International Journal of Ecology and Environmental Sciences 44 (3): 287-292, 2018
ISSN: 2320-5199 (Online)

Soil Organic Carbon and Total Nitrogen in Temperate Apple Orchards of South Kashmir

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ABSTRACT

Soil organic carbon and nitrogen play animportant role in soil sustainability and crop production. The C/N ratio is used as a sensitive soil quality indicator and as a guide for rate of mineralization; hence critical for the ecosystem response to elevated atmospheric CO_2. We studied SOC, total soil nitrogen (TSN) and C/N ratio of young apple orchard of district Kulgam. The SOC and TSN content ranged from 7.9and 0.75 g kg^{-1} in Kounserbal to 21.8 and 1.16 g kg^{-1} in Yaripora respectively. The C/N ratio ranged from 18.7 to Yaripora and 10.2 in Okey with a productivity of 12.1 and 9.1 Mg ha^{-1} respectively. We conclude that more efforts should be made to increase and maintain C/N ratio for effective soil CN balance and optimum C/N needs to be evaluated across conventional, high density planting and organic farming for achieving potential productivity of apple orchards under temperate conditions of Kashmir.

Key Words: Apple Orchards; C/N Ratio; Soil Organic Carbon; Total Nitrogen

INTRODUCTION

India ranks second in fruit production in the world. China tops the list with production of 161.211 million Mg (= metric ton) fruits in 2016 and is followed by India with 86.221 million Mg. In apple alone India ranks third after China and USA. During 2016, India's apple imports stood at USD 156.1 million. The domestic production is estimated to have declined to 1.892 million Mg in 2015-16 as against 2.369 million Mg in the previous year. Kashmir valley is the major apple producing state in India with a production of 1,348,151 Mg on an area of about 157,280 ha in 2016. The low productivity of apple in India (7.34 Mg ha^{-1}) as compared to that in China (14.96 Mg ha^{-1}) in 2015-16 is attributed to a number of factors with poor soil quality being one of the major factors.

Soil health is an important factor which determines the growth of plants. The soil physico-chemical and biological properties and their interactions play a vital role in soil quality (Glover et al. 2000, Benbrook 2017). The concepts of soil health (status of soil to hospitable environment for soil life) and soil quality (physical and chemical attributes of soil that support plant growth) have systematically evolved with an increase in the understanding of soils and soil quality attributes (Gupta and Yeates 1997, Badiane et al. 2001, Bastida et al. 2008, Cardoso et al. 2013, Koorem et al. 2014).

Availability of balanced nutrients (macro and micro) to plants determines the fertility of soil which is particularly sensitive to changes to soil environment which is subject to management practices (Wang et al. 2016). Deficiency of nutrients has become a major constraint to productivity, stability, and sustainability of soils of Kashmir Valley (Kirmani et al. 2011, Dar et al. 2014). The indiscriminate use of fertilizers and lack of awareness of micro-nutrients among the farmers is the major cause of low production and poor fruit quality in Kashmir (Dar et al. 2014). Excessive use of N fertilizers not only decreases the nutrient use efficiency and agricultural production but also aggravates physiological fruit disorders, diseases and environmental pollution (Zhang et al. 1995, Motavalli and Miles 2002, Vogeler et al.2009).

Key role in pedogenic processes and soil fertility is played by soil organic carbon (SOC) and nitrogen (Laurent et al. 2014). The storage of SOC and total soil nitrogen (TSN) reflects ecosystem response to natural and anthropogenic disturbances under different land use and management strategies (Zhang et al. 2013). The relationship between them represented by C/N ratio can be used asa sensitive indicator of soil quality and for assessing the C and N nutrition cycling of soils (Zhang et al. 2011). Both C and N status associated with C/N ratio may play a key role in regulating soil organic matter mineralization. The ratio indicates the organic matter decomposition rate which results in the release (mineralization) or immobilization of soil nitrogen. Being fairly imprecise indicator, however, as small changes in the quantity and nature of the soil organic matter can considerably affect soil quality and fertility.

