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Case Report

Soil properties in high density mango orcharding- a basis for orchard sustainability

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Abstract

High density orchard plantation is a viable option for sustaining orchard productivity. Precision farming approaches are needed for maintaining the soil health in such a system. The present study was conducted in the density plantation system of mango cv *Dashehari* maintained since 1992 under subtropical climatic condition with six different spacing of 2.5 × 2.5, 2.5 × 5.0, 5.0 × 5.0, 5.0 × 7.5, 7.5 × 7.5 m and 10.0 ×10.0 m with 1600, 800, 400, 267, 177 and 100 plants per hectare respectively. The average yield at 18th year was recorded as 15.5 t ha^{-1}. Changes in soil properties, estimation of organic carbon and micronutrients stock under long-term orchard management system were quantified. A range of 4.15 ± 0.26 to 8.27 ± 0.12 Mg ha^{-1} SOC stock was estimated across different density systems with 6.28 ± 0.36 Mg ha^{-1} in recommended medium density system. Fifty per cent of the total soil samples were estimated to have SOC stock in the range of 6.1 to 9.0 Mg ha^{-1} followed by 33 per cent in 5.1 to 6.0 Mg ha^{-1}. Lowest (17%) was observed in 1 to 5 Mg ha^{-1} range. Majority of the Zn stock lies in the range of 1.1 to 2.0 kg ha^{-1} category while 21 to 30 kg ha^{-1} Cu stock had lowest percentage. A 21 to 40 kg ha^{-1} had highest percentage of Fe stock across different mango density system and Mn stock of 31 to 40 kg ha^{-1}.

Key words: High density system, precision farming, soil properties, stock estimation, mango

Introduction

High density mango orcharding and its scope

Arable lands are getting limited because of increasing urbanization and other industrial purposes resulting into severe shrinkage in per capita land availability. Of late, horticultural ecosystem is getting more importance globally because of its significant contribution to the calorific energy and nutritional needs of the people across agroecological zones. High density orchard plantation is a viable option for improving yield, sustainability and offsetting the impact of land shrinkage because of its advantages over the traditional orcharding in mango due to efficient use of inputs, higher net returns per unit area (1). Under high density system, chances of overcrowding are more pronounced compared to traditional system leading to excessive shading and reduction in photosynthesis resulting in poor yields. By regular training and pruning of the trees, the shape and size can be managed for realizing the optimum productivity on sustainable basis through good orchard management practices (2). Mangoes are traditionally planted at 80-100 plants ha^{-1} but keeping the quality production in varying level of distance including 2.5m × 2.5m for Amrapali (yield at 11^{th} year: 22t ha^{-1}), 5m × 5m for Arka Aruna (yield at 5^{th} year: 16t ha^{-1}) and Dashehari (Yield at 18^{th} year: 15.5 t ha^{-1}). It has been showed that double hedgerow planting system (cv. Amrapali) with 3556 plants ha^{-1} recorded maximum fruit yield in Bihar while single hedgerow system (2670 plants ha^{-1}) was found best for cv. Kalapady in Tamil Nadu.

Role of soil health management under HDP system

Long-term orchard management impacts soil health indicators *viz*., physical, chemical and biological properties over a considerable time span (3, 4). This impacts the spatial and temporal changes in land use, tree density, species richness, root volume and density, leaf litter, microbial activities, biogeochemical reactions etc (5). Soils management under orchard ecosystem is different than intensively cultivated annual crops. Changes occurring in land use history/conversion of agricultural land to fruit tree ecosystem may have substantial influence on the nutrient release pattern (6). Relatively higher soil carbon stock (amount of carbon stored in soil) under deeper soil profiles in agroforestry systems as compared to treeless agricultural or pasture systems under similar ecological conditions. Soil micronutrients dynamics, organic carbon and other related properties are associated with the short/long term soil productivity over time period (7). In view of this, there is a strong need to understand the changes in soil physico-chemical indicators and their stock estimation for higher density tree plantation system in order to manage the sustainability of production system. Precision farming is needed to sustain the high density system (8).

