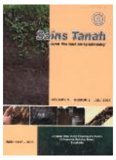
SAINS TANAH – Journal of Soil Science and Agroclimatology

Journal homepage: http://jurnal.uns.ac.id/tanah



Sweet potato is a strategic root crop in Oceania: A synthesis of the past research and future direction

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ARTICLE INFO

Keywords:
Climate change
Cultural practices
Food and nutritional security
Oceania
Sweet potato

Article history
Submitted: 2022-10-08
Accepted: 2023-04-07
Available online: 2023-06-16
Published regularly:
June 2023

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ABSTRACT

Sweet potato is an important food, industrial, and pharmaceutical crop worldwide and highly adapted to adverse ranges of agroclimatic conditions, making it one of the strategic crops under climate change. Despite the importance, sustainable crop production continues to be an issue because of the pressure put on land, the decline in soil fertility, the buildup of pests and diseases, and no standardized production practices. Production is highly mechanized in temperate regions, whereas, in the tropics, it is still a subsistence crop confined to subsistence farming systems. These issues are compounded by a lack of generically and agronomically improved genotypes adapted to wider agroecological zones with adaptive tolerance to existing and new stresses. In the recent past, significant progress has been made worldwide; however, the outcomes tend to be locality-specific, and cannot be extrapolated, needing decentralization of the current approaches. This review points out that the crop is a critical strategic crop in the Oceania region because of its ability to grow under adverse ranges of agroclimatic conditions and can produce a reasonable yield. The paper continues to emphasize the current trends in emerging modern technology that can be used to efficiently improve and enhance traits of agronomic importance and wider adaptivity. In addition, land use plans, farming systems, and cultural production practices need to be changed for sustainable production. The need for these is further strengthened by pointing out alternative strategies, e.g., using organic matter as a relatively cheap and readily available source of soil nutrients compared to inorganic fertilizers.

How to Cite: Peter, T.M, Michael, P.S. (2023). Sweet potato is a strategic root crop in Oceania: A synthesis of the past research and future direction [Review]. Sains Tanah Journal of Soil Science and Agroclimatology, 20(1): 51-65. https://dx.doi.org/10.20961/stjssa.v20i1.66319

1. INTRODUCTION

Sweet potato (*Ipomoea batatas*) is a root crop and the 7th most important after rice, wheat, potato, maize, and cassava, supporting millions of people around the globe (Clark et al., 2012). The sweet potato (here after SP) is significantly a vital staple food (Michael, 2020c), a fodder, industrial, and pharmaceutical crop around the globe. Nutritionally, SP is a high-energy food, and a 100 g produces 113 calories of energy compared to 75 for potatoes (*Solanum tuberosum*). The roots contain 25-30% carbohydrate, of which 98% is digestible (Villordon et al., 2013) and that the content decreases within the first 60 days of storage. The roots and the leaves are essential sources of nutrients and vitamins (Motsa et al., 2015). The leaves contain vitamins C (7.2 mg), B complexes (thiamin, riboflavin, and niacin), E (1.6 mg), and K (0.6 mg). The protein content on a dry matter basis is 2.5 – 7.5% for roots and 25.8 – 29.8% for the leaves (Table 1). Similarly, the leaf's protein, Ca, and Fe contents are higher than the roots, pointing out the importance of fodder for livestock (Motsa et al., 2015).

Pharmaceutically, SP has been exploited for medicinal purposes (Islam, 2014) and is essential for the regulation of blood sugar due to the high fiber content and its effect on adiponectin levels in the blood, which affects carbohydrate and insulin levels. The glycemic index (GI) ranking is 63±6, essential for managing type 2 diabetes mellitus. The Glycemic index ranking is lowest in boiled compared to baking and roasting values. The high anthocyanin (peonidin and cyanidin) is essential for antioxidants and anti-inflammation effects (Mu et al., 2021).

Table 1. Nutritional importance (Villordon et al., 2013)

Content in roots (mg 100 g^{-1})								Content in leaves (mg 100 g^{-1})							
Cab.	Pro.	Vit.	P	K	Ca	Mg	Fe	Cab.	Pro.	Vit	P	K	Ca	Mg	Fe
98	7.5	30	49	340	30	24	0.8		29.8	7.2			117		1.8

Remarks: Cab., Pro., and Vit. are carbohydrates, proteins, and, vitamins, respectively. The values for carbohydrates and proteins are in the percentage of dry matter

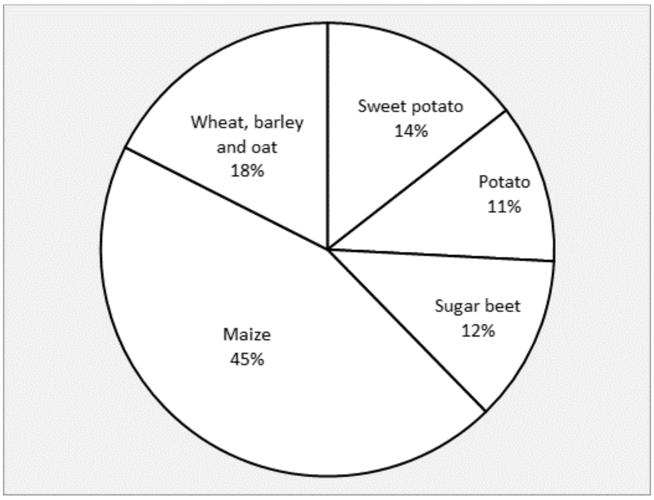

Figure 1. The industrial importance of SP in ethanol production (Villordon et al., 2013)

One study reported 15 anthocyanin and six polyphenolic compounds that are pharmaceutically important as antioxidants, antimutagenic, anti-inflammatory, anticarcinogenic, antibacterial, and antidiabetic effects. The protein content is 80% sporamine, an antioxidant inhibitor of trypsin, essential for livestock when fed as fodder. Villordon et al. (2013) showed that the protein's lysine content is higher than in rice but low in leucine.

Industrial utilization is not entirely familiar in a global scenario, and SP has sufficient starch for industrial uses for ethanol production (Fig. 1), biofuel, and other products (Chen et al., 2013). In China, Japan, and South Korea, nearly 63% of SP produced is used for starch extraction for ethanol production. Villordon et al. (2013) pointed out that SP is essential for ethanol production compared to potato, sugar beet, maize and wheat, barley, and oat combined (Fig. 1). In the USA (Alabama and Maryland), ethanol yields in cubic meters per hectare is near 6.4 for SP, 2.8 for maize, and 4.0 for cassava (Villordon et al., 2013).

As part of ongoing research in SP production management in PNG, this review aims to emphasize the importance of SP as a strategic crop to address food and nutritional security under climate change in the Oceania region because of its ability to grow under a range of adverse agroclimatic conditions (Kismul et al., 2014). The second aim is to point out future research directions and the underlying need for crop genetic improvement, particularly in Oceania and West Papua (Indonesia), where more than 99 percent of the people depend either on SP alone or on a few root and tuber crops, namely cassava and taro.

