# Assessment of Soil Nutrients Status of Mandarin Orchards in Dagana

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ABSTRACT

*Mandarin is an important fruit crop for Bhutan's economy. In 2017, 38.28% of income earned from the sale of fruits was from mandarin. Mandarin is cultivated in 17 districts of Bhutan. Dagana district in west central Bhutan is an important mandarin growing district. The productivity of mandarin trees in Dagana is low as compared to other districts. In 2017, a mandarin tree which has at least attained three years of age and started bearing fruits of economic value on an average yielded 39 kg of fruits in Dagana, whereas a mandarin tree in Trashigang on an average yielded 81 kg of fruits.There is a scope of improving productivity of mandarin trees in Dagana. One way to improve productivity of the plant is through balanced manuring and fertilization at right time as plant productivity is directly linked with soil fertility level in the orchard. Mandarin performs best in sandy loam soils with pH ranging from 5.5 to 6.5. Generally, soils with low nutrient content will have high response to fertilizer application than soil with high nutrient content. In order to study the soil fertility level in mandarin orchards of Dagana, five important mandarins growing gewogs in the district namely Drugyegang, Trashiding, Tsendagang, Goshi and Kana were selected. Soil sampling was done in those pilot gewogs to study the status of important soil parameters in orchard. Eighty composite soil samples consisting forty top soils and forty subsoil were collected from five pilot gewogs. From each gewog, sixteen composite samples were collected consisting of eight topsoil and eight subsoil from eight different mandarin orchards. Top and subsoil samples were collected from 0-20 cm and 20-40 cm depth respectively. Samples were analyzed and soil fertility level among five gewogs was compared followed which fertilizer recommendations were drawn. Analysis results showed that in general, the soil pH was moderate to slightly acidic, percent carbon at medium level, nitrogen at low level, available phosphorus at high level, available potassium at medium level and cation exchange capacity at low level. The most common soil texture was sandy loam. It could be concluded that the improvement in the level of percent carbon, nitrogen and potassium in soil could improve the productivity of mandarin in Dagana.*

**Keywords:** *Percent carbon, Nitrogen, Available potassium, Soil texture, Cation exchange capacity*

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## 1. Introduction

Mandarin (*Citrus reticulata* Blanco) is the most important fruit crop in Bhutan as 60% of the population is involved in its cultivation and mandarin is grown in 17 out of the 20 districts in Bhutan (Joshi & Gurung, 2009). In terms of the percent distribution of agriculture area in Bhutan, mandarin (5%) has the highest agriculture land followed by cardamom (3%), apple (2%) and areca nut (1%) (NSB, 2018). In 2017, it contributed 51.26% to the total fruit production and 38.28% to the total income generated through the sale of fruits both within and outside the country RSD, (RSD, 2017). Dagana district in west central Bhutan contributed most to the total production over the years (RSD, 2017; DoA, 2014, 2015, and 2017). In 2017, 21.63% of the total production was from Dagana (RSD, 2017).

In 2017, the high production of mandarinwas due to the large number of bearing trees with 17.85% of the total bearing trees found in Dagana and not due to the high productivity of the trees as the average yield was only 39 kg/tree in Dagana which is far less than 81 kg/tree obtained in Trashigang (RSD, 2018). Bearing trees refer to mandarin trees which have at least attained three years of age and started producing fruits of economic value. The huge gap between the average mandarin yield of Dagana and the highest average yield obtained in Bhutan shows the scope for improving the productivity of mandarin in Dagana.

Improper and inadequate manuring and fertilization under rain-fed farming aggravated by pests and diseases declined mandarin yield in Bhutan (Tshering, Tshering, Khampa & Tomiyasu, 2008). Soil nutrition affects tree growth, yield, fruit size and quality of mandarin (Hardy et al., 2017). Crowley (2011) highlighted the importance of macronutrients and micronutrients in mandarin production. N-P-K fertilizer application improves overall mandarin growth and development (Boughalleb, Mhamdi & Hajlaoui, 2011) and significantly increases the yield (Hume et al., 1985; Nasreen, Ahmed, Ullah, & Hoque, 2013). Integrated nutrient management (INM) was suggested to optimize mandarin yield and production in Bhutan (Dorji et al., 2016).

