
26 to 30	27.00[c]
30 and above	17.00[d]
SEm (±)	2.77
F-probability	***
LSD	8.29
CV, %	12.34
Grand mean	**37.76**

Note: The treatment mean followed by common letters are not significantly different from each other based on Duncan Multiple Range Test at 5% level of significance, *** is significant at P<0.001

3.1.5 Available potassium

Maximum available potassium was observed in six to ten years old orchard (464.33) followed by thirty and above years old orchard (421.17), twenty-six to thirty years old orchard (399.00), twenty-one to twenty-five years old orchard (357.00), eleven to fifteen years old orchard (327.83), sixteen to twenty years old orchard (297.50), and the least available potassium content was found in one to five years old stand (259.00). According to standard ratings for soil parameters put forward by Shahu, 2015, the majority of sampled soils is found to have high available potassium content. Some researcher also reported that Nepalese soils are rich in potassium content (Carson, 1992). High level of potassium content might be due to parent material of rock. The soil potassium is affected by the parental material of the soil in bed rock.

Potassium from deep subsoil horizons is taken up by deep rooted perennials and recycled to soil surface through translocation into leaves and following leaf fall and decomposition (Lehman and Scroth, 2002). In this study, maximum available potassium was observed in six to ten years old orchard which was similar to the finds put forward by the study conducted in Aurangabad of India. A scientist also found that potassium content of orchard significantly increased in orchards of 6 to 10 years and decreased in concentration of 11 years and above age groups (Sonajirao, 1994). This trend of change in soil available potassium content might be due to higher uptake during advanced stage of mandarin orange orchard for developing of fruits (Upadhaya and Patiram, 1996).

Table 7: Age-wise effect of sweet orange orchards on soil potassium content of Junar Superzone, Tinkanya, Sindhuli (2021)

Age of sweet orange orchards (years)	Potassium ($kgha^{-1}$)
1 to 5	259.00^g
6 to 10	464.33^a
11 to 15	327.83^e
16 to 20	297.50^f
21 to 25	357.00^d
26 to 30	399.00^c
30 and above	421.17^b
SEm (±)	14.71
F-probability	***
LSD	19.59
CV, %	3.05
Grand mean	360.83

Note: The treatment mean followed by common letters are not significantly different from each other based on Duncan Multiple Range Test at 5% level of significance, *** is significant at P<0.001

3.2 Simple correlation coefficient(r) among different soil nutrient parameters.

This section includes the correlation analysis of soil pH and SOM with soil nitrogen content, phosphorus availability and potassium availability.

Table 8: Correlation coefficient among different soil nutrient parameters in different aged sweet orange orchards in Junar Superzone, Tinkanya, Sindhuli (2021)

Parameters	Nitrogen (%)	SOM (%)	Phosphorus ($kgha^{-1}$)	Potassium ($kgha^{-1}$)
pH	-0.742***	-0.819***	0.769***	-0.461*
SOM (%)	0.955***		-0.799***	0.399

Note: ***. Correlation is significant at the 0.001 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

3.3 Relationship of soil pH with different soil nutrient parameters

3.3.1 *Relationship between soil pH and soil nitrogen content*

The correlation between soil pH and Soil nitrogen content was significant (r = -0.742) negatively. The coefficient of determination (R^2) value was 0.5539 which means that the variation in soil pH level contributes to 55.39% to variation in soil nitrogen level while the rest effects was due to other factors (Figure 10). Soil pH had significant effect on soil nitrogen content.

The negative correlation between soil pH can be explained by inhibition of nitrogen cycling due to low pH leading to low soil nitrogen content. Similar results were also put forward by a study conducted in Western Nepal (Khadka et al., 2016). In contrast, positively significant correlation was observed by (Athokpam, et al., 2013).