2. METHODOLOGY

This study of SP in Oceania involves a systematic review of existing literature related to SP cultivation in the Oceania region. The methodology includes conducting a comprehensive search of academic databases, research repositories, and grey literature to identify relevant studies. The search terms will be carefully selected to capture all the relevant publications on SP cultivation, including the geographical area of Oceania.

Once the relevant literature is identified, the study will thoroughly review the content, including the study design, methodology, and findings. A qualitative analysis approach will be used to synthesize the results of the studies and identify key themes and patterns. The analysis will be guided by a set of pre-defined research questions, such as the historical significance of SP in Oceania, the diversity of SP cultivars and their associated traits, and the impact of environmental factors on SP cultivation in Oceania.

The study will also identify gaps in existing knowledge and highlight potential avenues for future research, including the use of artificial intelligence and machine learning in SP cultivation, the impact of climate change on SP cultivation in Oceania, and the socio-economic factors that influence the adoption and success of SP farming in the region. Overall, the study aims to provide a comprehensive overview of the past research on SP in Oceania and to identify future research directions that could improve the sustainability and productivity of SP cultivation in the region.

3. Origin, domestication, and dispersal

Sweet potato is a dicotyledonous plant belonging to the morning glory family (Convolvulaceae) and the genus *Ipomoea* (Agili et al., 2012). *I. batatas* is known to have evolved from two autopolyploidization events in the wild population of a single progenitor species, *I. trifida*. The origin and domestication were in Central or South America, and the domesticated SP was present in Central America for at least 5000 years. The origin of the *I. batatas* is somewhere between the Yucatan Peninsula in Mexico and the mouth of the Orinoco River in Venezuela around 3000 BC. In Peru, SP remains to date back to 8000 BC, but a lower molecular diversity in the Peru-Ecuador region is evident. Analysis conducted using molecular markers confirms Central America as the region of genetic diversity and origin.

The local people spread the cultigen to the Caribbean and South America in 2500 BCE. The dispersal of SP from the Americas to the neighboring Pacific islands might have happened well before the arrival of humans (Muñoz-Rodríguez et al., 2018). The crop was growing in Polynesia well before the arrival of Westerners (Roullier, Kambouo, et al., 2013) and has been radio-carbonated from 1210-1400 in the Cook Islands. The crop spread across Polynesia, then to Easter Island (1526) and Hawaii (1635), and there is a suggestion that it was as early as 1 AD to New Zealand (800 – 1500 AD). There is a second suggestion that the SP may have been introduced to New Zealand between 1250 – 1300 AD. SP was introduced to PNG from Indonesia between 1600 – 1700 (Roullier, Kambouo, et al., 2013) and to Fiji, Tonga, New Caledonia, and Samoa as early as 500 BC by the Polynesians. When precisely the Polynesians introduced it into Melanesia and Melanesia to PNG (if any) is not entirely clear (Roullier, Duputié, et al., 2013; Roullier, Kambouo, et al., 2013). Similarly, the Australian introduction is not clear but probably in the 19th Century by Europeans.

The SP was introduced into the Philippines between 1521 – 1598 by the Spanish, China in about 1594 through the Philippines with the possibility of an earlier introduction from India and Burma around 1563, Japan in early 1615 by an Englishman but was not accepted until a reintroduction from China in 1674, and to Korea in 1764 probably by the Japanese and a project to grow it began in Seoul in 1766. The Portuguese introduced the crop into Africa in the 1600s, initially in Mozambique and into Angola between the 1700s and the 1900s by the British. The crop entered Europe between 1492–1604 during the Colombian Exchange, where widespread transfer of plants, animals, and other things occurred. Introduction into North America occurred around 1610, and the Indians were seen growing it in Florida in 1775. PNG, the Philippines, and parts of Africa are now the secondary center of the diversity of SP (Roullier, Kambouo, et al., 2013).

4. Botany, vegetative growth, and reproductive development

Sweet potato is a herbaceous perennial grown as annual by stem cuttings or plant sprouts from storage tubers (modified stems). SP produces underground storage, fibrous, and pencil roots. The adventitious roots develop from the node or the internode of the underground stem portion of the vines, and storage roots form within 13 weeks after planting. Monostori and Szarvas (2015) pointed out that the tubers are closed or open-cluster, dispersed or dispersed with varying shapes and sizes (round, round-elliptic, ovate, obovate, oblong, long-oblong, long-elliptic, long-irregular or curved. The flesh can be whitish, creamy, yellowish, orange, brown-orange, pink, red-purple, and dark purple. The number of cultivars in production is variable. Still, the most common include the "staple type" with whitish to creamy flesh, high starch and protein content, and the "desert type" of orange flesh and higher beta-carotenoid content (Monostori & Szarvas, 2015). In PNG, an estimated 5,000 cultivars are used in production.

It is a short-day plant, and its growth and developmental characteristics (branching patterns, height, internode length, vine length, petiole length, leaf shape, and size) are variable, even on the same plant. The vines are prostate, twine, indeterminate, and roots at the node. The stem is purple with variable internodes and produces spirally arranged leaves. Most leaves are deeply lobed to entire and green but may be inconsistent with purple pigmentation. The flowers are complete; the petals are united into a trumpet-shaped corolla, usually white with pink to purple throat. In many genotypes, flowering (short, long, or day-neutral) is poor, and sterility prevents open pollination. The seed is a hard-coated capsule that is dark brown or black, and most seeds have prolonged dormancy because of the hard testa. Stress may include flowering at the expense of low yield and general growth under adverse agroecological conditions (e.g., drought).

5. Global production

The global production of SP is well over 89 million tons (Fig. 2) produced on an estimated 8.1 million ha of land (FAO, 2021). The biggest producers and consumers are China (53.9%), Nigeria (4.5%), Tanzania (5.6%), Ethiopia (2.3%), Indonesia (2.3%), Angola (2.3%), Uganda (1.1%), Vietnam (1.1%), and USA (1.1%). In Europe, Spain (62,000) and Portugal (23,000) are the biggest producers, followed by Italy (9,000), Greece (2,000), and others (FAO, 2021).