The major sources of soil nutrition in Bhutan are manures (organic) and fertilizers (inorganic) in mandarin and their balanced application at the right time can improve productivity of mandarin as plant productivity is directly related to soil fertility level in the orchard (NSSC, 2009). Regular soil testing is important in nutrient management of any crop to obtain optimum yield (Horneck, Sullivan, Owen & Hart, 2011). In order to know the soil fertility status, soil sampling and soil analysis are necessary.

With information on the soil fertility status of the orchard soil, necessary recommendations to improve the soil for improved productivity can be made. Thus, the study was conducted to determine the fertility status which is necessary for soil improvement recommendations to improve the mandarin productivity.

## 2. Materials and Method

The study was carried out in Dagana, awest central district of Bhutan. Five Gewogs (Drugyegang, Trashiding, Tsendagang, Goshi and Kana) were covered in this study. The soil samples were collected from Drugyegang, Trashiding, Tsendagang, Goshi and Kana as it forms important mandarin growing Gewogs in the district (NSSC, 2005a). The pilot Gewogs were selected in consultation with district agriculture sector. The elevation of sampled area ranges from 500 to 1300 meters above sea level (masl). Eight orchards between 10 to 35 years were selected randomly for soil sampling with help from extension supervisor and orchard owner. Trees in all orchards covered in this study were at fruit bearing stage with a minimum of 20 trees in an orchard.

A total of eighty composite samples consisting of forty topsoil and forty subsoil from the selected mandarin orchards were collected. Each composite sample was formed by minimum of eight sub-samples collected from a location randomly. Topsoil samples were collected from 0-20 cm depth and subsoil from 20-40 cm depth. The soil sampling was done from1$^{st}$to 15$^{th}$ of February, 2018. The samples were properly packed and sent to Soil and Plant Analytical Laboratory at National Soil Services Centre (NSSC) for analysis. The samples were collected as per the soil sampling guideline provided by NSSC.

Seven important soil properties were analyzed from the soil samples thus collected. Google docs sheets were used for compiling and organizing data and then exported to STAR (Statistical Tool for Agricultural Research), version 2.0.1 International Rice Research Institute. Data analysis was maintained at 95% confidence interval. Soil parameters and methods used for analysis are given in Table1.

Table 1. Method used for soil analysis

| Sl. No. | Soil Parameter Analyzed | Method Used for Analysis |
|---|---|---|
| 1 | Soil pH | pH ($H_2O$) method |
| 2 | Percent Carbon | Walkley and Black method |
| 3 | Total Nitrogen | Kjeldahl method |
| 4 | Available Phosphorus | Bray method |
| 5 | Available Potassium | 0.01M $CaCl_2$ |
| 6 | Soil Texture | Hand bolus method |
| 7 | Cation Exchange Capacity | eCEC method |

## 3. Results and Discussion

3.1 Soil pH

In general, soils of the five gewogs were moderate to slightly acidic in nature and soil pH values falls in favorable range of 5.5 to 6.5 as given in Table 2.

Table 2. Descriptive statistics for soil pH

| Variable | N | Min | Max | Mean | Range | StdDev | SE_Mean | CV |
|---|---|---|---|---|---|---|---|---|
| SoilpH | 80 | 4.50 | 6.69 | 5.93 | 2.19 | 0.4073 | 0.0455 | 6.87 |

The comparison of soil pH among gewogs was done (Figure 1). The soils were moderately acidic (average pH=5.5) in Drugyegang. Goshi and Tsendagang have favorable soil pH (5.5-6.5) for growing mandarin. In Kana and Trashiding, soils are slightly acidic (average pH=6.5).