Soils are considered as one of the largest reservoir of carbon storage. Soil is recognized as an excellent sink for increasing atmospheric CO_2 and if managed properly, it can store a considerable amount of SOC in the terrestrial ecosystem. Around 1500 Pg carbon is stored in top 30 cm soil layer across globe while for India the value is only 9 Pg. At the top of soil layer (up to 20 cm soil depth), about 615 Gt C is stored in terms of global soil organic carbon (SOC) and with increasing the depth up to 3 meter, the corresponding value falls around 2344 Gt C. Storage of stabilized organic carbon may influence the ecosystem functioning. Improvements in aggregate stability, water holding capacity, nutrient retention, the ecosystem functioning. Improvements in aggregate stability, water holding capacity, nutrient retention, etc. are some of the direct beneficial impacts. Alternate land use planning like agroforestry, agri-horti system, silvi-pastoral, wherein fruit tree crop are one of the components, contributing to the storage of SOC. SOC content reportedly gets doubled in agroforestry and agro-horticultural system as compared to sole cropping. SOC has been broadly increased along with the C sequestered rate (877 kg C/ha/y and 325 kg C/ha/y) after 38 and 10 years of cultivation when coconut tree intercropped with guava under same agro-ecological situation.

It has revealed that tree response to chemical fertilizers undoubtedly depends on soil moisture, temperature, aeration, compaction and organic carbon content. Microbial activities are also governed based on these parameters. Distribution of micronutrients in mango orchard as a function of soil moisture and organic carbon content has been found significantly correlated in Dashehari mango orchard under subtropical conditions of Lucknow (9). The degree of variability of such nutrient dynamics appeared to be 41-82 per cent under different fertigation regimes. Tree density and species richness also have profound influence on the soil organic carbon and its stock variation.

Materials and Methods

A case study of high density mango plantation at CISH, Lucknow

Keeping in view the impact of orchard ecosystem on nutrient dynamics, its storage and utility for soil properties, a study was conducted at Central Institute for Sub-tropical Horticulture, Rehmankhera, Lucknow, Uttar Pradesh, in order to assess the spatial changes in soil properties, estimation of organic carbon and micronutrients stock under long-term orchard management system. The density plantation system of mango cv *Dashehari* was maintained since 1992 under subtropical climatic condition and six different spacing of 2.5 × 2.5, 2.5 × 5.0, 5.0 × 5.0, 5.0 × 7.5, 7.5 × 7.5 m and 10.0 ×10.0 m with 1600, 800, 400, 267, 177 and 100 plants per hectare respectively. The area under plantation of each density was 0.095, 0.1, 0.1, 0.105, 0.118 and 0.1 ha respectively.

Results and discussion

Soil physical components under high density system

It was observed that higher density plantations had higher bulk densities (1.49 to 1.53 g cm^{-3}) than normal density (1.36 g cm^{-3}) of 100 plants ha^{-1}. Compaction of soil under densely populated systems might have resulted in such higher BD. True density (particle density) varied from 2.45 to 2.69 g cm^{-3} across different plantation systems. Variations in porosity and water holding capacity (WHC) were also recorded (Fig. 1). In fact, variations in soil physical properties after 20 years of high density plantation systemsare expected because of the fact that soils have undergone continuous dynamic changes over space and time. Dynamics of organic matter content, tillage practices, water and nutrient management systems adopted, biological activities, climate etc. attributed to such changes. Biological activities near the root zone, compaction during tillage operations, wetting and drying phenomenon during the tree growing season contributes to the changes in BD and porosity by way of rearranging soil pore size distribution and total soil porosity as a function of soil particle movement.