SOC and N content are not only affected by climate, topographic altitude, aspect and slope and vegetation influencing the biogeochemical cycle in soil, but also by land use management (Yang et al. 2010, Ge et al. 2013). There is a considerable variation of SOC and N across the major fruit producing districts of Kashmir valley (Anantnag, Kulgam, Shopian, Pulwama and Baramullah) due to landscape changes and typical topography of lesser Himalayas (Dar et al. 2016, Bangroo et al. 2017). However, precise estimates of total SOC and TN in apple orchards are missing from these regions.

The objectives of this study were (1) to determine the SOC and TN content and (2) to assess the C/N ratio as soil quality indicator vis-à-vis productivity in young apple orchard (15-20 yr old) soils of district Kulgam.

STUDY AREA

The study was conducted in young apple orchards of district Kulgam in Kashmir valley. District Kulgam is located at 33º 65' N latitude and 75º 02' E longitude and is situated on the southern side of Jammu & Kashmir State of India. It has an average elevation of 1739 m above mean sea level. The region falls under the cold humid zone with soils ranging from clay loam to sandy loam in texture and alluvial in origin rich in illite. The sampling site covered 11 young apple orchard villages (Table 1) differing in productivity and management practices. The high yielding areas follow more precisely the package of practices as compared to low yielding orchards. A definite uniform age group was selected for two reasons: 1) to avoid potential yield vigor variation of the trees, and 2) to study effect of C/N ratio on the yield of young orchards.

Table 1. Location of orchard villages for soil samples

Village	Geographic Location		Altitude (m)
Yaripora	33º 43' 25.07" N	74º 01' 04.98" E	1671
Ves Batpora	33º 40' 16.48" N	74º 59' 08.20" E	1768
Pranhal	33º 37' 26.23" N	74º 59' 26.80" E	1770
Ganasargom	33º 37' 34.11" N	75º 02' 31.43" E	1776
Okey	33º 39' 32.79" N	74º 58' 30.86" E	1790
Arreh	34º 40' 34.72" N	74º 57' 36.25" E	1701
Guder	33º 37' 22.29" N	74º 59' 45.16" E	1849
Hariwath	33º 38' 39.99" N	74º 54' 58.21" E	1916
Kapran	33º 39' 46.24" N	74º 53' 56.16" E	1938
Nihama	33º 38' 07.86" N	74º 53' 56.16" E	1973
Kounserbal	33º 36' 01.48" N	74º 55' 56.00" E	1978

METHODS

Composite soil samples were taken from 0-9 inch soil depth within the drip line of the canopy at more than 10 random points in each orchard with three orchards selected per village in September 2015 after the fruit harvest. The soils were air-dried processed and sieved though 2mm sieve after removing visible plant debris including roots.

The soils were analysed for pH in 1:2.5 soil:water suspension with the help of glass electrode pH meter (Jackson 1973) and particle size distribution was determined by international pipette method (Piper 1966).

The SOC concentration was determined using the Walkley-Black dichromate oxidation procedure (Nelson and Sommers 1982) and total N concentration was determined by the Kjeldahl procedure (McGill and Figueiredo 1993).

Data Analysis

The data were analysed for ANOVA (analysis of variance) using SPSS package and difference of $p<0.05$ were considered statistically significant.

RESULTS AND DISCUSSION

Soil Organic Carbon (SOC)

Texturally soils were loamy to silty loam and pH ranged from 4.93 to 6.65 (Table 2). SOC is one of the most important constituents of the soil ecosystembecause of its capacity as energy source to plant growth and a trigger for nutrient availability through mineralization (Scotti et al. 2015, Faucon et al. 2017). Significant difference in SOC content of orchard soils of district Kulgam was observed (Table 3). The highest SOC content of 21.8 g kg^{-1} was recorded from Yaripora and the lowest SOC content of 7.9 g kg^{-1} from Kounserbal. The difference in SOC content is mainly attributable to management practices though belonging to same age group. Further, it was observed that SOC content decreased with the altitude. Altitude as such is not a variable directly influencing the ecosystem but an index of climate functions that govern the nature of the vegetation and process of soil formation (Hanawalt and Whittaker 1976). Kato et al. (2006), Zhang et al. (2011), and Garcia et al (2016) also reported variation of SOC along the altitude as an inverse relation under natural vegetation.