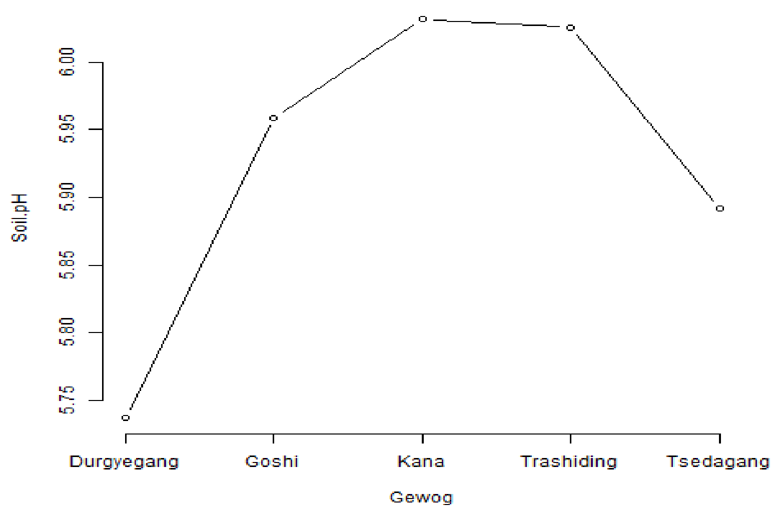


Figure 11. Comparison of soil pH among gewogs

Mandarin does best in soils with pH ranging between 5.5-6.5 as most soil minerals become available for use in that range (Hardy et al., 2017; NSSC, 2005a). It is important to have soil pH in favorable range as it controls nutrient availability and microbial activity in the soil (Espinoza, Slaton & Mozaffari, 2010). National Soil Services Centre (NSSC) also reported the soil pH in all five Gewogs within the range of 5.5-6.5 (NSSC, 2005a). As of now, the mandarin orchards in Dagana have favorable pH for growing mandarin. Extra care must be taken in case of Drugyegang (average pH=5.5), Trashiding and Kana (Average pH=6.5) to maintain the pH in favorable range in years to come. Sandy soils have low amounts of reserve acidity due to low CEC resulting in low soil pH.

## 3.2 Percent Carbon

In general, the total organic carbon levels were medium as shown in Table 3.

Table 3. Descriptive statistics for percent carbon

| Variable | N | Min | Max | Mean | Range | StdDev | SE_Mean | CV |
|---|---|---|---|---|---|---|---|---|
| Percent C | 80 | 0.7000 | 6 | 2.31 | 5.30 | 0.8718 | 0.0975 | 37.72 |

The level of organic carbon was moderate in all five gewogs (Figure 2). Tsendagang had the lowest percent organic carbon levels in soil.

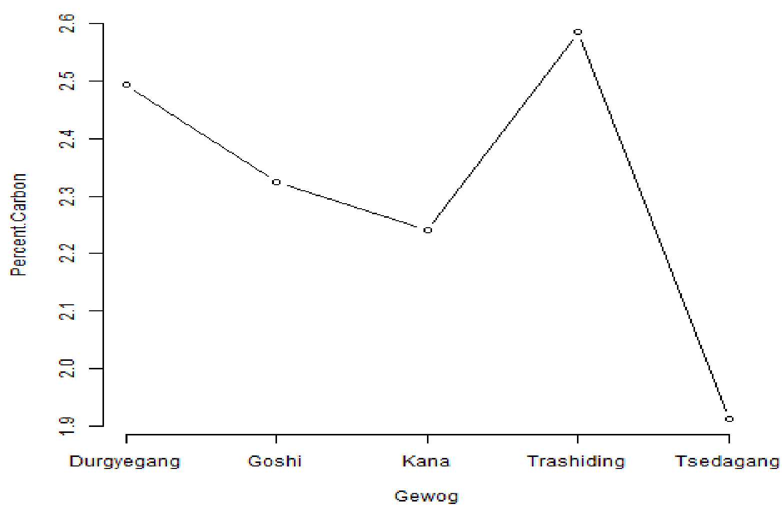


Figure 2. Comparison of percent carbon among gewogs

Soil organic carbon is part of the soil organic matter (SOM), which includes other important elements such as calcium, hydrogen, oxygen, and nitrogen (Espinoza et al., 2010). SOM serves as a reserve for many essential nutrients, especially nitrogen and also influences soil physical, biological and chemical properties (Bolsa Analytical, 2011). The addition of organic matter will supplement nitrogen supply. The low CEC value and sandy loam soil texture could be some of the reasons for the medium levels of organic carbon in Dagana.