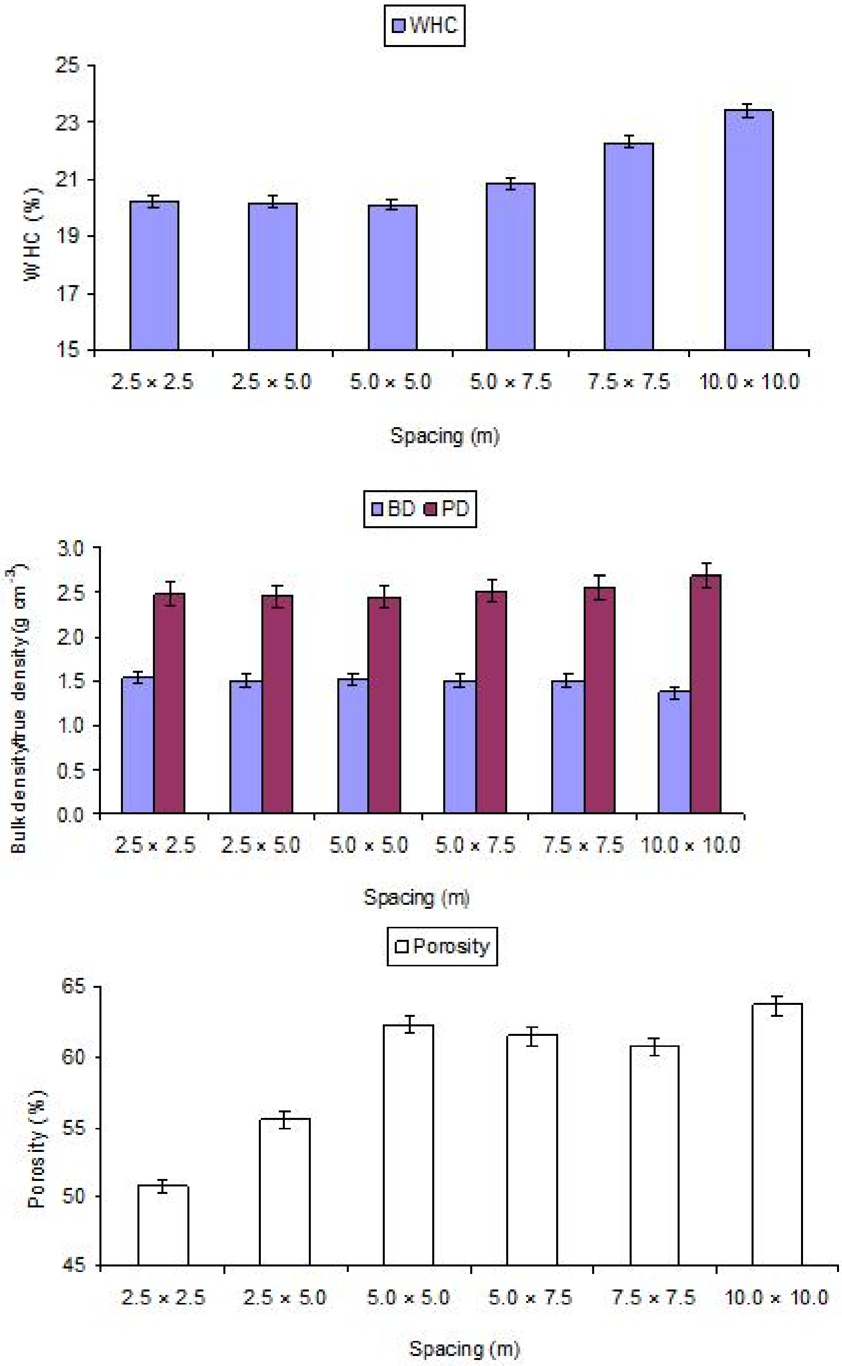