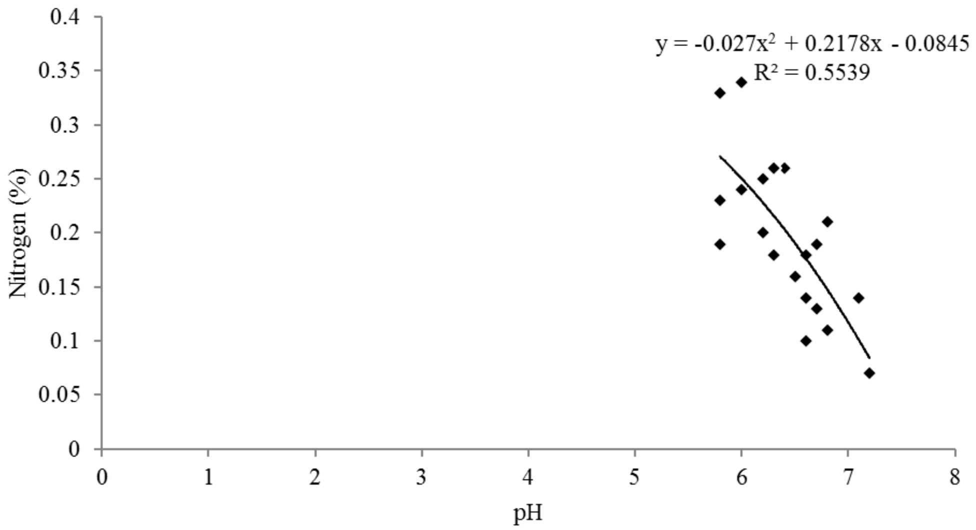

Figure 1: Relationship between soil pH and soil nitrogen content in different aged sweet orange orchards in Tinkanya, Sindhuli (2021)

3.3.2 *Relationship between soil pH and available phosphorus content*

The correlation between soil pH and available phosphorus content was significant (r =0.769) positively. The coefficient of determination (R^2) value was 0.6619 which means that the variation in soil pH level contributes to 66.19% to variation in available phosphorus level while the rest effects was due to other factors (Figure 11). Soil pH had significant effect on available phosphorus content.

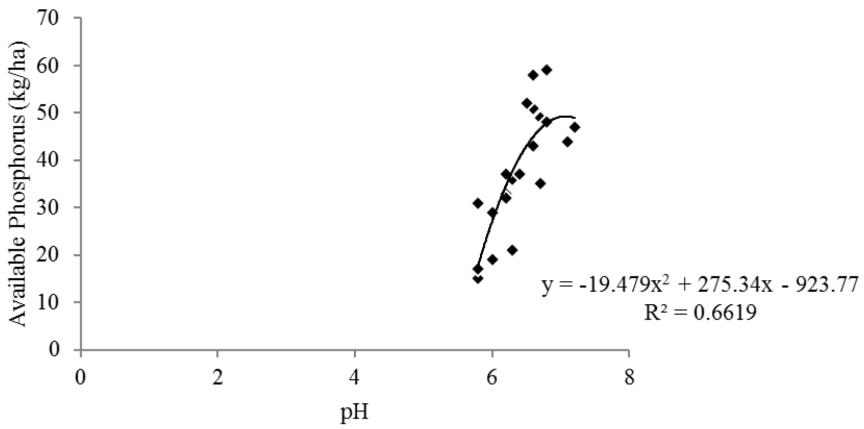

Figure 2: Relationship between soil pH and available phosphorus content in different aged sweet orange orchards in Tinkanya, Sindhuli (2021)

The correlation between soil pH and available phosphorus content is found to be positive that means there is more phosphorus availability at higher pH. If soils are too acidic, reaction of phosphorus takes place with iron and aluminium leading to unavailability of phosphorus to plants (Chakravoty, 2018). Whereas, with the increase in soil pH due to various reasons like addition of lime, availability of phosphorus decreases up to at least pH of 6.2 (Mallarino et al., 2013).

3.3.3 Relationship between soil pH and available potassium content

The correlation between soil pH and available potassium content was significant (r = -0.461) negatively. The coefficient of determination (R^2) value was 0.2151 which means that the variation in soil pH level contributes to 21.51% to variation in available potassium level while the rest effects was due to other factors. Soil pH had significant effect on available potassium content.