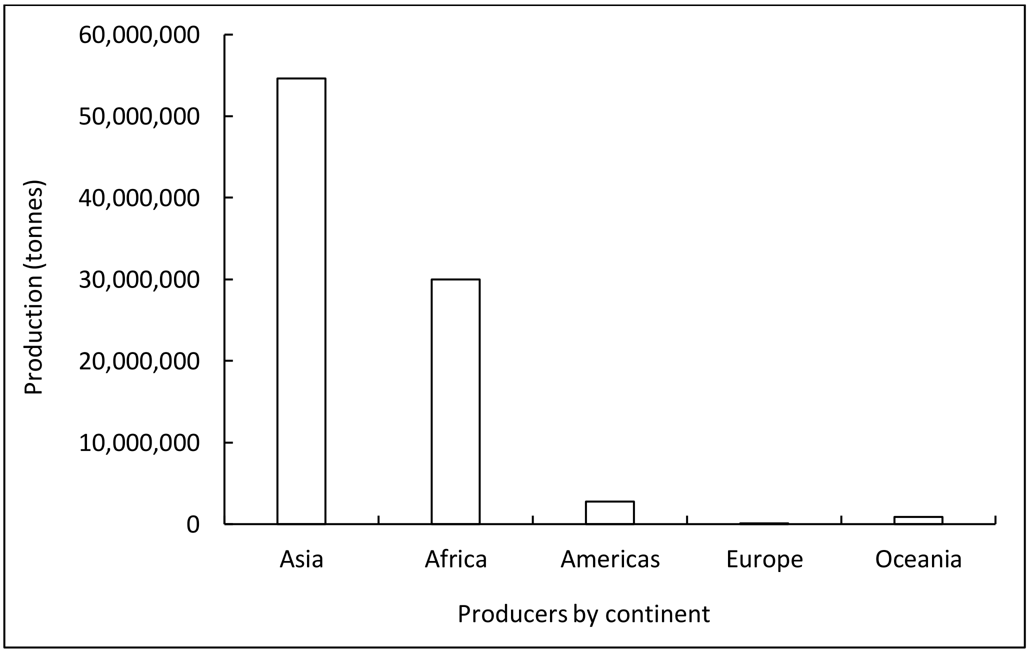

Figure 2. Global SP production by continent (FAO, 2021).

The Americas produce 3.7% of the total production; 33.3%, 33.3%, 16.67%, and 3.3% come from South America, North America, the Caribbean, and Central America, respectively. Oceania produces about 1.0% of the global production, and Australia has 8.6% of this quantity. Considering the landmass, the European countries, including the four (see above), contribute 0.1%, much lower than the 1.0% produced in Oceania, indicating the crop is more critical in Oceania than in Europe. For example, SP is stable in PNG and feeds more than 6 million people in the villages, with an estimated production of 700,000 tonnes only. Although commercial production is standard in the temperate regions, widespread production in the humid tropics and sub-tropic areas is limited to subsistence farming (Monostori & Szarvas, 2015), making sustainable production of SP in the Oceania region an essential strategy in the light of climate change, altered agroclimatic conditions and new pests and disease statuses.

5.1. Production in the Oceania and West Papua region

Sweet potato remains a minor crop in developed countries compared to the widespread production in tropical and subtropical Africa, Southern Asia, and the Pacific. SP is the staple in the PNG highlands compared to cassava, taro, yam, coconut, and sago, which are common in the lowlands (Michael, 2020a, 2020c). In West Papua (Indonesia), SP production has similar significance to PNG highlands, with an estimated output of 1.5 million tons per year, compared to smaller staples available in the lowlands. In the Solomon Islands and Fiji, SP is grown in all the islands, and an estimated 107,000 and 9,501 tonnes are respectively produced. The staple foods in Vanuatu are taro, cassava, yam, and banana, and SP is of lesser importance. SP is a minor crop in Fiji, New Caledonia, Tonga, Samoa, the Cook Islands, Micronesia, and Polynesia. In Fiji, Tonga, and the Cook Islands, cassava is dominant over SP (Bourke, 2020). It is also a minor crop in Australia and New Zealand, but production is rapidly increasing, with the crop having a cultural significance to the Maori people. This points out that the countries and the islands in Oceania, apart from Australia and New Zealand, face a severe threat to food and nutritional security and place SP as a strategic crop in the light of climate change.

6. Production constraints

6.1 Ecology

Agriculturally, SP is widely grown in the tropics, subtropical, and temperate regions from between 40° N and 40° S of the equator from the sea level to over 2,850 m in the tropical highlands. The crop is severely damaged by frost and requires a frost-free period of 120 – 150 days (fewer in the lowlands) and a lot of sunshine and warmth. The minimum temperature requirement for optimal growth is 24°C, and the plant does not do well at 10°C. Short days promote rooting and flowering, and long days promote vegetative growth (Monostori & Szarvas, 2015). The rainfall requirement is between 500 – 1,000 mm at any time and is more critical during the first 50 days after planting for root formation. Water stress affects tuber development, and the need for rain is minimal towards the maturity and harvesting time (Clark et al., 2013). Preferably, a well-drained, light, sandy loam or silt-loam with a pH range of 5.5 – 6.8 is required for quality root development as heavy soils result in poor root growth (Michael, 2020c). High soil moisture content affects root performance, and good surface and internal drainage are needed (Michael, 2020a). A recent study showed soil with high organic matter content affects roots average growth and development.

6.2. Nutritional requirements

Plant nutrients are chemical elements that are obtained from air, water, or soil for optimal growth and development. Plants need 17 elements; of these, carbon, hydrogen, and oxygen, abundant in plants, are obtained from the air and water. The others are minerals of soil and organic material origin. The minerals are divided into macro and micro-nutrients, depending on the relative abundance in plants. On a dry matter basis, macronutrients are in abundance of 1 – 60 mg kg^{-1}, and the micronutrients in 0.1 – 100 mg kg^{-1}. The primary macronutrients are nitrogen, phosphorus, and potassium, and the secondary macronutrients are calcium, magnesium, and sulfur. Iron, boron, manganese, zinc, copper, and molybdenum are micronutrients. Nutrient deficiency results in severe disorder and yield reduction. Therefore, it needs proper management. When excessively available, minerals such as boron, manganese, and copper are toxic to plants, and the effects can be devastating. This includes the impact of aluminum and sodium when their concentrations are high. The availability of these elements and their attention in the soil is primarily influenced by pH. The optimum pH requirement range for most plants, including SP, is between 5.6 to 6.8 units, and toxicity increases as the pH decrease to <4.5 units (Michael et al., 2015).

Nutrients' supply and availability to plants mainly depend on abundance, the proportion in available form, and the plants' ability to acquire the minerals. As pointed out above, a decline in soil fertility is associated with a decrease in abundance, particularly the macronutrients nitrogen, phosphorus, and potassium. At lower pH, the availability of some of these minerals, e.g., phosphorus, becomes limited, while that of aluminum and manganese rises to toxic levels, causing more nutrient disorders. Rhizosphere toxicity is one of the main reason plants fail to capture soil nutrients, as retardation and deformation of roots, reduced root growth, and poor development occur. The resultant deficiencies of the primary macronutrients, which are needed in more significant amounts, are evident in the aboveground biomass.