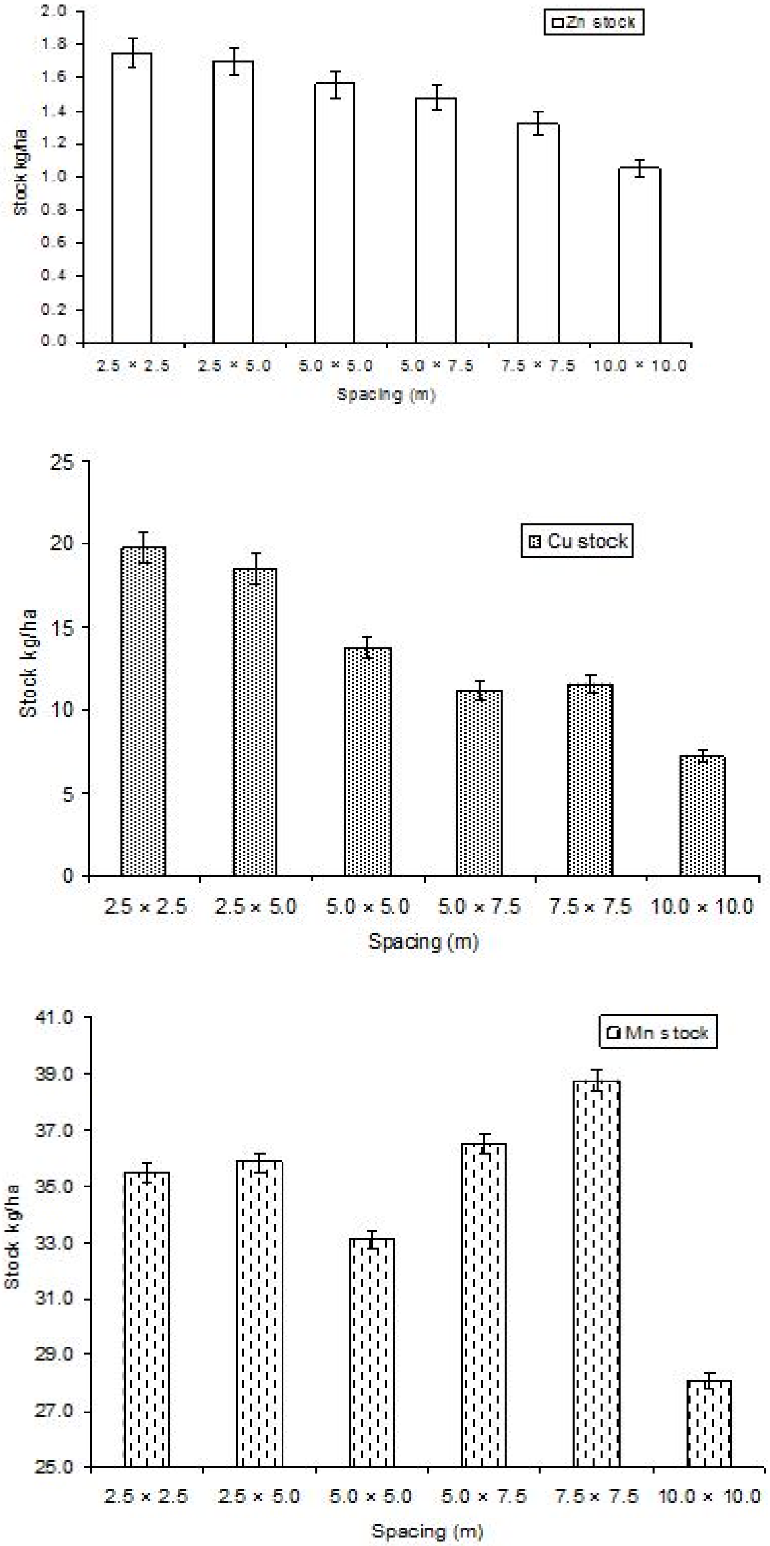