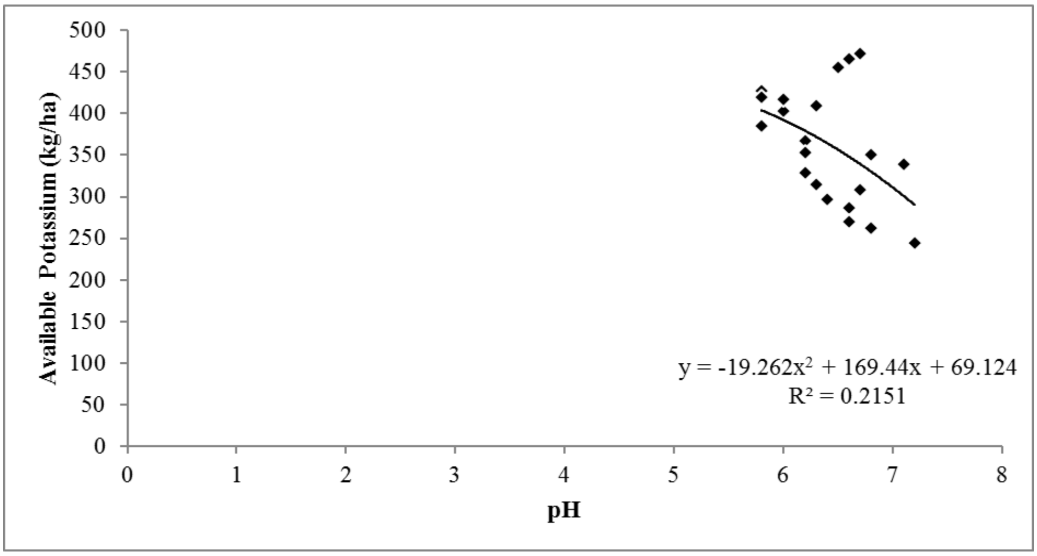

Figure 3: Relationship between soil pH and available potassium content in different aged sweet orange orchards in Tinkanya, Sindhuli (2021)

Negative correlation was observed in this study between soil pH and available potassium content. Similar results were forward by a study in western Nepal, which means that at low pH, there is higher potassium availability (Gautam and Chettri, 2020). In contrast to this study, another study put forward by Preston stated that low pH decreases soil's ability to keep supplying to the plant. At low pH, K has more complex reactions at Cation Exchange Capacity sites due to high H^+ concentration and high soluble aluminium which displace other exchangeable cations K^+ moving them into soil solution and therefore increasing their leaching potential leading to lower potassium availability (Preston, 2021). At higher pH, due to more presence of dominant positive ion Ca for reactions for both potassium and phosphorus at higher pH, there is higher potassium availability (Hargreaves, 2015).

3.4 Relationship of SOM with different soil nutrient parameters

3.4.1 Relationship between SOM content and soil pH

The correlation between soil organic matter and soil pH was significant (r = -0.891) negatively. The coefficient of determination (R^2) value was 0.6699 which means that the variation in soil organic matter level contributes to 66.99% variation in soil pH level while the rest effects was due to other factors. Soil organic matter had significant negative effect on soil pH. Similar findings were put forward by one of the studies in China (Zhou et al., 2019; Paudel and Sah, 2003). As soil organic matter increases, pH goes on decreasing which might be due to production H^+ ions during the decay of organic matter resulting in soil acidity (Zhou et al., 2019).