In most farming systems, the need to manage the deficiencies is higher in highly intensive monoculture plantations (industrial agriculture) than in low-intensity, mixed farming systems, as seen in Oceania outside of Australia and New Zealand (Aipa & Michael, 2019). As such, a high supply of external nutrient sources is required in industrial agriculture to address nutrient deficiency. In the low-intensity, mixed farming systems, low-cost and ecologically friendly approaches such as allowing the farmland to revert to natural vegetation (fallow), rotation with legumes, and crop stubble management to replenish the soil minerals are essential. The micronutrients become limited in soil when the abundance is depleted, and under most cropping systems, require tailored management strategies, some of which may be crop-specific requirements as the need for them is in minute quantities and disorders are not as severe as in nitrogen or phosphorous deficiencies (Aipa & Michael, 2018). The plants' responses to nutrient deficiencies occur when a critical limitation (deficiency) level has been reached and are particularly evident in the foliage of plants. The limitations are confirmed through chemical analysis of foliage and soil samples. A sampling of foliage for chemical analysis of a deficient mineral may be organ or tissue-specific, e.g., younger leaves versus older ones. At the same time, soil samples can come directly from the rhizosphere.

A strategic approach to managing the deficient nutrient can be made based on the chemical analysis, especially by applying an appropriate inorganic fertilizer. And in most economies, the affordability of chemical fertilizer or the facilities to do chemical analysis of plant and soil samples is still an issue (Michael & Reid, 2018). An integral part of managing a deficient nutrient is to contain minerals that cause toxicity by approaches such as reduced application, soil pH management by application of alkaline material, e.g., agricultural lime, or organic matter addition (Michael et al., 2015, 2016, 2017). Issues such as drainage, soil moisture levels, and organic matter availability need to be addressed for sustainable production and high yield of crops (Michael, 2020c). Breaking a cropping cycle with legume rotation, crop stubble, and strategic crop waste management (reuse, recycle, recover, and reduce) and avoiding growing hungry crops are part of land-use and management plans.

Sweet potato is quite tolerant to low soil fertility, and production is good even in the high-altitude areas, well over 2850 meters above sea level, e.g., in the highlands of PNG. The crop's requirements depend on the yield considered adequate. On a kg ha^{-1} dry-weight basis, the primary and secondary nutrients removed from the roots were potassium (60) > nitrogen (26) > phosphorus (6) > calcium (3.6) > magnesium (3) > sulfur (1.8). The number of micronutrients removed was in the range of iron (0.06) > zinc (0.04) > boron, manganese, and copper (0.02) > molybdenum (0.004). The values were higher when the nutrients removed from the vines were combined and considered. Based on these results, the macronutrient requirements for SP are potassium, nitrogen, phosphorus, iron, zinc, and the rest as secondary. Soil nutrient requirement is also growth- and development-specific. Potassium and nitrogen are needed during the early stages of plant establishment for leaf development and flower initiation, and phosphorus for root formation. Therefore, such results may be the accumulated values of nutrients taken from the soil, and it is difficult to establish the order of removal. Michael (2020c) observed from soil chemical analysis using samples taken from the rhizosphere under SP that nitrogen content remained related to the control soil. Potassium and phosphorus contents decreased by more than 90%, indicating the latter two minerals are heavily removed. Nitrogen influences leaf area and yield, and potassium increases dry matter and tuber number.

Nutrient deficiency in SP is widely known for all the primary macronutrients, secondary macronutrients in magnesium, and the micronutrients in boron and iron (Monostori & Szarvas, 2015). In PNG, for example, studies in the 1960s studied the effects of fertilizer application on SP and confirmed that macronutrient such as potassium was essential for high yield. Nitrogen deficiency is common in sandy soil, low organic matter, and under waterlogged conditions due to denitrification. Under such conditions, SP displays small, pale green and dark leaves and red pigmentation on the petioles and veins of younger leaves. Dead of older leaves is familiar as nutrients are translocated to support growth in other parts of the plant. Phosphorus solubility is slow, and the proportion available to plants, including SP, is small, therefore, more limited in soil. The solubility is enhanced by the association of mycorrhizae (fungi), which infects the roots and increases phosphorus extraction. Phosphorus binding is high in oxisols, ultisols, and volcanic soils, and a very high rate of fertilizer applications is required to maximize production (Monostori & Szarvas, 2015).

The binding capacity of phosphorus becomes saturated over time, and fewer rates are required to maintain soil fertility. The deficiency symptoms of phosphorus are challenging to detect until severe, including darker leaves than normal and reduced growth. The most visible include red-brown or purple pigmentation on the older leaves. Yellowing of the older leaves is common and may spread from one-half of the blade (Monostori & Szarvas, 2015). Purple pigmentation also appears on the younger leaves; the whole plant is dark green and not pale, as in nitrogen deficiency. Potassium deficiency is common in sandy, oxisols, and ultisols and is usually high in volcanic soils. This mineral becomes limited during the root formation when the plants are a few months old and develops light chlorosis on the mature leaves, the oldest becoming yellow around the margin and between the central veins. The yellowish tissues die out, turning dark brown and brittle. Organic matter or inorganic fertilizer addition can correct the deficiency.

Magnesium deficiency is the only secondary macronutrient severe in SP under sandy soil or soil of high potassium, which inhibits uptake. The crop tends to have pale color, vines become thin and twining, older leaves are pale green to yellow interveinal chlorosis, red or purple pigmentation occurs on the upper surface of the older leaves, and the older leaves, the yellow areas become brown and necrotic (Monostori & Szarvas, 2015). SP is more susceptible to boron deficiency, affecting the actively growing roots and shoots. The leaves are reported to become small, thickened, and brittle. The leaves curl under and the petioles twist. Young leaves become pale, and under severe cases, shoot tips wither and die. Solubility of iron becomes less at alkaline pH and is a common issue in calcareous soils, and may be induced by over-liming and overuse of phosphate fertilizers. In server cases, young leaves become necrotic, and the tips and axillary buds die (Monostori & Szarvas, 2015). A 1% ferrous ammonium sulphate solution can be sprayed on the leaves and assess the regreening.

Table 2. Common root-borers and feeders

Pests	Description of damage	Management
Clyas spp. (Coleoptera: Curulionidae) (i) *C. formicarius* (ii) *C. puncticollis* (iii) *C.* (iii) *C. brunneus*	Adults – damage vines and leave, and roots. Larvae - tunnels into vines and the roots.	No single method of control is available. IPM is ideal with an emphasis on the prevention of infestation. Cultural practices, e.g. use of the clean planting materials is important. Microbial and predators are important.
Euscepes postfasciatus (West Indian weevil)	Adults - Feed on the stems and roots. Larvae– feed on the tissues.	IPM (cleaning vines and roots, and removal of alternate hosts). Biocontrol is recommendable.
Blosyrus sp. (Rough weevil)	Adults – feed on foliage. The larvae are the most damaging, creating channels in the roots, reducing marketability.	Cultural practices – rotation and sanitation are common practices.
White grubs (*Phyllophaga* spp.)	The larvae damage the roots.	Hand-picking and weeding are good practices to manage it.
Omphisia anastomasalis (Stemborer)	The larvae channel into the neck of the roots through the stem.	Clean planting materials and crop rotation. Hilling-up is a further control method.
Alcidodes dentipes and A. eroneus (Striped weevil)	Bore into the vines and into the roots.	Earthing-up and crop rotation are important measures.