Soil organic carbon (SOC) forms about 55-60 % of soil organic matter (SOM). SOM is a surrogate for SOC and reflects the overall soil health (Horneck et al., 2011). SOM forms a reserve for many essential nutrients especially nitrogen and its addition into soil sustain the desirable physical, chemical and biological properties of the agricultural soil (Dinkins, 2013). Soil organic matter has been termed as the lifeblood of the soil (Bianchi, Miyazawa, Oliveira, & Pavan, 2008). Organic matter is critical for biological processes and soil nutrient supply. As a general rule, for every Mt of carbon in soil organic matter about 100 kg of nitrogen, 15 kg of phosphorus and 15 kg of sulphur becomes available to plants as the organic matter is broken down (Zhao, He, Huang, Zhang, & Shi, 2016). SOM is critical for retention and release of plant nutrients and sustainable soil management practices that increases SOC in soil should be practiced (Clara et al., 2017/2017).

3.3 Nitrogen

In general, the level of average nitrogen was low in all five gewogs as given in Table 4.

Table 4. Descriptive statistics for nitrogen

| Variable | N | Min | Max | Mean | Range | StdDev | SE_Mean | CV |
|---|---|---|---|---|---|---|---|---|
| Total N. | 80 | 0.0100 | 0.3800 | 0.1730 | 0.3700 | 0.0843 | 0.0843 | 48.75 |

The level of nitrogen was observed low in four out of the five Gewogs. The level of nitrogen was lowest in Kana followed by Tsendagang, Trashiding and Drugyegang. Only Goshi gewog had medium level of nitrogen in the soil (Figure 3).

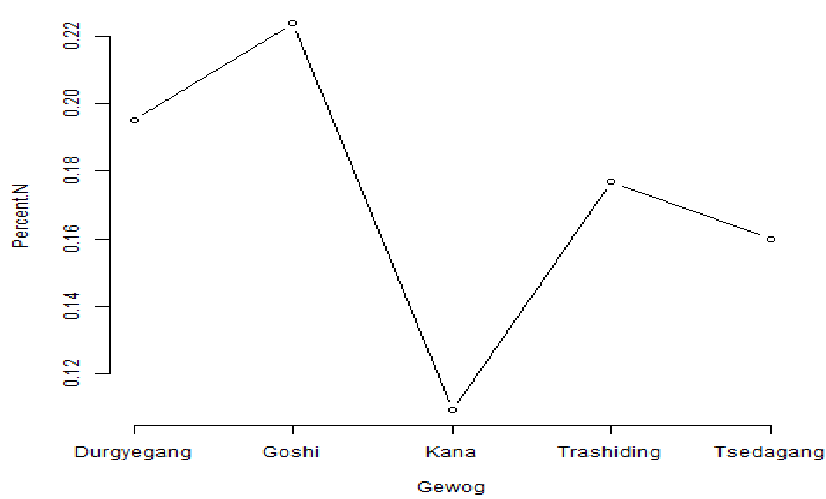


Figure 12. Comparison of total nitrogen among gewogs

Nitrogen forms the major component of the protein and chlorophyll. Tissue nitrogen levels are strongly related to photosynthesis by leaves, and the production of carbohydrates for growth, flowering and fruit development (Crowley, 2011). Hardy et al. (2017) reported high yields of mandarin through management of tree nitrogen supply appropriately and it was also found to have a major impact on fruit quality in combination with P and K. Hume et al. (1985); Wang, Shi, Wei, Yang, & Uoti (2006) also reported significant difference in yield of mandarin through supply of nitrogen. The supply of nitrogen to mandarin promises improvement in productivity. The moderate organic carbon levels and sandy loam soil texture could be reasons for low nitrogen level in Dagana soil.

3.4 Available Phosphorus

In general, the available P levels were high in most soil as shown in table5.

Table 5. Descriptive statistics for available phosphorus

| Variable | N | Min | Max | Mean | Range | StdDev | SE_Mean | CV |
|---|---|---|---|---|---|---|---|---|
| Available P | 80 | 0.0500 | 164.70 | 42.16 | 164.65 | 43.31 | 4.84 | 102.72 |

The available phosphorus was found high in Drugyegang soil and medium in four other gewogs (Figure 4).