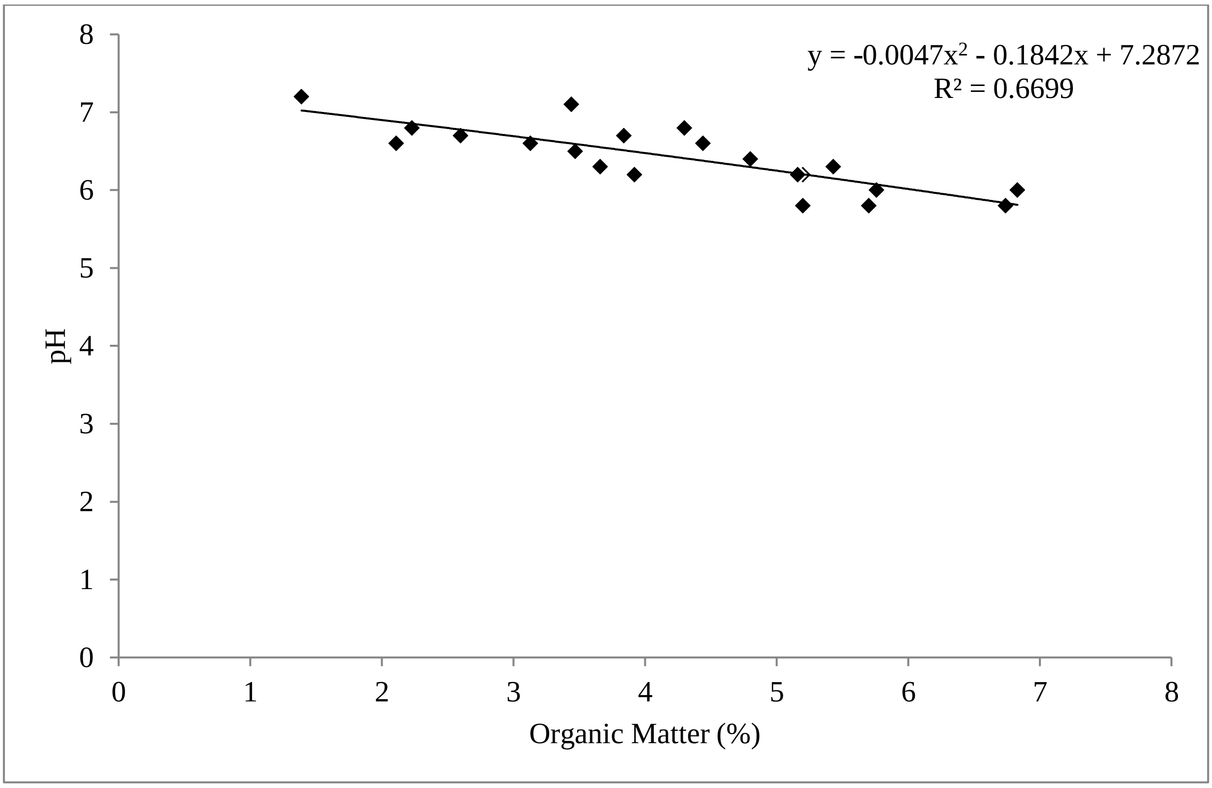

Figure 4: Relationship between soil organic matter content and soil pH in different aged sweet orange orchards in Tinkanya, Sindhuli (2021)

3.4.2 Relationship between SOM content and soil nitrogen

The correlation between soil organic matter and soil nitrogen was significant (r =0.955) positively. The coefficient of determination (R^2) value was 0.9115 which means that the variation in soil organic matter level contributes to 91.15% variation in soil nitrogen level while the rest effects was due to other factors. Soil organic matter had significant effect on soil nitrogen.

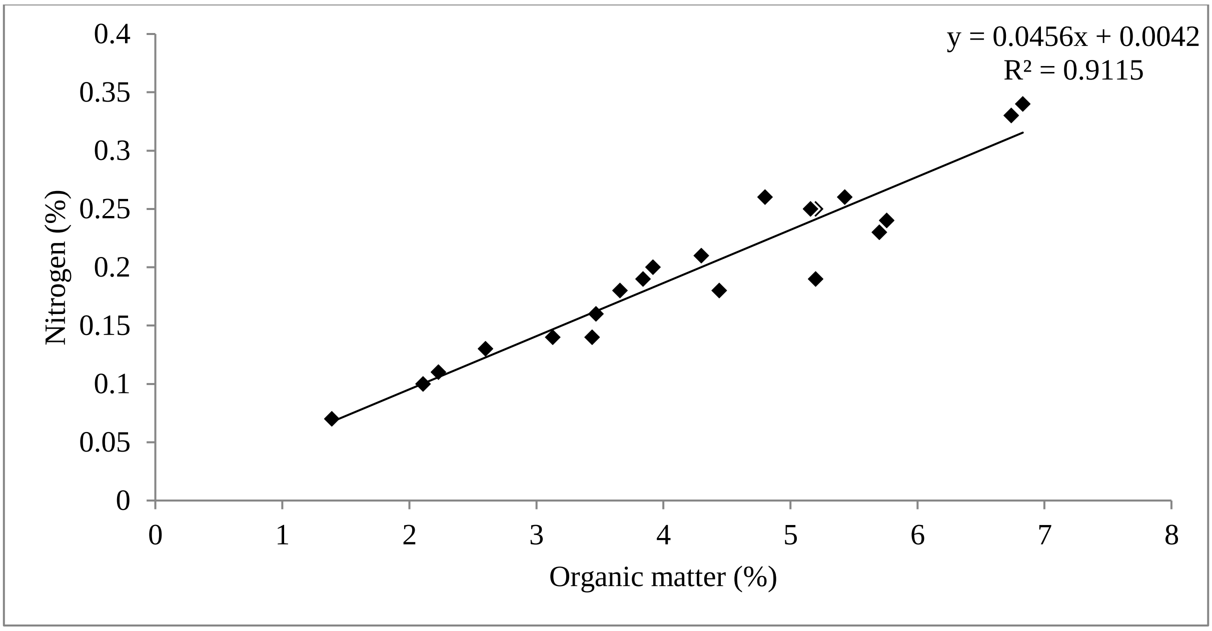

Figure 5: Relationship between soil organic matter content and soil nitrogen in different aged sweet orange orchards in Tinkanya, Sindhuli (2021)

