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Improving the BRIS Soil management and practices for growing roselle (*Hibiscus sabradiffa* L.)

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Abstract

Beach ridges with interspersed swales (BRIS), commonly referred to as BRIS soil or sandy soil, are extensively distributed along the eastern coast of Peninsular Malaysia. Despite the challenging nature of the lowland agricultural soil, characterised by its sandy texture and sterility, agricultural activities on BRIS soils have experienced an upward trend in recent times. The objective of this study was to conduct a literature review on the challenges and possibilities of roselle (*Hibiscus sabdariffa* L.) growth in the BRIS soil environment. Soil concerns can be classified into three categories: physical, chemical, and biological. The soil in BRIS is characterised by its acidic nature and low CEC values, with sand content occasionally reaching as high as 95 percent. Significant challenges associated with sandy soil conditions encompass soil water repellency (SWR), soil compaction, surface crust formation, soil erosion, low fertility, and Cation Exchange Capacity (CEC) value, as well as nutrient leaching into the groundwater, leading to pollution. The roselle plant is currently being commercially cultivated in the state of Terengganu as a substitute for tobacco in BRIS soil. This is due to the plant's exceptional aeration and deep root zone. However, owing to its diminished fertility, its output is restricted. This book concentrates on the challenges related to BRIS soil and environmental concerns, including issues such as inadequate nutrient levels, weak soil structure, and excessive drainage. This review comprehensively elucidates the management strategies for sandy soil in the context of agricultural operations and evolving climatic conditions, thereby contributing to the advancement of research on the prospective cultivation of roselle.

1. INTRODUCTION

The plant species *Hibiscus sabdariffa*, also referred to as roselle or red sorrel, is classified under the Malvaceae family. The plant species in question is indigenous to tropical areas and is extensively farmed for its diverse applications. The botanical specimen is widely recognised for its vividly coloured red calyxes, which have various applications in the fields of gastronomy, medicine, and aesthetics. It holds considerable significance across diverse industries. This substance finds application in the culinary sector both as a culinary component and as a constituent of beverages. The plant in question possesses medicinal attributes and is employed in the manufacturing of herbal infusions and nutritional additives. Moreover, it has various applications in industries such as cosmetics, skincare, textiles, and horticulture.

Effective soil management and practices play a pivotal role in the prosperous cultivation of roselle by ensuring the availability of optimal nutrients, appropriate soil pH, favourable soil structure, efficient water management, weed control, and the prevention of soil erosion. These factors collectively contribute to the promotion of healthy plant growth and increased yields. The utilisation of BRIS soil for the growth of roselle demands precise irrigation and fertiliser management due to the sandy soil's rough consistency and superior drainage. This is necessary in order to ensure the plant's health. On the other hand, it does come with a number of benefits, such as a reduction in the risk of waterlogging, the possibility of planting earlier, improved root growth, more favourable aeration, and faster procedures for harvesting.

1.1 Methodology

The methodology utilised in this review paper focuses on the collection of extensive information from diverse reputable sources in order to investigate the potential strategies for improving soil management and practises in the context of BRIS soil for the cultivation of roselle (*H. sabdariffa* L.). In order to accomplish this objective, a comprehensive review of the existing literature will be undertaken, encompassing a wide range of reputable scientific databases, academic journals, conference proceedings, and pertinent books. This review will include research articles published from the inception of the field up until the present time. The identification of relevant studies will involve the utilisation of keyword

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combinations such as "roselle cultivation," "*H. sabdariffa*," "soil management," "sustainable practices," "BRIS approach," and other related terms. The collected data will subsequently undergo a rigorous analysis, synthesis, and presentation in a logical and organised fashion. This will yield valuable insights and recommendations for enhancing soil management practices in BRIS, with the aim of promoting sustainable roselle cultivation and enhancing crop yields and agricultural productivity.