The difference in SOC along altitude may also be attributed to higher application of organic manure in lower altitude accessible orchards than in orchards at higher altitude which are mostly inaccessible because of difficult terrain features of the Himalaya. Also insolation difference along the altitude and northern and southern aspect affect the soil water content and soil temperature and thereby affect the decomposition rates of litter (Smith et al. 2002, Zhang et al. 2011) and residence time of SOC and N in the litter as reported by Kato et al. (2006). Several studies have shown that organic fertilizer combined with inorganic fertilizer is more beneficial to the improvement of the SOC content compared to single inorganic chemical fertilizer application (Goyal et al. 1999, Zhang et al. 2010).

Table 2. Physico-chemical properties of the orchard soils of district Kulgam (mean ± SE)

Village	Sand (%)	Silt (%)	Clay (%)	pH (1:2.5)
Yaripora	46.3	33	20.7	4.93±0.10
Ves Batpora	27.8	51.3	20.9	5.84±0.06
Pranhal	36.8	38.6	24.6	5.80±0.46
Ganasargom	19.5	53.2	27.3	5.38±0.19
Okey	26.2	47.3	26.5	6.05±0.09
Arreh	25.1	46.2	28.7	5.16±0.14
Guder	23.8	43.7	32.5	5.54±0.10
Hariwath	18.3	48.2	33.5	5.08±0.28
Kapran	34.2	47.1	34.7	5.54±0.23
Nihama	15.3	49.0	35.7	5.97±0.03
Kounserbal	17.4	42.8	39.8	6.65±0.30

Table 3. SOC and TSN contents of orchard soils of district Kulgam (mean ±SE)

Village	Yield (Mg ha^{-1})	SOC (g kg^{-1})	TSN (g kg^{-1})
Yaripora	12.1	21.8±1.23	1.16±0.04
Ves Batpora	11.6	17.8±1.28	1.08±0.05
Pranhal	11.5	15.9±3.13	0.97±0.04
Ganasargom	10.5	15.3±2.12	0.97±0.05
Okey	9.1	9.3±1.09	0.91±0.03
Arreh	10.2	11.2±3.32	0.95±0.02
Guder	9.2	10.1±2.14	0.97±0.05
Hariwath	9.8	12.5±1.14	0.88±0.03
Kapran	9.5	10.2±1.04	0.94±0.06
Nihama	9.2	8.2±2.20	0.78±0.05
Kounserbal	9.2	7.9±2.11	0.75±0.03

Total Soil Nitrogen (TSN)

Soil N also plays a major role, in addition to C in soil ecosystem functioning. Although essential for life, its bio-available forms are considerably low which constrains plant growth. The N cycle in many ecosystems therefore controls the overall soil dynamics and working of C and N in organic matter (Batlle-Aguilar et al. 2011). The highest TSN content of 1.16 g kg^{-1} was recorded

from Yaripora and lowest TSN content of 0.75 g kg^{-1} from Kounserbal (Table 3). The TSN fallowed a trend similar to that of SOC and showed a positive C/N relationship with its content high in areas where the SOC was high. High clay content typically decreases SOC oxidation which indicates a positive relationship between clay and TSN content (Sakin et al. 2010). Cote et al. (2000) stated that N mineralization decreases when the clay amount increases in soil. We obtained similar results and found higher TSN content in areas low in clay content. Also, McLauchlan (2006) explained that clay content increase in soil increases aggregation which is responsible for decrease in potential N mineralization.

The significantly higher values of TSN in Yaripora (1.16 g kg^{-1}) and Ves Batpora (1.08 g kg^{-1}) is ascribed to high N-fertilizer application rate in these two areas. In general the soils of district Kulgam are low in TSN with an average value of 0.93 g kg^{-1} (Table 3).