The positive correlation was observed between SOM and total nitrogen content. Similar findings were put forward (Luyssaert et al., 2008). There is direct relation between soil organic matter and total nitrogen content which is affected by several factors like the mean annual rainfall and mean annual temperature (Bi et al., 2018). Land use system also has important role on distribution of soil organic matter which in turn affects total nitrogen (Xue and An, 2018).

3.4.3 Relationship between SOM content and available phosphorus

The correlation between soil organic matter and available phosphorus content was significant (r = -0.799) negatively. The coefficient of determination (R^2) value was 0.6434 which means that the variation in soil organic matter level contributes to 64.34% variation in available phosphorus level while the rest effects was due to other factors. Soil organic matter had significant effect on available phosphorus content.

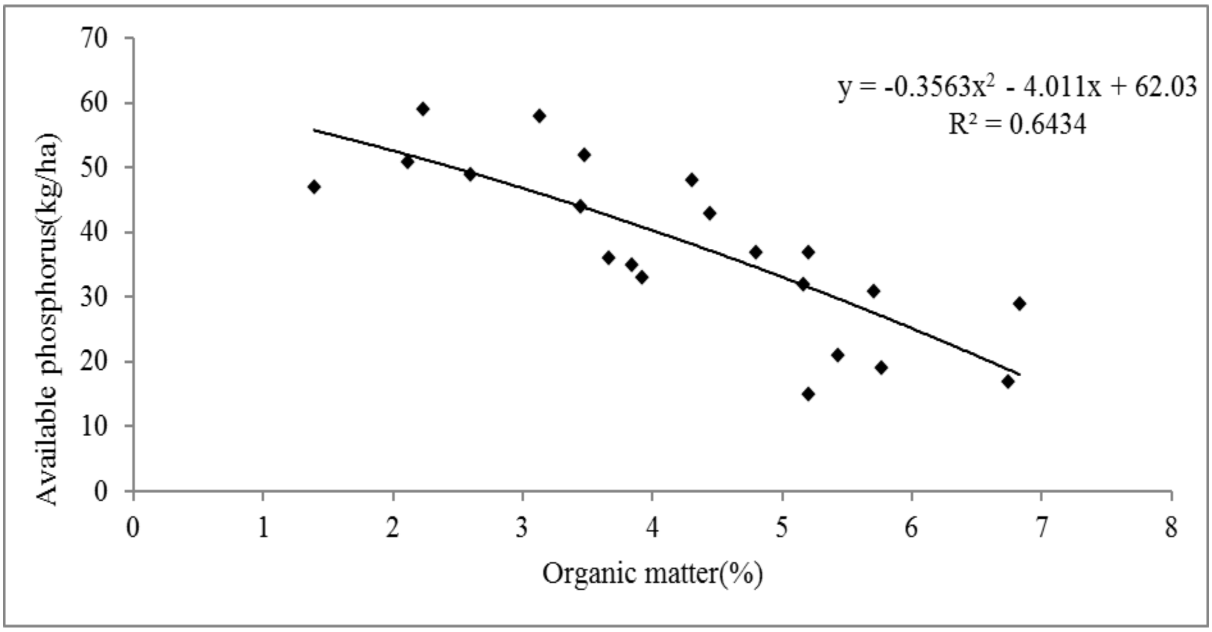

Figure 6: Relationship between soil organic matter content and available phosphorus in different aged sweet orange orchards in Tinkanya, Sindhuli (2021)

The negative correlation was observed between SOM and available phosphorus in this study which similar to the findings of Rao. In case of intensive agriculture which is highly phosphorus fertilized, there might be low soil organic matter but available phosphorus can be in high amount (Rao, 2015).