2. ROSELL CULTIVATION AND SOIL REQUIREMENT

2.1 Roselle (*Hibiscus sabdariffa* L.)

H. sabdariffa L., known as roselle, is a crop of an annual herbaceous shrub and a family member of Malvaceae, which grows well in the tropics and subtropics because of its high drought tolerance (Borrás-Linares et al., 2015). In Malaysia, roselle is normally called “Asam Paya”, where “Asam” means sour and “Paya” means swamp. Next, the other names are “Asam Kumbang” (sour beetle), and “Asam Susur” (sour-rail) or well known as “Ribena Malaysia” (Mohd-Esa et al., 2010). The calyces, leaves, and young shoots of the plant are harvested and consumed raw or prepared like vegetables.

Around the 1990s, roselle was commonly grown in Malaysian plantations. However, its planting has decreased because of too limited market demand, and most farmers have switched to other crops. Terengganu state used to be Malaysia's top roselle grower, with a planted area of roughly 12.8 hectares (ha) in 1993, but that number jumped to 506 ha in 2000 and less than 150 ha in 2003 (Sembok et al., 2015).

The roselle plant has attractive foliage and flowers and can grow up to 2 meters high. Many parts of the roselle, like the leaves, seeds, roots, and fruits are used in the pharmaceutical and food sectors. However, the fleshy, bright red-cup-like outer structure of the flower, known as the calyx, is the most economically valuable portion of the roselle (Dhar et al., 2015). The roselle calyces are water-soluble, with a sour and agreeable acidic taste, aiding digestion.

Furthermore, the calyx is the hibiscus plant's red-coloured pointed pods that support and protect the plant. Roselle calyx may be used to make jams and beverages, and it also has several health benefits, including the prevention of hypertension and diarrhoea (Cassol et al., 2019). Roselle is useful in animal feed, nutraceuticals, cosmetics and pharmaceuticals, in addition to its extensive use as a beverage and in the culinary business (Wang et al., 2012). Furthermore, due to its high pigment concentration, roselle calyx can be used as a natural source of food colourants, which leads to health benefits as it is a good antioxidant source. Hervert-Hernández and Goñi (2012) stated that dried calyces are used worldwide in cold drinks and hot infusions. The high quantities of protein, carbs, vitamin C, iron, beta-carotene, and polyphenols such as flavonoids in roselle contribute to its exceptional nutritional value (Alara and Abdurahman, 2019). The seed of roselle is regarded as a high-protein and antioxidant-rich food. Roselle seed is a good source of oil (21.1%), with oleic and linoleic acids being the primary unsaturated fatty acids (Eltayeib and Elaziz, 2014).

2.1.1 Morphology of roselle

Roselle is a plant that takes about six months to mature. Figure 1 depicts the morphological characteristics of roselles (Ansari, 2013). Leaves can be divided into three to five lobes. Furthermore, their length ranges from 8 to 15 cm, and they are alternately arranged on the stem. Young plants have simple leaves that become lobed alternating, stipulate, free lateral, red or green, and range in length from 0.5 cm to 1.0 cm.

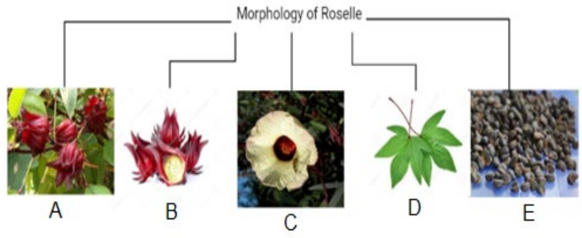

Figure 1: The morphology of the roselle plant. (A) Red fresh calyces; (B) Fruit; (C) Yellow flower; (D) Leaves; (E) Dark brown seeds.

Furthermore, each roselle flower's calyx lobe has two border ribs and a prominent central rib. The velvety and fleshy calyces are near the base of the flowers, where the flowers range in colour from white to pale yellow. The flowers are 8 to 10 cm in diameter, 1 to 2 cm wide, and grow to three to 3.5 cm, and each petal has a dark crimson mark at the base (Puro et al., 2014). The full fruits are bright red in hue. The hue of the petals can range from white to pink, orange, yellow, red, or purple. Roselle has piqued the interest of the beverage, food, and pharmaceutical industries due to its commercial potential as an indigenous food and colouring agent that can replace a few manufactured things (Eslaminejad and Zakaria, 2011). The stems are solid, unbranched, erect, cylindrical, typically bristling, rarely glabrous, green, red, or regimented in varying colours, and also grow to a height of 1 to 5 metres (Islam, 2019).