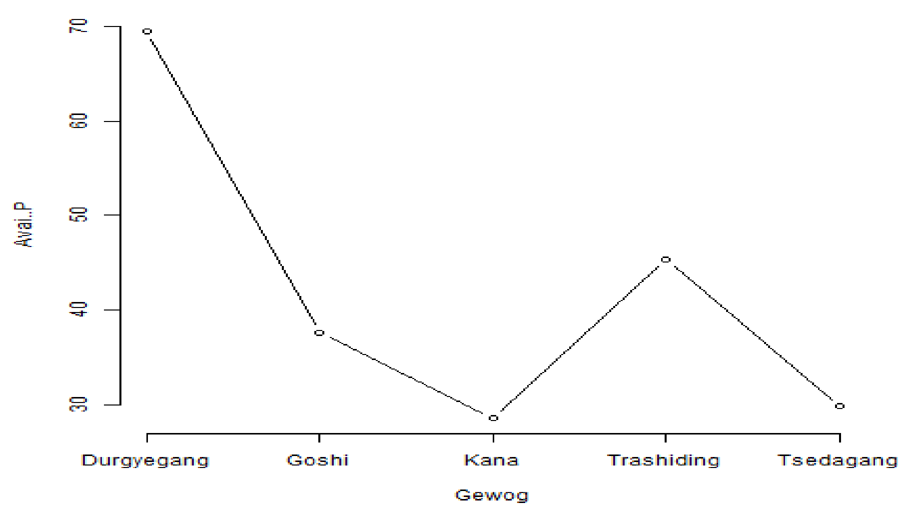


Figure 4. Comparison of available phosphorus among gewogs

Phosphorus plays an important role in plant processes that require energy, including cell division and growth, photosynthesis, sugar and starch formation, and the movement of carbohydrates within the plant (Crowley, 2011). The favorable soil pH could be one reason for its high levels in

Dagana as at pH of 5.5 to 6.5, Phosphorus does not get fixed by elements like aluminum, iron and calcium in soil.

3.5 Available Potassium

In general, available K levels were moderate in most soils as given in table6.

Table 6. Descriptive statistics for available potassium

| Variable | N | Min | Max | Mean | Range | StdDev | SE_Mean | CV |
|---|---|---|---|---|---|---|---|---|
| Available K | 80 | 31.66 | 422.69 | 196.29 | 164.65 | 83.80 | 9.37 | 42.69 |

The available K levels were high at Drugyegang and Tsendagang gewogs. The other three gewogs had medium level of available K (Figure 5).

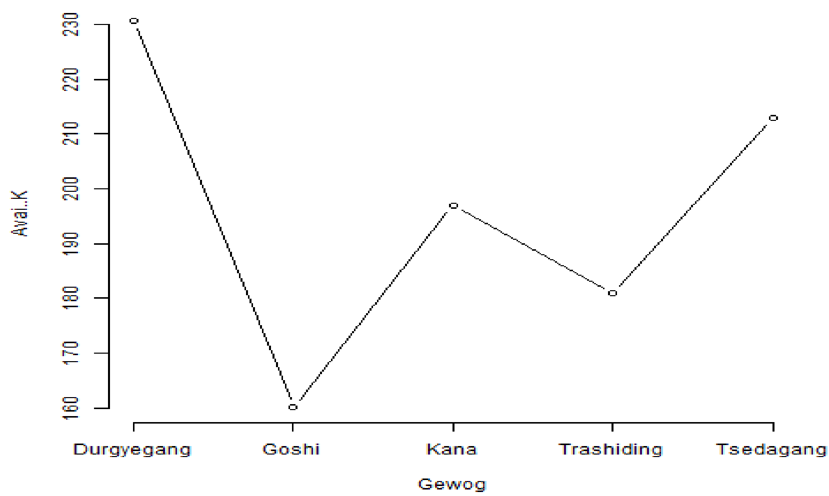


Figure 5. Comparison of available potassium among gewogs

Potassium plays an important role in plant metabolic processes including photosynthesis, protein synthesis and sugar transport and it is needed for cell division and maintaining the balance of salts and water in plant cells (Crowley, 2011). Potassium is the main mineral element in fruit and has more effect on fruit quality than any other element and help trees tolerate stress (e.g. cold and drought) and can improve disease resistance (Nasreen et al., 2013). The addition of potassium fertilizers is essential during fruit development stage (Hardy et al., 2017). Sandy loam soil texture with low organic carbon content could be reasons for medium potassium levels in Dagana as this type of soil has low capacity to hold nutrients.