3.4.4 Relationship between SOM content and available potassium

The correlation between soil organic matter and available potassium content was found to be non-significant (r =0.399). The coefficient of determination (R^2) value was 0.1689 which means that the variation in soil organic matter level contributes to 16.89% variation in available potassium level while the rest effects was due to other factors (Figure 16). Soil organic matter had significant effect on available potassium content. SOM directly affects dynamic process which helps in increasing availability of potassium to plant which signifies their positive correlation. With the increase in organic matter in soil, cation exchange capacity increases and potassium being of lower positive charge is easily up taken by plants (Wang and Huang, 2001).

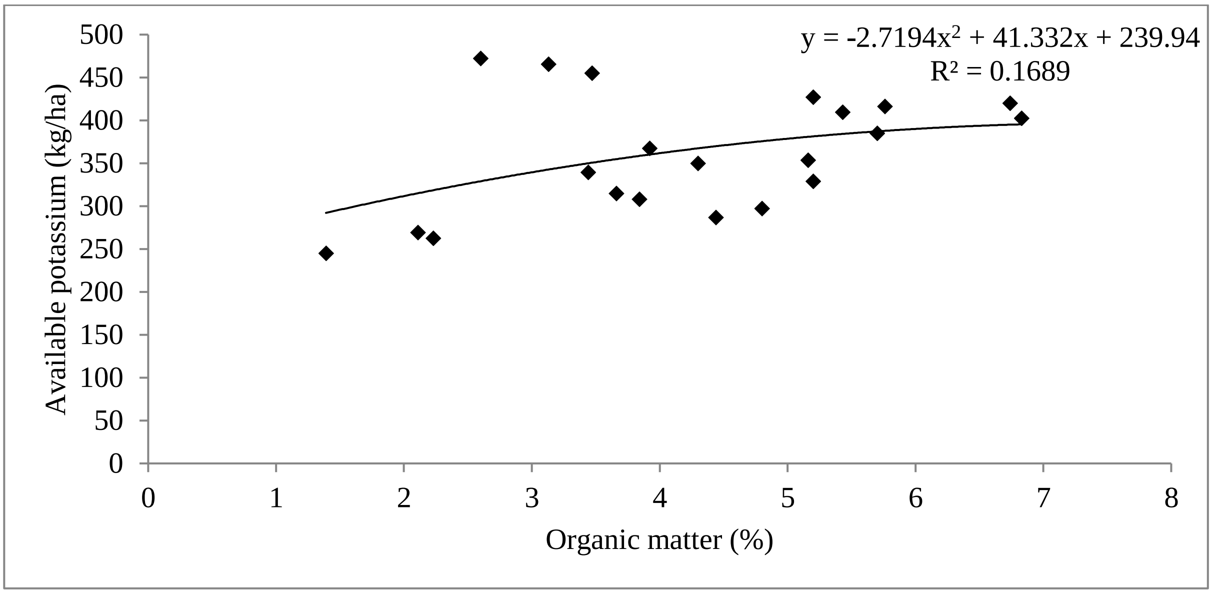

Figure 7: Relationship between soil organic matter content and available potassium content in different aged sweet orange orchards in Tinkanya, Sindhuli (2021)

3.5 Optimum nutrients requirement and nutrient status in sweet orange orchards

Standard soil rating only helps to characterize the soil but it may not be in accordance with the exact sweet orange nutrient requirement. So, comparing soil nutrient status in accordance with optimum range as sweet orange requirement, will help to identify which nutrient factor is the most limiting factor in the production of quality sweet orange.