2.1.1 Nutritional value

Anthocyanins and protocatechuic acid are plentiful in roselle. The flavonoids gossypetine, hibiscetine, and sabdaretine can be found in dried calyces. Daphniphylline has been identified as the primary pigment, previously called hibiscine. There are also minimal numbers of myrtillin (delphinidin 3-monoglucoside), chrysanthemum (cyanidin 3-monoglucoside), and

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delphinidin. The seeds of roselle, particularly γ-tocopherol, are high in lipid-soluble antioxidants (Mohamed et al., 2012). The roselle calyces contain huge amounts of organic acids like citric acid, malic acid, tartaric acid, and hibiscus protocatechuic acid.

Besides, the acid content of calyces rises during growth but falls when they mature. The iron content of roselle calyces was more significant (164.78 mg/kg) (Maregesi et al., 2013). Minerals, particularly potassium and magnesium, are abundant in the plant. There were also significant levels of the vitamins such as niacin, ascorbic acid, and pyridoxine (Puro et al., 2014). Roselle contains a high vitamin C and anthocyanin concentration, making it unique in terms of nutritional value. Examples of anthocyanins in the roselle are cyanidin 3-sambubioside, delphinidin 3-glucoside, delphinidin 3-sambubioside, and cyanidin 3-glucoside. According to nutritionists, roselle calyces are abundant in calcium, potassium, magnesium, sodium, niacin, riboflavin, and iron.

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3. BRIS Soil management system

Soils have a unique role in agriculture, serving a variety of tasks for civilisation, including primary productivity. Soils perform multiple tasks simultaneously, and the level of functionality for each function is determined by soil formation factors, and physical, chemical, and biological soil features (Schulte et al., 2014). The capacity of soil to offer plant nutrients and water for supporting plant growth to provide food, fibre, and fuel for living beings is known as productivity (Sandén et al., 2019). Sustaining agricultural lands' fibre and food production capacity in the face of a growing global population poses serious concerns to some soil processes and ecosystem services (Barão et al., 2019). The cropping strategies used during agriculture, such as crop rotation, crop diversification, intercropping, and other agricultural approaches, have different geographical and temporal impacts on soil health and quality (Vukicevich et al., 2016).

Furthermore, as for the soil profile, the organic horizon has a high percentage of organic matter like plants, leaves, and dead animals. The coarse soil fraction is usually in the topsoil, while the subsoil is commonly dominated by very fine sand (Roslan et al., 2010). Furthermore, the topsoil layer is up to a depth of 30 cm, which may be taken as the greatest depth at which a farmer can cultivate and in which most of the plant roots are found, and it is a source of plant nutrientsre (Figure 2). The parent material layer lies above the bedrock, and this layer may accumulate more soluble compounds or inorganic material. According to the data presented in Table 1, it can be observed that each soil type exhibits distinct horizons within its soil profile.

Figure 2: Profiles of BRIS soil at Cherating Station, MARDI, and the adjacent remnant forest in Sungai Baging, Cherating District, Pahang State of Malaysia (04°04′N, 103°25′E) (Yusoff et al., 2017).

Table 1: A comprehensive soil profile by the presence of different horizons (Ishaq et al., 2014).

