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Review

SOIL HEALTH AND *ORGANIC COFFEE SYSTEM*
(Kesehatan Tanah dan Tanaman Kopi Organik)

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ABSTRAK

Tanah yang sehat adalah media tumbuh yang ideal untuk pertumbuhan tanaman, Namun di tanah juga berdiam berbagai jenis mikroorganisme penyebab penyakit pada tanaman (soil borne disease). Tanaman kopi adalah salah satu tanaman yang pertumbuhannya ikut dipengaruhi oleh hama dan penyakit tanaman. Agar dapat mengenal tanah yang sehat, diperlukan pengetahuan tentang karakteristik tanah dan prinsip pengelolaan tanah sehat menurut National Resources Conservation Service NRCS. Tulisan ini juga memuat sekelumit informasi tentang penyakit pada tanaman kopi yang disebabkan oleh mikrorganisme tanah, serta deskripsi tanaman kopi organik dan beberapa aspek budidayanya.

Kata kunci: Kesehatan tanah, penyakit pada tanaman yang berasal dari tanah, tanaman kopi

FAO (2018) defines soil as 'the natural medium for the growth of plants' (p.1). According to Natural Resources Conservation Service (NRCS) soil is a solid substance that is formed because of natural process in the upper earth surface. Soil is comprised of minerals, organic matter, liquid, and gaseous substances. Based on the analysis of soils composition, several soil common features like soil appearance, formation, stability, colour, chemical, biological, and physical properties are different from its main forming sources (FAO, 2018). Soil aggregates shape and size, aggregates stability and pores configuration are important factors that responsible for soil structure. A stable aggregate increase water absorption and reduce erosion whilst volatile aggregates are likely to dissolve. Moreover, aggregates stability is influenced by the type of clay and its chemical composition, the quality of decomposed substances and characteristic of microbial population. Furthermore, burrowing animals and the root growth systems altogether with environmental factors (e.g., freezing and thawing, drying, and wetting), are also determine aggregates stability.

Soil Definition and its Features

Soil Health

A healthy soil always supporting the life of terrestrial organism. Soils are the source of 90 % food production. In an ecosystem, soil existence is very dynamic. A healthy soil is part of the organic system which are characterized by its chemical, physical and biological features. Therefore, considering the soil usage and its location is vital since it enables the measurement of soil health, vitality, and bio productivity. This might also ensure its sustainability (Brevik, 2009).

Natural Resources Conservation Service (NRCS) lays the four principles of managing soils for health. The principles as follows as the diagram in figure 1.

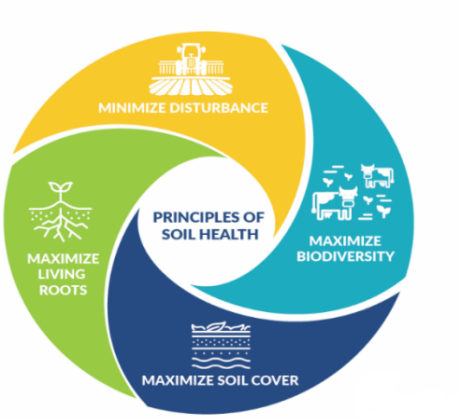

Figure 1. Principles to manage soil for health (NRCS)

Moreover, MacEwan (2007) in Murphy (2014) defined soil health as:

> *'Soil health is the condition of the soil in relation to its inherent (or potential) capability, to sustain biological productivity, maintain environmental quality, and promote plant and animal health. A healthy soil is productive, sustainable, and profitable.'*

In food chain, healthy soil promotes plant and animal health which consequently ensure human health. Villain (2018) states that organic farming allows a better management of soil health as it replace the use of synthetic fertilizers with animal and green manure and substitute pesticide with biocontrol agents.

It has been known that the amount of soil organic matter (SOM) affects soil health. In a sustainable agriculture system, an increasing in SOM lead to a healthier soil condition. Physically, an improvement in soil organic matter (SOM) will increase aggregate formation and its consistency which are consequently reduce soil erosion. In addition to SOM rising, aeration and water storage are more likely to increase simultaneously. However, root penetration tends to decrease. Nutrients such as nitrogen, sulphur and phosphor are derived from SOM. To be specific, a high level of SOM also enhances nutrient cycling. Under certain soil pH condition, the increasing in SOM boost cation exchange capacity (COC) and buffering capacity in soil which in turn makes fertilisation more efficient.