3.5.1 Overall soil fertility status according to optimum nutrient requirement of sweet orange

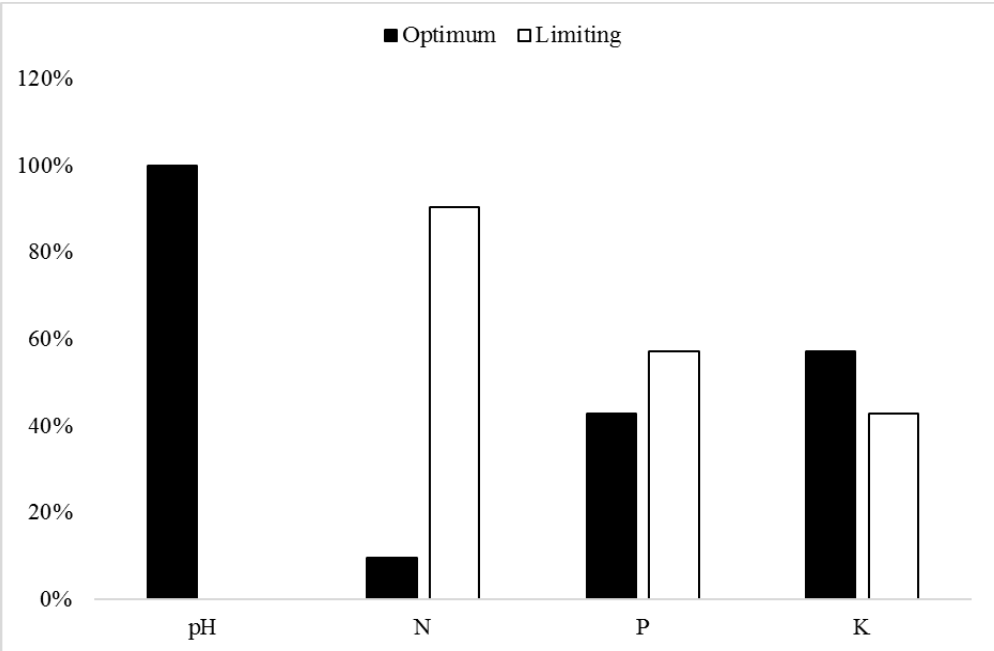

Figure 8: Bar diagram showing overall fertility ratings of soil at sampled locations according to optimum nutrient requirement of sweet orange

It was revealed that the most limiting nutrient for sweet orange production is nitrogen in each of the treatments and overall sampled soils. As nitrogen is very important nutrient for plants growth and development, it is suggested to apply optimum amount of nitrogenous fertilizers in order to meet requirements of sweet orange plants and to maintain healthy and vigour plants.

3.5.2 Available soil nitrogen status

As per the optimum available soil nitrogen requirement of sweet orange, it was revealed that 90.48% of total sampled soils were in limiting range of available nitrogen whereas, 9.52% of total samples soils were in optimum range. It was observed that nitrogen is the most limiting nutrient as compared to other nutrients for sweet orange orchards as per optimum requirement range. Hence, Producers are suggested to apply optimum amount of nitrogenous fertilizers in order to meet requirements for growth and development of sweet orange. Also, it is suggested that nitrogen should be applied in split doses instead of bulk so as to control leaching and increase its availability to plants.

Table 9: Status of available soil nitrogen status as per the sweet orange requirement in Tinkanya, Sindhuli (2021)

Variable	Rating	Range	Percentage
Available Soil Nitrogen	Limiting	<86.77, >122.4	90.48%
	Optimum	86.77-122.4	9.52%

3.5.3 Available soil phosphorus status

As per the optimum available soil phosphorus requirement of sweet orange, it was revealed that 57.14% of total sampled soils were in limiting range of available phosphorus whereas, 42.86% of total sampled soils were in optimum range.

Table 10: Status of available soil phosphorus status as per the sweet orange requirement in Tinkanya, Sindhuli (2021)			
Variable	**Rating**	**Range**	**Percentage**
Available Soil Phosphorus	Limiting	<5.9,>17.8	57.14%
	Optimum	5.9-17.8	42.86%

3.5.4 Available soil potassium status

As per the optimum available soil potassium requirement of sweet orange, it was revealed that 42.86% of total sampled soils were in limiting range of available potassium whereas, 57.14% of total sampled soils were in optimum range.

Table 11: Status of available soil potassium status as per the sweet orange requirement in Tinkanya, Sindhuli (2021)			
Variable	**Rating**	**Range**	**Percentage**
Available Soil Potassium	Limiting	<173.4,>403.2	42.86%
	Optimum	173.4-403.2	57.14%

4. Conclusion

The soil of Tinkanya, Sindhuli from the majority of sampled soil was neutral in soil pH, medium in soil organic matter, medium in total nitrogen, low in available phosphorus, whereas high in available potassium content. Soil pH was neutral in lower age groups of orchards and acidic in higher age groups. As compared with optimum soil test value for sweet orange, Nitrogen was found to be the most limiting nutrient. Thus, it is suggested to the farmers of Tinkanya, Sindhuli to apply optimum level of nitrogenous fertilizers and apply them in split doses to control leaching as well as to increase its availability to plants. Likewise, it is suggested to carry out regular soil tests to know about status of soil nutrients and apply fertilizers accordingly. For further studies, it is also suggested that this research be carried out in different locations in different seasons for studying the basis of change in soil nutrient parameters with the age of orchards and for the further verification of this study.

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