Soil Horizon	Category	Description
O	Organic (Litter layer)	The layer of roots, leaves, and decaying material
A	Topsoil	Organics mixed with mineral matter
B	Subsoil	Mixture of sand, clay and silt
C	Substratum	Unconsolidated parent material (loose)
R	Bedrock	Solid parent material or solid rock unweather

For soil quality, it is divided into three aspects: soil productivity, environmental quality, and natural health. As for soil productivity, the soil can improve biological production. For ecological quality, the earth can clear up environmental pollutants and germs, and the ability of soil to influence flora, fauna and human health is for physical health. Other than air and water, soil quality is also one of the environmental quality components (Andrews et al., 2002). The air and water quality are primarily determined by the amount of pollution they contain, which directly impacts human and animal consumption and health, as well as natural ecosystems.

On the other hand, soil quality typically acts as the capacity of soil to function within the ecosystem and land-use constraints to sustain biological productivity, maintain environmental quality, and promote plant and animal health rather than the degree of soil pollution. Quantitative analyses of soil chemical, physical, biological and markers can reflect the quality of the soil and ecosystem development status objectively and directly (Kiani et al., 2017; Valani et al., 2020; Çelik et al., 2021; Vasu et al., 2021).

3.1 Properties of BRIS Soil

Successful characterisation of BRIS soil physical, chemical, and biological aspects has enhanced the understanding of the ways and management of environmental and soil challenges in sandy soils. As a result of the categorisation, various features of sandy soils have been examined over the last few decades (Figure 3). According to Hengl et al. (2017), sandy soils have an average content of sand larger than 50%, and the content of clay soils is smaller than 20% to a depth of 30 cm. This sandy soil is distinguished by its grain size, little clay concentration, and predominance of coarse particles. The lack of clay in soils decreases the physical protection of organic compounds, speeding up the pace of disintegration.

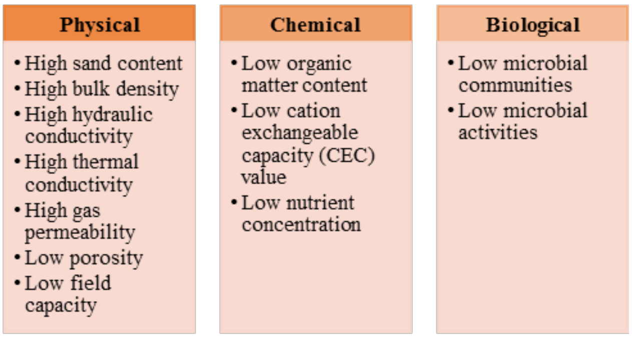

Figure 3: The properties of physical, chemical and biological in BRIS soils.

The large sand particles dominate soils, which do have large pore spaces and consequently high saturated hydraulic conductivity levels, higher bulk density, and high thermal conductivity. The infiltration rate of soil may be used to estimate its permeability. Wide pore pores in sand-textured soils enable rainfall to move rapidly through the soil. Sandy soils are recognised for their high permeability, which promotes high drainage and infiltration. Soil porosity represents the number of pores in the soil. It has an impact on water circulation and air. In healthy soils, there are many holes between and within the aggregates. Sandy soils are much more susceptible to changes in water intake, such as irrigation and precipitation, and outflow, such as evapotranspiration, since they have a lower porosity than other soils (Fernandez-Illescas et al., 2001). Next, the capacity of the field is low due to its low water storage capacity. The amount of moisture in the soil or water content held in the soil is referred to as field capacity.

Furthermore, as for the chemical properties of sandy soils, they have low organic matter content, low concentrations of nutrients, and low CEC values. Because of the huge particles in sandy soils, they dry up rapidly, are typically deficient in nutrients, and are acidic (Sheoran et al., 2010). Water and fertilizer both tend to leach from the soil, escaping into waterways before the plants can use them. Because sand appears to have no electrical charge, it is incapable of exchanging cations. This shows that adding organic matter to sandy soils with low CEC, such as podzolic topsoils, potentially improves their performance. In addition, because sandy soils have poor buffering capacity, plants significantly impact their characteristics and microbial populations more than other soils. For example, a previous study investigated the impacts of mangrove vegetation microbial communities on the soil in coastal sandy soils and discovered that natural mangrove vegetation had higher counts of bacterial and total fungal than non-mangrove coastal sandy soils (Saravanakumar et al., 2018).