3.6 Cation Exchange Capacity

In general, CEC were low in most soils as shown in Table 7. Tsendagang had the lowest CEC value (Figure 6).

Table 7. Descriptive statistics for CEC

| Variable | N | Min | Max | Mean | Range | StdDev | SE_Mean | CV |
|---|---|---|---|---|---|---|---|---|
| CEC | 80 | 2.11 | 14.37 | 7.53 | 12.26 | 2.85 | 0.3188 | 37.85 |

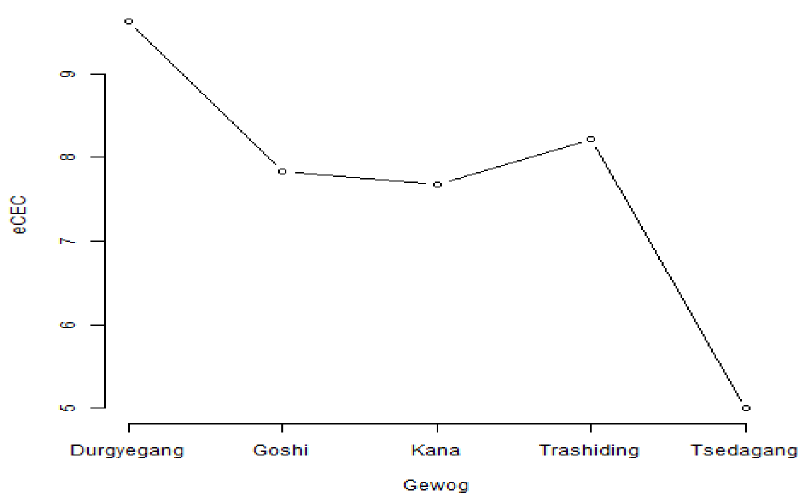


Figure 6. Comparison of eCEC among gewogs

CEC is a measure of the ability of soil to adsorb positively charged nutrient ions (cation) by electrical attraction and generally soil with higher value of CEC will have higher content of clay and organic matter (Bose Analytical, 2011). NSSC (2009) reported low CEC value indicating low content of calcium and magnesium in Dagana soil. The low value could be due to low organic carbon levels in sandy loam soil texture.

3.7 Soil Texture

Sandy loam (SL) was found most common in Dagana region followed by sandy clay (SCL), slit clay (ZCL), loam (L) and loamy sand (LS) and slit loam (ZL) (figure 7).

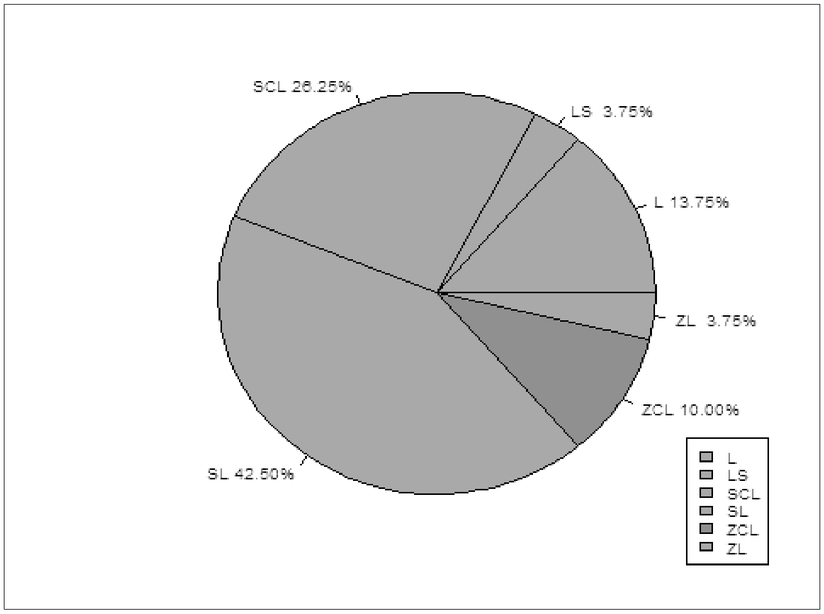


Figure 7. Distribution of soil texture

Soil texture is the relative proportions of sand, slit and clay in the soil and is considered as the permanent soil property. National Soil Services Centre also reported sandy loam (SL) as common soil texture of mandarin orchardsin Dagana and recommends sandy loam and loamy soil for mandarin cultivation (NSSC, 2005a). Mandarin does well in sandy soil with proper drainage (Hardy et al., 2017). Orchard soils need to be well drained to prevent tree roots from being subject to waterlogging for prolonged periods. However, it is important to maintain organic carbon level in such type of soil for retention of nutrients and water in soil.