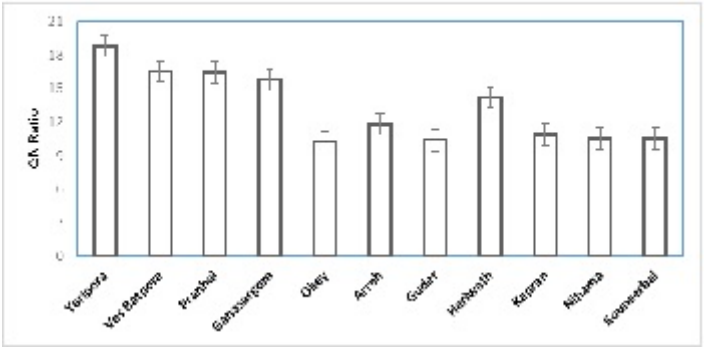

Figure 1. C: N ratio of soils of young apple orchards of district Kulgam

Soil C/N ratio

The soil C/N ratio has considerably been developed and used as a sensitive indicator for the assessment of soil quality and C and N nutrition balance in soils.The C/N ratio is related to the patterns of nitrogen immobilization and mineralization during organic matter decomposition by micro-organisms (Swift et al. 1979). High soil C/N ratio (>25)slowdowns the decomposition rate of organic matter and organic nitrogen by limiting the soil microbial activity, whereas low soil C/N ratio accelerates the process of microbial decomposition of organic matter and nitrogen, which is not conducive for carbon sequestration. Figure 1 shows significant differences in soil C/N ratio among the 11 young apple orchards of Kulgam. The C/N ratio in 7 orchard villages was below 15. The highest C/N ratio of 18.7 was found in Yaripora and lowest ratio of 10.21 in Okey with overall average C/N of the district as 13.26. The litter with wider C/N ratio takes time for decomposition and slowly releases CO_2 to the atmosphere. It leads to increase in storage time of the C in soil. Various studies have suggested an increase of the soil C/N ratio with a decrease in temperature and an increase in moisture (Jenny 1941). However, it also depends on the nitrogen contents of the litter itself (Swift et al. 1979, Jordan 1985), local variations in soil conditions according to topography and parent material. The higher soil C/N ratio illustrates faster increase in soil carbon than nitrogen. To maintain the steady growth of soil C/N ratio, it is advocated that the addition of carbon be paid more attention than the

The higher fruit yield (Table 3) was recorded in orchards having C/N ratio >15 with highest productivity of 12.1 Mg ha^{-1} in Yaripora and lowest 9.1 Mg ha^{-1} in Okey. This may be attributed to positive correlation of C/N ratio with microbial population and root colonization (Yong et al. 2016). Higher C/N ratio also promotes soil biological activity and enhances soil structure and soil water-nutrient-crop productivity relationships (Wang and Sainju 2014, Xia et al. 2013, Zhang et al. 2011a). Though our results indicate higher C/N ratio as an index for higher fruit productivity but there is a need to find out optimum C/N ratio for achieving potential productivity in apple orchards under conventional, high density and organic farming.

CONCLUSION

Average SOC and TSN for the study soils was 12.75 g kg^{-1} and 0.93 g kg^{-1} respectively. Altitude and clay content effect on SOC and TSN was observed as an inverse relation respectively. Seven villages exhibited the C/N ratio below 15 with average value of 13.27 exhibiting direct correlation with the fruit productivity. It may be therefore concluded that 1) more efforts should be made to increase and maintain C/N ratio for effective soil C and N balance and harness the potential of young

apple orchards as C sink under temperate conditions, 2) the optimum C/N ratio should be evaluated across conventional, high density planting and organic farming for achieving potential productivity of apple orchards, and 3) further study needs to be conducted on decomposition rate of different types of litter under time and space existing in temperate orchards.

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Received 24 February 2018
Accepted 31 May 2018