One of the essential variables influencing soil properties is fertilisation. In addition to improving soil nutrition management, fertilizer nutrients control the soil's biological, chemical, and physical aspects (Ge et al., 2018). Sandy soils are frequently deficient in nutrients, organic matter adsorption capacities, and the production of soil aggregates, all of which are exacerbated by their low water-retention capacity.

3.1.1 Soil Water Repellency (SWR)

Water-repellent soil is a soil surface feature induced by hydrophobic compounds, and it can occur in soils varying in texture from clay to sand (Lichner et al., 2012; Mao et al., 2016). Soil hydrophobicity refers to the ability of some soils to reject water, and the plant community may play a part in its growth. Generally, soil water repellency (SWR) is strongest in eucalyptus woods, followed by pine forests, grassland, and scrub, with plant roots inducing greater SWR than leaf waxes owing to phenolic materials and levels of high humic (Flores-Mangual et al., 2013). SWR frequently occurs in sandy soils because they have a limited specific surface area. It is also because they are more prone to water repellency than silt or clay because it requires a less hydrophobic substance to coat individual particles. The amount of soil particles with a hydrophobic surface covering determines the level of repellent. Thus, because sandy soils have the smallest surface area, a hydrophobic surface will affect a greater proportion of particles than loamy or clayey soil.

Moreover, SWR necessitates a furnish of hydrophobic organic matter from the biosphere, and interactions among the hydrophobic organic material and the lithosphere's surface organic. The physical features determine the hydrophobic phenomenon's strength and endurance (Uddin et al., 2019). Hydrophobic chemicals can come from surface waxes from plant leaves, plant root exudates, decomposing organic matter, and fungal species, thus generating SWR (Hallett, 2008). When these compounds are present in the soil, they can react with the mineral grains, generating aggregates held together by weak bonding processes such as hydrogen bonding, π-bonding, van der Waals forces, and hydrophobic interactions, resulting in membrane-like structures. These waxy coats effectively reject water from the soil, decreasing the amount of water available to the crop.

Besides, SWR influences both water and wind erosion because it creates easily transportable loose particles (Cawson et al., 2016). The main factor of SWR is controlled by the soil's surface area, which differs significantly depending on the texture of the soil. Other than that, the different factors that impact soil water

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repellency include soil moisture conditions, climate, fire, vegetation, pH, and organic compound polarity. When the soil is moist, the materials are frequently poorly linked and hydrophilic, but the highly bound hydrophobic surfaces are exposed when the soil dries. SWR increases as Ph decreases, possibly due to higher humic acid concentrations (Mao et al., 2016).

3.1.2 Soil compaction

When soil particles are forced together, the pore space between them is reduced, resulting in soil compaction (Figure 4). Soil compaction caused by agricultural usage poses a substantial danger to crop productivity and the soil's ecological functions and has a significant economic impact (Tim Chamen et al., 2015; Schjønning et al., 2015). It limits the plant’s root growth by increasing the soil bulk density, reducing root penetration, also reducing air and water permeability (Bengough et al., 2011; Lipiec et al., 2012; Szatanik-Kloc et al., 2018). By raising the bulk density of the soil, the compaction decreases the connectivity and volume of the soil pore network. Soil compaction in arable systems is a global environmental concern due to agricultural modernisation and, in particular, increases in machinery weight. According to Chen and Weil (2010), soil compaction can obstruct water and air movement, root penetration, and seedling emergence.

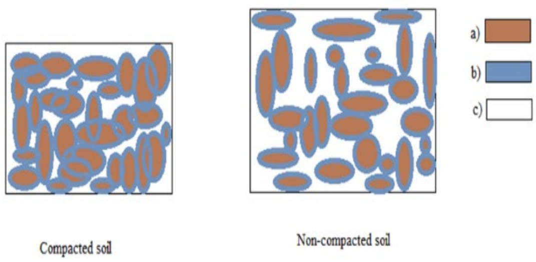

Figure 4 : Compacted soil and non-compacted soil. (a) Soil solid; (b) Water; (c) Air.