Table 3. Major stemborers and feeders

Pests	Description of damage	Management
Synanthedon spp. (Lepidoptera: Sesiidae), (Clearwing Moth)	Larvae - burrow the leaves and into the stems, and often into the roots.	Earthing-up around the base of the plants, and cultural methods.
Omphisia anastomasalis (Lepidopthera: Pyralidae) (SP steamborer)	Larvae – bore the main stem and into the neck of the tuber. Attached stems enlarge and lignify.	Use clean planting materials and avoid planting in infested fields.
Alcidodes dentipes and *A. erroneus* (Coleoptera: Curculionidae) (Stripped SP weevil)	Larvae – burrow into the vines then into stems to enter the roots. Adults – damage the vines and cause wilting.	Regular earthing-up and cultural methods.

6.3. Pests

The SP pests, like diseases, are important from two perspectives, the first being produced and the second being the quality of the produce. The most common way of understanding the pests is by grouping them according to the plant part (root, stem, and leaves) the damage is caused. Some of these pests with the types of damage caused, and their managements are given in Tables 2 and Table 3. The idea is not to review all the possible pests of SP but rather to point out that pest management is an essential consideration in sustainable SP production in Oceania. This is quite important from an altered agroclimatic point of view that pests may change their status and become an issue for SP production. The most economical pests are those of the roots and the stem, as severe losses can result in root quality as the main product of SP. Secondly, damaging the stems results in the loss of the entire above-ground biomass, which is the photosynthetic machinery of SP.

A root of low-quality faces issues throughout the postharvest processes unless managed well. The root is the primary product of SP that is economically important nutritionally (for humans and livestock), industrially (e.g., ethanol production), and pharmaceutically (e.g., bioprospecting), and the damage caused by the root-borers is a considerable loss. Many other root bores and feeders damage the root and are well described elsewhere. The losses ensured as a result of a low-quality product further result in quantity, which alone affects the profitability of the roots in the market and the consumption value in terms of nutrition and the health of the consumers (Mukherjee et al., 2012). In most places, the roots are an essential source of planting material and affected roots compromise the next cropping cycle when used. The use of unclean planting materials (e.g., vines or sprouts) in SP production is a hindrance and a compromise to quantity, quality, and profitability in the production cycle.

Sweet potato has several other minor stemborers that are of economic importance. The minor stemborers are *Peloropus* weevil (*P. batatae*), SP bug (*Physomerus grossipes*), and long-horn beetle. These insects either bore or burrow into the leaves and stem and damage both, which generally results in wilting. The defoliation of the leaves and damage of the stems leads to poor formation of the tuber and, consequently, poor crop yield. The insect may enter the neck of the tubers and enter the roots, too, causing deformation and low yield.

Table 4. Major viral diseases (Clark et al., 2012; Gibson & Kreuze, 2015)

Virus	Description of symptoms	Management
SP feathery mottle virus (*SP feathery mottle potyvirus*, SFPMP)	Irregular chlorotic spots, bordered by purpl pigments. Feathering along the midrib	Use clean planting materials and control aphids.
SP virus disease (*Potyvirus*)	Diseased plants are stunted and have small and narrow leaves.	Use clean planting materials and use resistant varieties.
SP mild mottle virus (*Ipomovirus spp.*)	Mottled and stunted leaves.	Use resistant varieties and clean planting materials.
SP sunken vein virus (SPSVV)	Changing and color change in the leaves, mild vein yellowing and sunken secondary veins, and swollen veins on the abaxial surface.	Use clean planting materials and resistant varieties.

Defoliation of the leaves affects the photosynthetic pathways and, in doing so, prevents food from being made in the leaves. At the same time, water and nutrient uptake from the soil is affected as more leaves are lost. Examples of foliage feeders are SP butterflies (*Acraea acerata*), Tortoiseshell beetles (*Aspidomorpha* spp.), SP hornworms (*Agrius convolvuli*), and Armyworms (*Spodoptera eridania*, *S. exigua*, and *S. litura*).

Several insects fold the leaves and cause similar problems as pointed out above for the foliage, significantly reducing the leaf surface area. The leave folders such as leaf folder (*Brachmia convolvuli*), strobiderus beetle (*S. aequatorialis*), a rough weevil (*Blosyrus* sp.), and SP weevil (*Cylas* spp.). Grasshoppers and locusts (*Zonocerus vareigatus*) are considered minor leaf feeders. Aphids (*Aphis gossypii*), whiteflies (*Bemisia tabaci*), and mites (*Aceria* sp.) damage the shoot system of SP as well as transmit viral diseases.

6.4. Diseases

The common SP diseases are viral (Clark et al., 2012), bacterial, fungal, and nematode (Johnson & Gurr, 2016; Motsa et al., 2015) are shown in Tables 4, 5, and 6. Each of these pathogens affects different parts of the plant (roots, stem, and leaves) and is discussed briefly to show their economic importance (Mukherjee et al., 2012). The biology and distribution of these pathogens are not covered in this review. As pointed out earlier, foliar diseases affect the leaves and therefore reduce the photosynthetic activities of the plant. Water and nutrient movement are affected when the stems are attacked by pathogens, starving the aboveground biomass. The root of the tuber is the most economical part of SP, and damage to the tuber results in severe economic loss to quality and quantity as well as the safety of consumers.

Other viral diseases, apart from SPFM, SPVD, and SPMMV, affect SP. The potyvirus SPFMV is transmitted by aphids, and whiteflies transmit the Closterovirus SPSVV and potyvirus SPMMV. The transmission of these viruses may vary depending on tolerant or susceptible varieties, where the SP is grown, and the climatic conditions that favor their spread. Apart from managing the insect vectors, the use of clean planting materials, the use of resistant varieties, or sanitation of tools used in propagation or planting, including harvesting, are essential management practices (Table 3). The standard bacterial stem, root, wilt, and soil rot are shown in Table 5.

As much as viral and bacterial disease management is essential to SP production, several fungal diseases and their management in the field and during postharvest stages are important. The fungal diseases can be stemmed and foliar or roots, depending on which biomass the pathogens attack the plant. The major stem and foliar fungi are Leaf and Stem Scab (*Elsinoe batatas* and *Sphaceloma batatas*), Alternariosis, Anthracnose and Blight (*Alternaria bataticola*), and Phomopsis Leaf Spot (*Phyllosticta batatas*) (Table 6). Fungal diseases whose management is not covered include Minor Leaf Spot Fungi, e.g., *Alternaria* spp., *Cercospora* sp., *Septoria* sp., *Ascochyta* sp., *Curvularia* sp., *Colletotrichum* sp., and *Pestalotia* sp.) Chlorotic Leaf Distortion (*Fusarium lateritium*), Fusarium Wilt (*Fusarium oxysporum* f. sp. *batatas*), Violet Root Rot (*Helicobasidium mompa*), Sclerotial Blight and Circular Spot (*Sclerotium rolfsii*), and Black Rot (*Ceratocystis fimbriata*). Similar to the foliage and stem, some fungi are of economic importance to the lower part of the SP, particularly towards the root (tuber).