Fig. 1: Variations in soil physical properties across different mango plantation system

Micronutrient dynamics and stock variations under high density system

Micronutrients are essentially required for productivity and sustainability of quality production. Hence, apart from their availability in soil, storage in the system is also an important aspect. The present study indicates a significantly higher Zn stock in high density planting systems compared to a normal density system. A range of 1.32 to 1.75 kg ha^{-1} Zn stock was estimated among different high density planting systems whereas, the lowest (1.05 kg ha^{-1}) was recorded in normal (10.0 ×10.0 m) spacing (Fig. 2). Similarly, highest Cu stock was recorded as 19.75



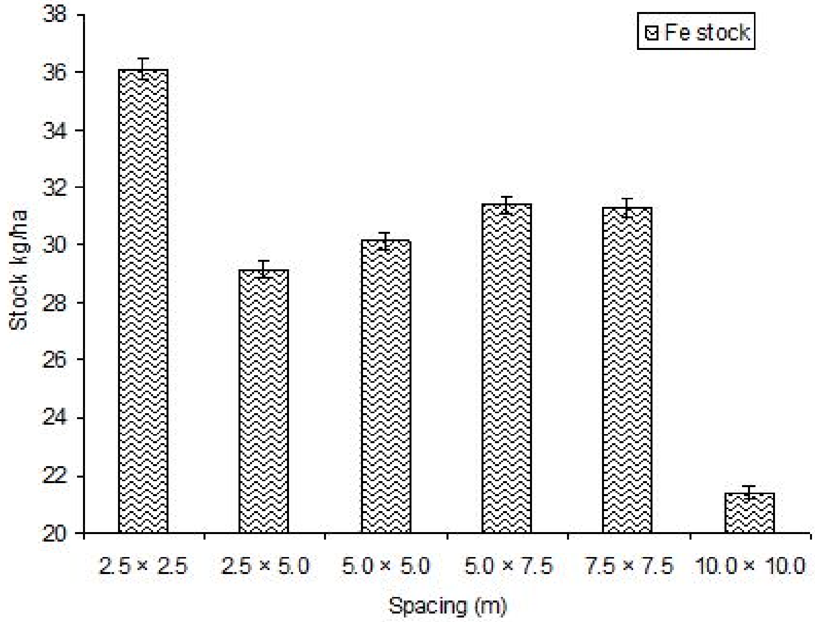
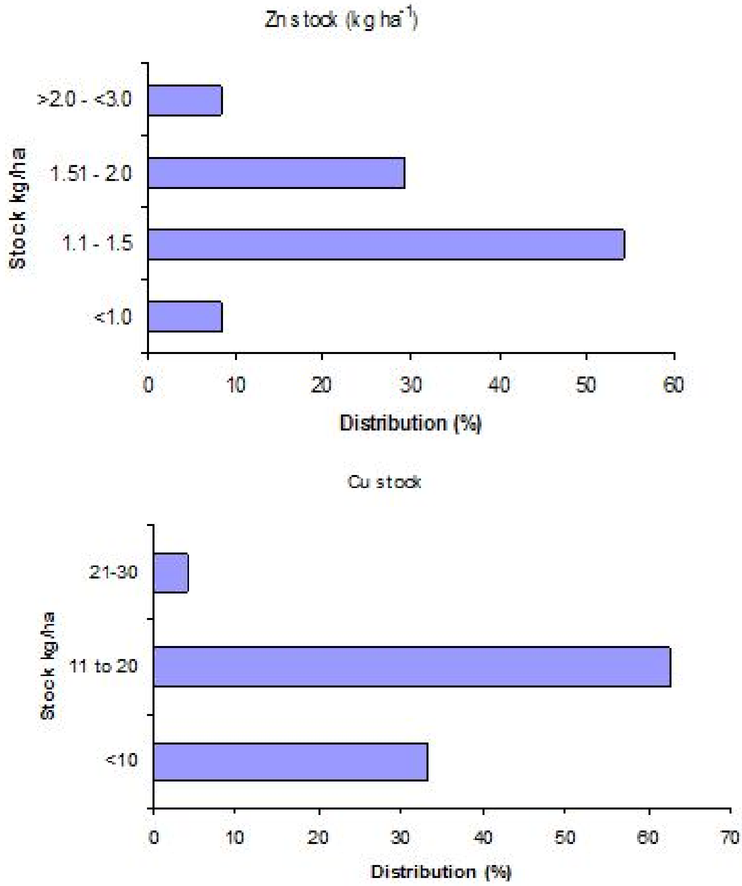