## 3.8. Key Recommendations to Improve Productivity of Mandarin

The recommendations are drawn based on soil analysis results to improve the productivity of mandarin in Dagana as given in Table 8. For fertility factors (N, P, K) very low and low classifications indicate a high probability for obtaining a fertilizer response; medium classifications indicate a fertilizer response may or may not occur; high and very high classifications indicate a fertilizer response is not likely to occur (NSSC, 2005a, 2009).

Table 8. Recommendations to Improve Productivity

| Gewog | Recommendations |
|---|---|
| Drugyegang | ● Soil pH can be increased with liming (12 kg/tree). Apply it after harvest and prior to spring flush.<br>● Integrated nutrient management (INM) can maintain the favorable level of organic carbon (OC) in soil. Well decomposed compost or FYM (2-3 t/acre) is recommended to apply whenever available.<br>● Urea (450 gm /tree) is recommended. Split application of150 gm in January-February, May-June and July-October should be practiced. |
| Trashiding | ● Gypsum (8 kg/tree) is recommended to reduce soil pH. Apply it after harvest and prior to spring flush. Avoid using base forming nitrogenous fertilizerslike ammonium sulphate, ammonium chloride, monoammonium phosphate and diaammonium phosphate.<br>● INM can maintain the favorable level of OC in soil. Well decomposed compost or FYM (2-3 t/acre) is recommended to apply whenever available.<br>● Urea (450 gm /tree) is recommended. Split application of 150 gm in January-February, May-June and July-October should be practiced.<br>● Muriate of Potash (MoP) (425 gm /tree) is recommended. Apply it after harvest and prior to spring flush. |
| Tsendagang | ● INM can maintain the favorable level of OC in soil. Well decomposed compost or FYM (2-3 t/acre) is recommended to apply whenever available.<br>● Urea (450 gm /tree) is recommended. Split application of 150 gm in January-February, May-June and July-October should be practiced. |
| Goshi | ● INM can maintain the favorable level of OC in soil. Well decomposed compost or FYM (2-3 t/acre) is recommended to apply whenever available.<br>● Urea (300 gm /tree) is recommended. Apply split application (150 gm) in January-February and July-October.<br>● MoP (425 gm /tree) is recommended. Apply it after harvest and prior to spring flush. |
| Kana | ● Gypsum (8 kg/tree) is recommended to reduce soil pH. Apply it after harvest and prior to spring flush. Avoid using base forming nitrogenous fertilizers like ammonium sulphate, ammonium chloride, monoammonium phosphate and diaammonium phosphate.<br>● INM can maintain the favorable level of OC in soil. Well decomposed compost or FYM (2-3 t/acre) is recommended to apply whenever available.<br>● Urea (450 gm /tree) is recommended. Split application of 150 gm in January-February, May-June and July-October should be practiced.<br>● MoP (425 gm /tree) is recommended. Apply it after harvest and prior to spring flush. |

## 4. Conclusion

Mandarin as a cash crop plays an important role in Bhutan's economy. Dagana district contributes most in terms of production of mandarin as most bearing trees are situated there. However, the low productivity of trees in the district is a concern and can be improved to achieve higher productivity. The improvement in soil fertility status of the orchard can be one ways to improve its productivity. After soil sampling and analysis, Nitrogen, potassium and organic carbon were found as limiting factors in Dagana soil. The productivity of mandarin trees in the selected gewogs can be significantly improved through supply of nitrogen and potassium with addition of organic matter into soil. Therefore, the supply of nitrogen and potassium in required quantity at the critical point between harvest and bud break stage, summer shoot development stage and during the onset of monsoon could prove crucial in improving its productivity in combination with the addition of well decomposed organic matter.

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