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Since various organism play vital role in creating a healthy soil and even causing disease to plant as well, then it is essential to maintain biological properties of the soils. While fungi and actinomycetes play their role in decomposing organic matter (OM) to soil organic matter (SOM), certain bacteria take part in a symbiotic relationship with plants, fixing nitrogen, including denitrification process as well as converting organic matter. Both termites and earthworm have capacity to form soil structures by digging and mixing soil hence enable nutrients to redistribute along the soil layers. Burrowing animals like rabbit, squirrel, gopher, and mice also play similar role while digging from upper layer to the lower part of soils vice versa thus creating more tunnels which are good for soil aeration (Murphy, 2015).

Soil-borne Disease

Soil can be a source of pest as well as disease to plants and animals. Soil-borne disease is a type of disease that is caused by pathogens or diseases causing agents that exist in soils and its residues in the soils surface (Villain, 2008). Disease causing agents in soils are including fungi, bacteria, actinomycetes, phytoplasmas, protozoa and viruses. Several higher organisms which have large body shape like nematodes, insects, slugs, snails, and rodents are also harbour disease to plants.

Majority of soil borne disease in plant is caused by fungi. There are two types of fungus action towards its host, namely: *Necrotrophs* (act by damaging hosts tissue) and *Hemibiotrophs* (living in the host as parasite for a long period of time to gain energy) (Murphy, 2015). Typically, the time length of soil disease causing agents are varied and limited by adequate biotic and abiotic environmental factors such as temperature, humidity, oxygen, and nutrients. Farming practices is also contributed to the soil function as pathogen reservoir. It is also known that competition between pathogen in obtaining available nutrients in soil and the existing host also affect pathogen life cycle (FAO, 2018).

Although with both the presence of susceptible host and adequate root exudates supply, a pathogen will grow and infect plants, in the absence of a host, most of it will be in inactive stage. Vascular, seedling and root rot disease are type of soil-borne pathogen which colonize plant roots that are not their main host without prompting obvious symptoms. During a half part of their life cycle, they occupy belowground organs and possibly reach the upper (Katan, 2017). Coffee plants are one of the agriculture crops which also susceptible to soil- borne pathogen. It is known that several pest and diseases might attack parts of the plant once it has an open wound that is caused by agricultural equipment such as machete during pruning or weed cleaning (Muller *et al*, 2009).

The Coffee Plant

1. *Description of coffee plants*

Coffee is one of important commodity for most countries in the world. Coffee grows in most of tropical countries. There are about 70 species grow mainly in the tropical region. While *Coffea arabica* contributed to 64 % of world coffee production, 35 % of world coffee production consists of *Coffea canephora* (Pohlan and Janssens, 2010). Moreover, Pohlan and Janssens (2010) describe that 'coffee is a plantation crop adapted to tropical highlands for *C. Arabica*, and to lowlands for *C. canephora*'. Coffee grows best at periodic rain fall interval and dry season not more than five months within a year.

2. *Origin of coffee plants*

Coffee is member of Rubiaceae family. The Rubiaceae family consist of 500 genus and approximately 6000 species. There are more than 100 species in genus *Coffea L.* and only *Coffea arabica* and *Coffea canephora* are intensively cultivated on a commercial basis. Coffea that has commercial value is cultivated originally in Africa. It is found that, *Coffea arabica* grows in the highlands in the South-west part of Ethiopia whereas *Coffee canephora* like robusta primarily grow in the West part of Congo basin and mostly in the lowland's areas with warm and wet climate such as in equator regions. Apart from the two well-known varieties, there are also two species of coffee which are rarely cultivated. They are *Coffea liberica* and *Coffea excelsa*. Based on their genetic features, these species are single complex. While *Coffea liberica* firstly grew in Liberia of West Africa, *Coffea excelsa* originated from dry land in Central Africa (Pohlan and Janssens, 2010).

Coffee Production System in General

1. *Typical plantation structure*

Coffee production can be varied between plantations. Araujo *et al*. (2009) states that 'in a coffee plantation system, the cycle of Four phases in the life cycle of coffee plantations can be differentiated: (i) seedbed and nursery establishment (5 to 12 months); (ii) planting and development of a young immature plantation (12 to 36 months); (iii) first production cycle (6 to 10 years depending on the pruning system used); (iv) rejuvenation and subsequent production cycles (4 to 10 years each).

In North America and The Caribbean, the young coffee trees are planted in the slope where rich nutrient soils derived from an active volcano. The coffee grows well with adequate rainfall and natural shade provide by the other plants and the usage of good quality varieties of Arabica coffee.