Fig 2: Estimation of micronutrient stocks in different mango plantation system under long-term orchard management

followed by 18.53, 13.73, 11.15 and 11.55 kg ha^{-1} intree density of 1600, 800, 400, 267 and 177 tree ha^{-1} respectively. However, Fe and Mn stock had a narrow range of 29.13 to 36.07 kg ha^{-1} and 33.07 to 38.75 kg ha^{-1} in densely populated mango orchard. Interestingly, out of total sample size, majority of the Zn stock lies in the range of 1.1 to 2.0 kg ha^{-1} category while 21 to 30 kg ha^{-1} Cu stock had lowestpercentage. A 21 to 40 kg ha^{-1} had highest percentage of Fe stock across different mango density system and Mn stock of 31 to 40 kg ha^{-1} (Fig. 3).



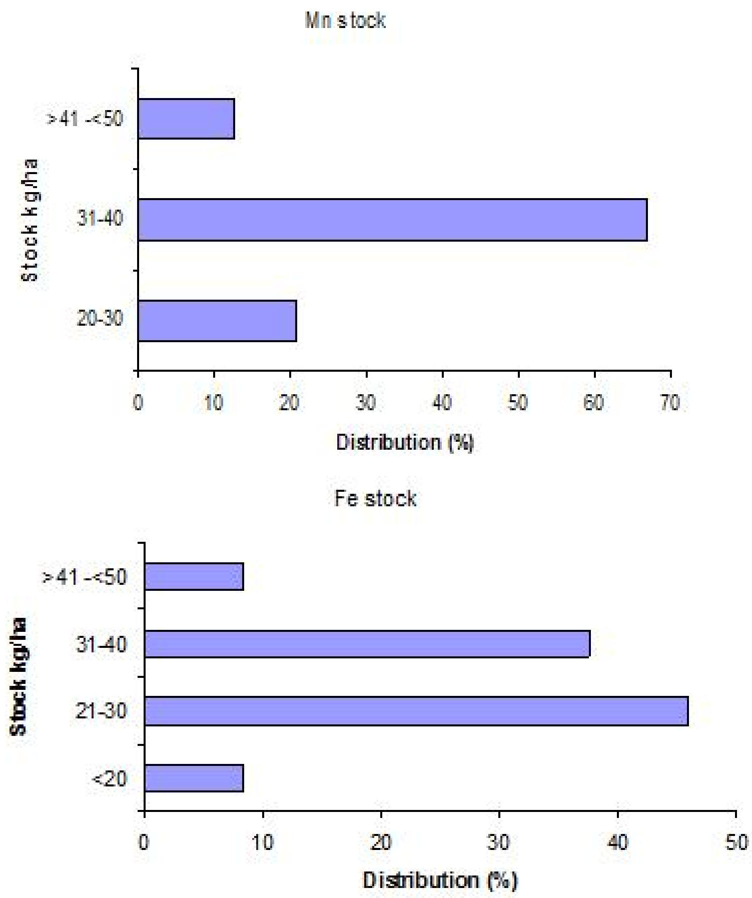


Fig. 3: Distribution of micronutrient stocks in different mango plantation system

Higher availability of micronutrient cations (Zn, Mn, Cu and Fe) in the tree rhizosphere was reported in high density systems. Micronutrient stocks have been found significantly higher in woodland land use system compared to annual crop cultivation system.