Sandy soils are less resistant to compaction than soils with more organic matter, clay content, and water content (Gregory et al., 2007). Compaction selectively reduces macropores by changing the morphology of the pore from complex to homogeneous and the pore alignment from vertical to parallel to the surface of the soil, resulting in a negative increase in water retention. Biological disturbance and tillage, such as grazing, can simply compact the macropores of sandy soils. The sandy soils’ porosity can also be squeezed by rearranging the silt and sand among the clays because of weak cohesive connections among silt and sand particles.

Compared to the organic and clayey soils, the sandy soil type has lower resistance and it is hard to return to its original form after compacting (de Andrade Bonetti et al., 2017). Compaction of sandy soils may result in a hard setting, hard to cultivate when dry and structureless. Hard-setting conditions are found all over the world and also have a higher soil strength that prevents root development and shoots emergence. Silica flowers and globules covering sand grains formed by the precipitation of silica can increase particle interactions and friction rather than cementation, resulting in greater soil strength in sandy soils. Thus, due to the sandy soils’ high permeability, limited capacity of the field, and prone to nutrient leaching, the modest depth of compaction can enhance water retention and boost nutrient and water efficiency.

3.1.3 Soil erosion and surface crust

Soil erosion is a critical environmental issue worldwide, according to Pi and Sharratt (2017), especially in areas where human activities have a large impact on ecosystems. It is one of the most important geomorphological processes that have an impact on land degradation rates and environmental sustainability. Aside from that, the soil crust is a thin layer of a hard, resistant material that covers the soil's surface. The soil crust is substantially more compact and packed than the underlying layer. A soil crust seems smooth and even when compared to freshly exposed dirt. Rainfall impact on exposed soil is the primary cause of soil crusting. Erosion crusts form when structural crusts' upper layers are eroded, whereas depositional crusts form when microscopic particles settle. Sandy soils benefit from crust formation because it reduces or prevents wind erosion. The crusting surface is widespread in sandy soils due to the little aggregate stability of material that is affected by feeble cohesive forces.

Furthermore, crusts are divided into three categories: chemical, physical, and biological crusts. The first is chemical crusts, which are formed on arid or semi-arid soils as a result of encrusted salt. Biological crusts form when ponded water stands and retreats on low-permeability soils, and the primary cause is algal development. Physical crusts can be classified as structural or depositional and form as a result of surface soil structural degradation. It has been established that the biological crusts play a significant part in desert restoration (Li et al., 2010). In desert places, the regeneration of forest trees has been used to manage water and soil erosion (Zhang et al., 2015; Liu et al., 2018). A crust may lower infiltration rates, resulting in overland flow and surface runoff and a higher risk of rill and gully erosion.

3.2 Challenges in improving BRIS Soil quality

Chemical, physical, and biological fertility are lower in sandy soils than in fine-grained soils. Aside from that, sandy soils have fewer surface areas, meaning less water is tightly bound to soil particles, resulting in hygroscopic water due to a lack of organic matter, low clay content, and limited water-holding capacity (Karami et al., 2012; Yilmaz and Sönmez, 2017). Sandy soils face several

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issues, including low soil fertility, low CEC value, and nutrient leakage, which lead to groundwater contamination.

3.2.1 Cation exchange capacity (CEC) and soil fertility

The capability of soil and other solid materials to adsorb exchangeable cations is known as cation exchange capacity (CEC) (Lago et al., 2021). It is a vital soil fertility measure for supplying nutrients to the plant while decreasing nutrient leaching (Xu et al., 2016). Calcium (Ca2+), potassium (K+), magnesium (Mg2+), hydrogen (H+), sodium (Na+), iron (Fe2+), aluminium (Al3+), zinc (Zn2+), copper (Cu2+), and manganese (Mn2+) are all positively charged ions. The negatively charged organic matter particles and clay were held in the soil through the electrostatic forces where the negative soil particles would attract the positive cations.