In Central America (Guatemala and Costa Rica), coffee is cultivated in volcanic soils where nutrients are plenty and totally affected by microclimates. Compared to Costa Rica, where coffee is wet-processed and run by smallholders, coffee production in Guatemala strongly influences by the rugged landscape with the altitude around 1370 MASL. Like Guatemala, coffee plantations in South America (Colombia and Brazil) are managed by a huge number of smallholders in rugged landscapes which makes it difficult to transport the harvest. As well as in Columbia, coffee in Brazil is produced in the large plantation where Arabica and Robusta are grown together.

In Ethiopia of East Africa, where the Arabica coffee comes from, the plantation areas including three regions: Sidamo, Harrar, and Kaffa, mostly in the highland where the altitude is 1100 – 2300 MASL, whereas in Kenya, the plantation is located in the Mount Kenya foothills. Apart from East Africa, Robusta coffee is produced in Ivory Coast of West Africa. Growing in arid land like in Yemen, coffee cultivation in the Arabian Peninsula is limited in the small terraces of family gardens, producing small size coffee cherries with asymmetric cherry shape.

As archipelagic country with warm climate, coffee from Indonesia very famous of its variety of taste. Several high-quality coffees including Arabica and Robusta are produced throughout the country (Sumatra, Sulawesi, Java, Bali, East Nusa Tenggara, and Papua). Like Indonesia, coffee production in Vietnam also operate in small farms in the Southern part of the country, although only limited for Robusta in the Southern part of the country.

2. *Shades*

The use of shade trees in coffee plantation is common and influence coffee production. According to Araujo *et al.* (2009) like in the beginning of traditional farming practices, the original coffee varieties will grow better under proper shade management. Furthermore, Pohlan and Janssens (2010) explain that 'Smallholder coffee production is often associated with various forms of shade management. It is well known that shaded coffee plantations are high in biodiversity and have some of the highest numbers and species of insects and migratory birds.

Another key point is the effect of shade on physical coffee quality and on cup quality of *Coffea arabica.*

3. *Propagation*

Coffee propagation can be done by seedling, cuttings, grafting and using tissue culture. The complete ripened berries that belong to the trees in the central block are used in seedlings to avoid cross pollination during seedlings. When the humidity is still high in the morning, and before lignification happen, the orthotropic shoots that has single node will be cut and stored in the propagator then planted in a pot for up to 3 months in the nursery. Grafting method only applied for C. *arabica* that vulnerable to nematodes and C. *liberica* which is more defiant to the same pest. Tissue culture is common to boost the growth of exclusive hybrids and clones. In general, there are three methods for producing new coffee plants, namely: axillary bud branching, shoot organogenesis, and somatic embryogenesis.

4. *Period of bearing*

It takes 3-4 years for the coffee tree to bear. According to Food and Agriculture Organisation (FAO), three to four years after planting, flowers grow in clusters in the axils of the coffee leaves. After fertilization, the subsequent fruit development is organized in five stages: (1) pinhead that spreads from 6 to 10 weeks after blossoming, (2) rapid swelling that takes place from 10 to 17 weeks, (3) suspended and slow growth that lasts about 2 weeks after the rapid swelling stage, (4) endosperm filling occurring 19–28 weeks, and (5) ripening stage that extends from 8 to 12 months after flowering`. It has been found that in most species, the time that is needed for flowering stage until ripening stage is from eight to twelve months. However, for the other clones, the time range is varied between 36-55 weeks. (http://www.coffeeresearch. org/ agriculture/harvesting.htm).

5. *Production life*

Like the other crops, growing coffee needs special requirements. The combination of environmental condition, both phenotype and genotype of species and farming practices are factors that involved in coffee production. The temperature for growing coffee also varies from 15-30^{o}C (Pohlan and Janssens, 2010). Moreover, Pohlan and Janssens (2010) showed that common farming practices in coffee plantation are separated into four stages: (i) seedlings and potting shed installation within 5 to 12 months; (ii) growing and expansion of infantile within 12-36 months; (iii) initial bearing period within 6-10 years which based on the pruning technique that are applied; (iv) regeneration followed with the next production period within 4-10 years. The regular cycle of a coffee plantation life are 20-25 years for conventional selection and 10-15 years for undersized selection that are grown in unshaded high-density population. Majority of farmers tend to gradually extend the duration.

6. *Harvesting*

Coffee is harvested annualy when the berries turn into solid and radiant sleek red.

In a multi harvesting system period (usually 2 to 5 times) in Columbia, the percentage of ripen cherry is varied between totally ripe, green, and dehydrated cherries. Therefore, coffee production cost increases. The common practice for harvesting coffee is using hand (picking and stripping), where both immature greenish as well as red coffee are gathered directly from the tree or using harvesting machine. (http://www.coffeeresearch.org/ agriculture/ harvesting.htm).

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