Soil organic carbon stock variations under high density system

Higher SOC content (0.37 to 0.52%) was observed in higher density plantations than normal density system (0.31%) possibly because of denser root system and leaf fall. The SOC content in medium density plantation (400 trees ha^{-1}) was 0.42 % (Table 1). A range of 4.15 ± 0.26 to 8.27 ± 0.12 Mg ha^{-1} SOC stock was estimated across different density systems with a 6.28 ± 0.36 Mg ha^{-1} in recommended medium density system. Majority (83%) of the soil samples had lower than 0.5% soil organic carbon with only 17 per cent found a place above critical level of 0.5% SOC (Fig. 4). Fifty per cent of the total soil samples were estimated to have SOC stock in the range of 6.1 to 9.0 Mg ha^{-1} followed by 33 per cent in 5.1 to 6.0 Mg ha^{-1} range. Variations in SOC stock were also revealed in tree plantations like poplar system which could sequester higher soil organic carbon of 6.07 Mg ha^{-1} $year^{-1}$ (first year of their plantation) as compared to 1.95-2.63 Mg ha^{-1} $year^{-1}$ (in subsequent years) in 0-30 cm profile. Moreover, an increase of SOC was noted from 3.8 Mg hm^{-2} in soils of open space to 19.5 Mg hm^{-2} under multipurpose trees after 16 years of plantations. Differences in vegetation cover, leaf litter fall, root activity, microbial decomposition etc. have profound influence on such kind of variations across scale of tree plantation system (10).

Table 1: Soil organic carbon and its stock under different density mango plantations

Tree spacing (m)	SOC content (%)	SOC stock (Mg ha^{-1})
2.5 × 2.5	0.52 ± 0.01	8.27 ± 0.12
2.5 × 5.0	0.45 ± 0.02	6.84 ± 0.20
5.0 × 5.0	0.42 ± 0.02	6.28 ± 0.36
5.0 × 7.5	0.39 ± 0.02	5.60 ± 0.37
7.5 × 7.5	0.37 ± 0.02	5.32 ± 0.22
10.0 × 10.0	0.31 ± 0.02	4.15 ± 0.26

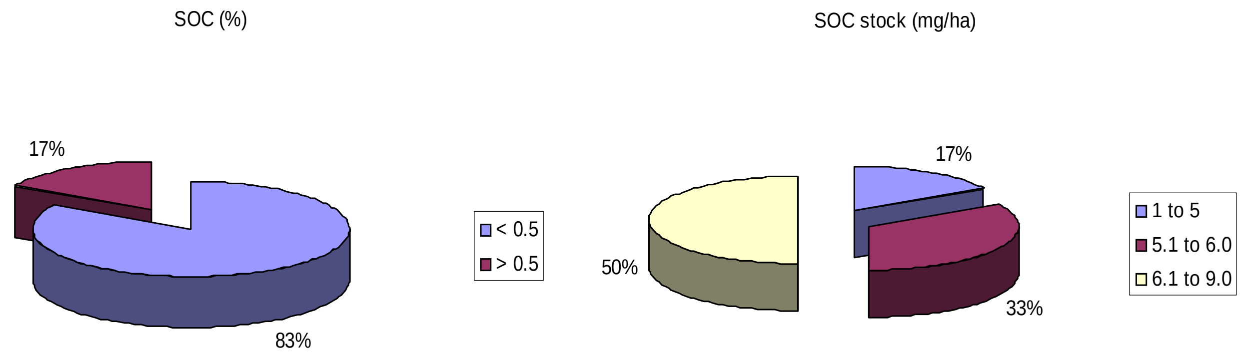


Fig. 4: Distribution of SOC and its stock in different mango plantation system under long-term orchard management

Conclusion

The present study indicates a wide variation in soil physical properties, organic carbon and micronutrients stocks under different density plantation system over space under long-term orchard management. An extended period of study is required to determine the above ground biomass quantity, microbial dynamics, root volume and biomass, changes in hydrothermal regimes in soil under long-term effects of plantation. Information about these factors would enable us to simulate the SOC stock and redefining our strategy for organic management and developing strategies for mitigation of negative impact of climate change.

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Author contributions

Dr. Tarun Adak, Kailash Kumar and Vinod Kumar Singh designed the study, conducted the experiments, collected data, and analyzed the soil samples. Dr. Tarun Adak analyzed the experimental data and wrote the manuscript. Dr. Kailash Kumar and V K Singh corrected and improved the manuscript. All authors read and approved the final manuscript.

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