As pointed out earlier, the root is the most economical part of the plant as a source of food and raw material for various industries. Fungal diseases that are important during post-harvest are Foot Rot (*Plenodomus destruens*), Jack Black Rot (*Lasiodiplodia theobromae*), Charcoal Rot (*Macrophomina phaseolina*), and Soft Rot (*Rhizopus stolonifer*, *Mucor* sp.). These fungal diseases cause various -

Table 5. Common bacterial diseases

Bacteria	Description of symptoms	Management
Stem and root rot (*Erwinia chrysanthemi*)	Water-soaked brown to a black lesion on stems and petioles.	Use clean planting materials and resistant varieties.
Bacterial wilt (*Pseudosomonas solanancearum*)	Various symptoms depend on what plant part is affected. Infected plants may look wilted, with stems with yellowish water-soaked lesions, and discoloration in storage tubers.	Use clean planting materials and resistant varieties. Crop rotation and flooding of infested fields.
Soil rot (*Streptomyces ipomoea*)	Chlorosis and bronzing of the foliage. Dark brown necrosis on storage roots.	Use of clean planting materials and maintaining soil moisture.

Table 6. Common fungal diseases of the foliage and stem.

Fungi	Description of symptoms	Management
Leaf and Stem Scab (*Elsinoe batatas*)	Brown lesions on the stem, and tinny lesions on the leaves.	Use clean planting materials, resistant varieties, and good sanitation.
Alternariosis, Anthracnose and Blight (*Glomerella cingulate*)	The brown lesion occurs on the older leaves. On the stem and petioles, a black lesion occurs.	Use clean planting materials, resistant varieties, and good sanitation.
Phomopsis Leaf Spot (*Phomopsis viticola*)	Brownish to a whitish lesion on the leaves. The lesions have brown to purple margins.	Use of clean planting materials, and good sanitation.

symptoms on the SP plant's foliage or stem, and tailored management strategies are required. The use of clean planting materials, proper sanitation practices, and the use of resistant varieties are the available management options most recommended (Henz, 2017).

On top of these, crop rotation, maintenance of soil moisture and other crop production, and best management practices are essential. These practices should not only break the pathogen cycle but help the plants to grow and thrive and overtake the proliferation of fungi. The management and control of fungal diseases post-harvest are essential as quality matters to the farmer, the nutrient content is a concern for safety and health, and the shelf-life of the product throughout the retail and consumer systems (Mari et al., 2016). The fungal spores or agents are initially managed by many pre-treatment techniques like washing, sorting, and cleaning, sun-drying to remove excess moisture, and even grading the produce. The packing materials and the mode of transport are managed to specific standards as a requirement for perishable produce, including the use of fungicides.

Some diseases caused by nematodes are common in SP and these diseases are Root-Knot Nematode (*Meloidogyne* spp.), Brown Ring (*Ditylenchus destructor*, *D. dipsaci*), Reniform Nematode (*Rotylenchulus reniformis*), and Lesion Nematode (*Pratylenchus* spp.).

The most common symptoms of nematode disease infected SP range from stunting and yellow foliage galls on the fibrous roots, necrosis in tubers, and deep cracks. The loss caused by nematodes in a range of product is estimated to be around 157 billion US dollars (Singh et al., 2015). Nematodes are managed by crop rotation, resistant varieties, organic matter application, and practices to increase the natural enemies (Mejias et al., 2019).

7. Synthesis of past research

Research and development, like for any crop, are essential for SP. The primary needs for SP research are in crop genetic improvement and improvement in traits of agronomic importance (high nutrient content, resistance to pests and diseases, and the ability to grow under different farming conditions) (Clark et al., 2012; Johnson & Gurr, 2016). Progress has been made globally in the conservation and utilization of SP in South East Asia, Africa, Europe, and the Americas supported by the International Plant Genetic Resource Institute (IPGRI) and Consultative Group on International Agricultural Research (CGIAR). However, more workers are required because of climatic conditions, the surge in pests and diseases, and altered climatic factors, which necessitate changes in production systems. In addition, the varied agroclimatic conditions under which SP production is undertaken make tailored research a priority for different regions, as production requirements are additional.

The most critical areas of development are identifying the genetic diversity, morphological and molecular characterization of the diversity, collection, and conservation *in situ* and *in vitro*, and distribution and utilization. Most genetically improved varieties are kept and maintained internationally, e.g., by the International Centre for Potato (CIP) and IPGRI. Therefore, cooperation between SP growing countries to have access to the germplasm for local research and development. Coincidentally, local agroclimatic conditions require specific research conducted within countries to address local needs that international plant genetic resource organizations, such as IPGRI or CIP, are not generally discussed. SP research in genetic improvement, abiotic and biotic (pests and diseases) stress resistance, and production systems, in line with the production constrictions presented in Section 6, are discussed under sections 7.1 and 7.2, respectively.

7.1. Crop improvement – genetic and stress resistance

Unlike many crops, genetic improvement has been a problem because SP is an allogamous autohexaploid with self- and cross- incompatibilities (Tanaka et al., 2017), making improvement and genetic analysis difficult (Katayama et al., 2017). The basic sets of chromosomes n = 15, with six sets of chromosomes (2n = 6x = 90). Only a few genetic studies are limited to polygenetic and germplasm evaluation. Areas of crop genetic improvement include: (1) high nutritional values and content, (2) resistance to abiotic and biotic stresses, and (3) high yielding can be widely cultivated in different agroclimatic zones (e.g., in the tropics, subtropics, and temperate).

Studies have been made addressing genetic and agronomic traits (Michael, 2020a). Due to the genomic complexity and incompatibilities hindering conventional genetic improvement, researchers have used several available modern technologies to advance the efficacy of cultivar development (Tanaka et al., 2017). Attempts in the use of genetic transformation technologies (particle bombardment, electrophoresis, *Agrobacterium tumefaciens*, and *A. rhizogenes* mediated transformation; random amplified polymorphic DNA, amplified fragment length polymorphism, simple sequence repeats) to transfer genes have been made (Chen et al., 2013) and procedures have been developed (Michael, 2019a; Michael, 2019b). Genome editing has been studied to improve agronomic traits, nutritional quality, and resistance to abiotic and biotic stresses (Lu et al., 2017; Zhan et al., 2021).