The CEC value is low for sandy soils because the sand has no electrical charge; thus, there is no ability to exchange the cations. Due to extensive weathering processes and age, highly weathered soils have inherently low CEC and fertility levels, making them prone to phosphate fixation, low nutrients, and high acidity (Lopes and Guimarães Guilherme, 2016; Xu et al., 2016). The prevalence of iron, kaolinitic clays, and aluminium oxides, which are low-chemical-activity clay colloids with little organic matter content, is linked to the low CEC in soils (Xu et al., 2016).

The fertility of soil and CEC are both poor in sandy soils. Sandy soil fertility is influenced by environmental conditions, such as soil organic matter (SOM), fire occurrences, and land use and management, which are some of these determinants (Tye et al., 2013; Gruba and Mulder, 2015; Ulery et al., 2017). During heavy burning, significant loss of SOM and the change of phyllosilicates may result in decreased CEC in the surface soil, which is especially noticeable in sandy soils.

3.2.2 Nutrient Leaching Contamination of Groundwater

Di and Cameron (2002) stated that nutrients might be leached after a downward water flow has been established in the soil. Examples of nutrients are nitrate and phosphorus. Nutrient leaching may lead to groundwater contamination in areas where extensive agriculture is done. Acidity in the soil can be caused by nitrate leaching. The nutrient leaching problem is worst in places with strong rainfall and sandy soils. Nutrient retention is limited in sandy soils, and about 20 to 80 per cent of an applied chemical or nutrients will leak into surface water and ground (Manevski et al., 2015). Loss of nutrients is greater in sandy soils than in fine-textured soils, except if the soils are compacted or the soil profile does have a discontinuity in texture that reduces percolation.

The factors that lead to nitrate leaching include the condition of soil moisture, climate, topography, soil texture (Li et al., 2018), the use of land (Koutika et al., 2014; Manninen et al., 2018), the modes of nitrogen fertiliser, demand harvest nitrogen, time of application (Shrestha et al., 2010; Fujii et al., 2013), and also microbes (Köhl and van der Heijden, 2016). The rates of nitrate leaching are expected to be boosted by a wetter environment, higher soil moisture levels, and a coarser soil structure. For instance, in the Netherlands, nitrate leaching was more significant in the agricultural regions than in the heath forest due to the increased nitrogen load caused by extensive animal husbandry. In a study worldwide, rates of nitrate leaching across dissimilar systems of land use were discovered to have the greatest probability of nitrate leaching, followed by cropland, ploughed pasture, woodland, grazed pasture, and cut grassland (Di and Cameron, 2002). Fanelli and Rothstein (2017) discovered decreased nitrate leaching and rates of nitrification in jack pine forest soils when wildfires were suppressed through whole-tree removal.

Next, Oliveira and Machado (2013) stated that eutrophication caused by manure and phosphorus fertilisers leaching had become a global environmental problem. Compared to other soils, sandy soils have lower phosphorus concentrations and require lower fertilisation rates (Martins et al., 2018). In these classes of soil texture, which are loamy sand, sandy loam, and loams, the insoluble phosphorus leaching rates decreased by increasing the content of sand, most likely because of the breakdown of soil aggregates as in the manual soil sample method (Glæsner et al., 2011). Enhancing phosphorus-use performance is usually vital due to surface water eutrophication and the global scarcity of mineral phosphorus sources, such as phosphate rocks. Phosphate rock production is likely to peak around 2030 to 2040, owing to a rising world population and phosphorus demand. The cost of phosphorus production is estimated to increase (Oliveira and Machado, 2013).

3.3 BRIS Techniques and Strategies for Roselle Cultivation

Best management practices (BMPs) are cultural practices that strive to reduce a load of nutrients while maintaining or improving productivity. It has been claimed that BMPs can enhance sandy soils' physical, chemical, and biological characteristics. As for the example, in Nottinghamshire, UK, the regional shift in fertilisation of soil of sandy soil where they discovered that the soil under woodland had an acidic pH, low base cations concentration, and moderately high soil organic carbon (SOC), which is 2.7% at 0 to 15 cm (Tye et al., 2013).