Several SP varieties contain improved carotenoid content (yellow and orange flesh), anthocyanins, and caffeoylquinic acids are under production. Studies trying to understand the mechanisms that elucidate carotenoid production have also progressed. A gene expression study between an orange-fleshed SP (Jewel) and its mutant line (White Jewel) showed the mutant line has differences in gene expression for the development of a chromoplast that functions as a storage organelle for carotenoids. Quantitate trait loci (QTL) using F1 progenies of orange- and white-fleshed cultivars and several QTLs associated with β-carotenoid were analyzed and detected, pointing out the DNA markers associated with the QTLs may be helpful to improve the carotenoid contents. Kim et al. (2012) and Kim et al. (2014) did several transgenic studies to identify a specific regulator gene that controls carotenoid accumulation and found none. However, key enzymes responsible for carotenoid biosynthesis essential for molecular breeding have been identified.

Several workers pointed out phytochemical, biochemical, and genetic studies are required (Isobe et al., 2017; Yang et al. 2016). A much better summary of the progress in genetics, genomics, and breeding is presented by Yan et al. (2022), and several databases are available, and studies using molecular markers to establish genetic diversity are available (Anglin et al., 2021; Moulin et al., 2012; Palumbo et al., 2019). Genome editing technologies have also been used in SP to improve critical agronomic traits, nutritional quality, and resistance to biotic and abiotic stresses (Butt et al., 2020; Lu et al., 2017; Ye et al., 2018; Zhan et al., 2021; Zhang et al., 2019).

Sweet potato grows in a wide range of agroecological zones and adverse conditions. Apart from the biotic stresses presented earlier, the principal abiotic stresses are drought (water deficit), low temperature, salinity (Shao et al., 2014), and soil nutrient constraints. Most of these stresses often lead to osmotic and oxidative (imbalance between free radicals) stress. Water stress causes physiological and biochemical reactions in plants and affects water and nutrient uptake, respiration, flowering, general growth, and stomatal functions (evapotranspiration). Problems further lead to salinity problems in most coastal areas. Calcium chloride becomes an issue when its ratio exceeds 1 (Begum et al., 2015).

Breeding for resistance against these stresses across agroecological zones is impossible, and genotype-by-environment studies are limited. Therefore, warrant decentralized SP breeding. Earlier comprehensive review of the effects of abiotic stresses and the literature show sufficient varieties resistant to stress like drought are available in germplasm collections (Agili et al., 2012) and there is merit in the selection of resistant SP under stress. Screening for most of these stresses is cumbersome, and fast screening technologies must be developed, e.g., screening for drought tolerance using polythene glycol *in vitro* (Agili et al., 2012). Evaluation of SP genotypes against salinity and resistance to drought and salinity (tolerant to the electrical conductivity of 4.0 dSm^{-1} in irrigation water) and to even boron (saturation extract of 2 mg L^{-1}) were attempted. Availability of these varieties, and maybe others resistant to other stresses, means that the SP-producing nations need to have access to them and conduct decentralized breeding to improve varieties adapted to local agroecological zones, e.g., in farmers' fields (Roullier, Kambouo, et al., 2013).

Figure 3. Subsistence SP production in the highlands of PNG. Manual application of inorganic fertilizer (a) and mature mounds (b). The photo insert is Topas Peter at his experimental site in Sirunki, Laiagam, Enga Province, PNG

7.2. Cultural production practices in tropical and temperate regions

Taking into consideration the nutritional, pharmaceutical, and industrial importance and the constraints of production pointed out, understanding the farming systems across different agroecological zones is essential as it is pretty variable where the crop is produced (in developed countries versus in the developing countries), the capital and resources used and who is involved (e.g., family units or individuals versus corporate farms). The technologies applied in SP production are variable (see Fig. 3 and Fig. 4). For example, farmers in the tropics and the subtropics use family units and simple tools that are easily affordable. The availability of farm machinery and agrochemicals is limited. Production size is limited to subsistence gardens or small plots (Fig. 3). In such places, mechanized farming systems (see Fig. 4) are not practiced. Inorganic fertilizer use is an issue because of accessibility and affordability. Chemical fertilizers are not readily available in the tropics; if they are, they are costly.

In tropical agroclimatic conditions, such as in PNG, SP is planted by hand during the onset of rain, so harvesting is done when dry. The propagule used is often the vines obtained from existing germplasm collections. In temperate regions, storage roots are pre-sprouted, and the sprouts are isolated and used as propagules. Land preparation usually involves raised beds or mounds. Mounds increase drainage, lower bulk density, and assist root development. Mounds also help in multiple land use, and crop diversification as more crops can be grown together at any time. The mound-making processes vary. E.g., in PNG highlands, composted mounds are made, whereas, in other places, only the soil is heaped up to make the mound. While mound-making is expected, the changes in soil chemistry induced by the organic matter in the mound need investigation (Michael, 2020a).

In temperate regions, availability and access to inorganic fertilizers are not a problem compared to the tropics. The addition of organic matter of varying nutrient content in mounds is further lacking in the literature and needs to be studied. When organic matter is added to mounds, the total nutrient in the soil as a fertility indicator or available as a nutrient to the crop depends on the type of organic matter added. The variety of nutrients released and used by plants at different stages of plant growth needs to be established, including nutrient acquisition under various stress conditions, e.g., drought. The vine canopy is established between 6 to 8 weeks, and the crop is ready to be harvested in 3 to 8 months, the longer duration in the cooler regions. There is a need to understand the type of nutrients needed at the early stages of growth and development and those that get stored in the storage tubers in the later stages of growth toward harvest. This study is essential not only to understand SP production but also for other uses, e.g., industry and pharmacology. In subsistence farms, multiple harvesting is done, e.g., in the tropics. The changes in soil chemistry induced by multiple harvesting, which results in regrowth and development of the underground vine and subsequent root and tuber formation, need to be established. In this cultural practice, e.g., in PNG, weeds and other plants take over the mounds, and not much effort is put in place by farmers after the primary harvest, and there is a need to understand the changes in soil chemistry that ensure. In temperate regions, the crop is mechanically produced and harvested mechanically. Some developed countries, e.g., Japan, have developed mechanized ways of harvesting and collecting SP that are economical and more efficient (Okonya et al., 2014). The differences in how SP is cultivated and harvested warrant region-specific and agroecologically independent research.

Comparatively, the volume of SP produced in the tropics is limited to subsistence needs compared to temperate regions. What is expected in both areas is what is harvested as a primary crop that is sold. Studies must establish the soil's recovery processes to replenish soil nutrients and other ecological services. In the tropics, for example, the land is allowed to follow, revert to natural vegetation, and help the soil rebuilding processes. In temperate regions, the land may be used with another land use plan without a rest. Considering these differences in cultural practices is essential for the sustainable production of SP under the projected changes in climate and altered agroclimatic conditions. To a certain extent, pests and diseases are checked by the existing agroclimatic conditions. When these conditions are altered, what will happen to the current pests and disease-causing pathogens, good or bad, is uncertain (Michael, 2020a, 2021b). Similarly, those pests and pathogens that were not a problem for SP may establish their status under the altered climate and may require new practices to manage them (Michael 2020a, 2021b).