Moreover, the soil under the arable land had a neutral pH, a high base cation concentration, and a lower SOC of 1.7% (Tye et al., 2013). Hungary (Demeter et al.,

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2018), Australia (Huang et al., 2018), and the USA (Huang et al., 2019) also reported similar results where the management of land practices has enhanced the fertility of the sandy soil over time, especially the pH and SOC concentration. Thus, using soil ameliorants, nutrient management and irrigation, conservation, decreased tillage and no-till, and crop residue control areas are all examples of management methods. The BMPs, benefits, and challenges of BMPs in sandy soils are shown in Table 2.

Table 2: Best management practices (BMPs), benefits and challenges of BMPs in sandy soils.

Best management practices (BMPs) in sandy soil	Benefits	Challenges of the BMPs	References
Soil additives like clay, biochar, surfactant	Improve the physical characteristics Enhance infiltration for water-repellent	Too expensive Not relevant to a big region	(Abagandura et al., 2021)
Management of nutrient sources	Increase efficiency of nutrient utilisation	Time-consuming	(He et al., 2012)
Irrigation control	Increase efficiency of water consumption	Too expensive Time-consuming Precision irrigation's efficacy is difficult to prove	(Liang et al., 2016)
Conservation tillage, reduced tillage, and no-till farming	Enhance the physical condition of the soil Improve carbon sequestration	Minimal impacts on soil carbon sequestration	(Mangalassery et al., 2014)
Management of crop residues	Reduce erosion of soils and evapotranspiration Improve the efficiency of nutrient usage	Few research on the dynamics of the water cycle	(Chinyama et al., 2019)

In addition, the use of organic and inorganic fertilisers and irrigation is needed to preserve crop productivity in sandy soils (Kraft et al., 2012). Organic fertilisers are an essential source of organic matter, productivity, and aggregate stability in the soil. Fertilisers are an important part of the agricultural and crop production processes. Crop production includes all operations, reserves, and nutrient flows connected with the production of arable crops, such as feed, horticultural, fruit and vegetables, and grasslands (van der Wiel et al., 2019). Cropping systems, such as crop rotation, crop diversification, intercropping, and related agronomic approaches employed in agriculture, have various geographical and temporal effects on soil quality and soil health (Vukicevich et al., 2016).

4. CONCLUSION AND FUTURE DIRECTION

In summary, this research review investigated the soil management techniques and practices employed for BRIS soil for the cultivation of roselle. Through an extensive review of literature and consultation with experts, we acquired knowledge regarding the challenges associated with roselle cultivation and strategies for enhancing soil management practices.

The success of roselle cultivation is contingent upon the prioritisation of sustainable farming practices that emphasise soil health and resilience. The use of BRIS soil in roselle cultivation provides advantageous outcomes for growers, as it effectively harmonises ecological, social, and economic considerations within the agricultural domain. The implementation of cover cropping, organic matter absorption, and precision irrigation techniques has been found to enhance soil structure, nitrogen retention, and water-use efficiency, thereby resulting in significant improvements in roselle growth and yield.

The utilisation of cutting-edge technologies and precision agricultural instruments has the potential to enhance soil management practices. The utilisation of data-driven insights and real-time monitoring enables farmers to customise their agricultural practices to suit the specific needs of their roselle crops and the prevailing environmental conditions in their local area.

In summary, the successful cultivation of roselle necessitates the implementation of a comprehensive soil management technique that is both environmentally sustainable and economically viable.

However, it is important to note that every agricultural environment presents unique challenges and opportunities. Therefore, it is imperative to engage in ongoing research and foster collaboration among academia, policymakers, and farmers in order to enhance the effectiveness of BRIS soil management practices across diverse geographical areas.

This review elucidates the significance of soil management and practices in roselle farming. Through the implementation of these sustainable practices, it is possible to establish an agriculture system that is both resilient and equitable. This system would effectively guarantee a sustainable supply of roselle, while also promoting long-term food security and economic prosperity.

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