Figure 4. Mechanized production of SP (Louisiana Sweet Potato Farmers, USA). Machine-assisted planting (a) and production management (b)

Most biological, chemical, and physical changes that occur in the soil during production and following harvest are naturally induced. That means that soil must slowly get back to near-perfect natural conditions to enhance organic matter to build up, moisture to return, nutrients to replenish, and biological activities to commence. These ecological processes take time, particularly in heavily mechanized soils such as temperate regions, compared to tropical soils where SP production is limited to subsistence farming. The available cultural practices, such as the fallow or planting of green manure plants to manage and enhance the soil-building processes, need to be studied and established. In the tropics, fallow is the common practice but is time-consuming (3 to 15 years).

The populations of most tropical countries are increasing and putting pressure on the limited land available, resulting in a decrease in the fallow period. The reduction in the fallow period means the soil has not recovered correctly to support the following land use plan. In the temperate region, where the availability and affordability of inorganic fertilizer is not an issue, accessing chemical fertilizers and affording them, especially in the subsistence farming systems in the tropics, is an issue. This issue is not only an SP production issue but a food security issue and needs to be strategically addressed. One of the strategies to manage soil infertility is to use an organic matter of plant and animal origin. Compared to inorganic fertilizers, organic materials are relatively cheap and readily available (Michael et al., 2015), e.g., in the tropics. Organic matter addition does not only address the inherent loss of soil fertility. Still, it helps reduce bulk density, build up moisture, create micro-soil environments conducive to attracting microbes, and even regulate other chemical and physical properties that improve soil productivity (Michael et al., 2017), e.g., pH and reduction-oxidation (redox) potential (Michael, 2021b).

A recent study by Michael (2020c) using Cogon grass plant matter in addition to mounds reported improvement in soil nutrients and other properties. These kinds of studies need to be conducted using organic matter that is locally available and can easily be accessed by farmers. In many soil types, not all nutrients are limited. Therefore, targeted use and application of organic matter, the rate or how much to be applied, and how long the plant matter will last in the soil even after the crop has been harvested are important information still lacking in the SP literature. In PNG, for example, we are investigating what type of organic matter locally available can be used to address a specific nutrient lacking to manage the deficient nutrient under SP production. Again, the broader publicity of these types of studies in the tropics is essential for farmers and the advancement of science. Farmers use locally available materials, such as organic manure and compost (Olivares & Franco, 2015), to improve soil fertility and enhance the growth of SP and other crops in indigenous communities (Michael, 2020c). This can help increase the resilience of SP production to changing climates. In summary, SP cultural production practices in tropical regions are essential for food and nutrition security in the face of climate change. These practices need additional research to help farmers adapt to changing climatic conditions while promoting sustainable and resilient production of SP.

8. Future research directions

Sweet potato is an essential crop in the tropics for humans and livestock and a potential raw material source in the temperate agroecological zones industrially and pharmaceutically. SP needs to be strategically produced in light of land scarcity due to the current global socio-economic trends and projected climate changes (Bourke, 2019). Strategic areas that need consideration include land use plans, e.g. use of organic matter as a substitute for chemical fertilizer application, cropping, and cultural practices that manage production constraints, particularly pests and diseases, and imbalances in soil fertility (Michael, 2020a). The existing issues are compounded by the projected agroclimatic conditions, which may lead to changes in pests and disease status and many new cultural production practices. The new cultural practices would include SP production and production management methods against soil infertility, pests and diseases, weeds, moisture deficits, and even harvesting methods. The literature on SP agronomy shows that some research was conducted, e.g., in PNG, but limited widely. Further research would look at establishing the most efficient, less labor-intensive, and cost-effective ways of addressing the issues (Bourke, 2021). Michael (2021b) pointed out that using organic matter is an important option to address the problems related to accessing inorganic fertilizers; the types of studies need to be promoted. Time-dependent use of soil nutrients by SP needs to be established for production management (Michael, 2021a).

The compromised agroclimatic conditions, existing and projected (Michael, 2020a, 2020b), indicate there is a need for research to improve the SP varieties that are grown globally to be able to grow under the altered climate (e.g. tolerance against abiotic and biotic stresses), produce a high yield with improved nutritional values and wider adaptability (Bourke, 2018a, 2018b, 2020). Conventionally, it is time-consuming and labor-intensive to identify traits of genetic and agronomic importance. However, the availability of advanced technology using molecular techniques, e.g., gene editing, is now possible to address many of these issues once (Andrade et al. 2017), even from a single study. The use of conventional methods to screen extensive germplasm collections for traits of agronomic importance was something of the past and can now quickly be addressed by marker-assisted selection (Diaz et al., 2022).

Transboundary movement of plant materials continue to be a bottleneck until the widespread introduction of tissue culture facilities. Some of the modern biotechnological techniques need to be widely promoted, so variety development is decentralized to regions of importance, e.g., PNG, which is a secondary center of diversity with over 5000 varieties, which are either maintained in germplasm collections or found in the farmers' fields. Unless this crop is systematically produced with broader community involvement, the more significant potential of the harvest to meet the needs will not be fully realized.

In the future, artificial intelligence (AI) and machine learning are likely to play an increasingly important role in SP cultivation as demonstrated by studies applied to other crops (Olivares, Vega, Calderón, Rey, et al., 2022). There are several areas of potential research, including developing models that can predict yield based on environmental factors (Olivares, Vega, Calderón, Montenegro-Gracia, et al., 2022), identifying disease and pest outbreaks (Olivares, Rey, et al., 2022), automating harvesting, improving soil quality (Olivares, Calero, et al., 2022), and enhancing crop resilience. By leveraging the power of AI, researchers and farmers could optimize cultivation practices, reduce labor costs, and minimize environmental impact, all while increasing the quantity and quality of SP crops. As AI technology continues to advance, there is great potential for it to revolutionize the field of agriculture and enable more sustainable and efficient food production.

9. Conclusion

Sweet potato is a strategic crop under climate change because of its potential to grow under a range of agroclimatic conditions and produces a reasonable yield even under minimal input. The crop is a staple food of the people in the humid tropics and the subtropics, where food and nutritional security are a significant concern under the projected climate change. In Oceania, e.g., in the highlands of PNG and Papua, SP is the only staple compared to its status as a minor in the other Pacific Islands. The crop has the potential to grow under a wide range of environmental and climatic conditions and feed millions of people, yet widespread production is limited and its potential not being realized by many areas in Oceania makes research and development a priority in the region. At this point, research priority areas include crop genetic improvement in traits of agronomic importance (tolerance against a range of abiotic and biotic stresses) that may become more common under the new and altered climate and improved crop production practices, such as use of organic matter as a substitute for chemical fertilizers.

Acknowledgement

This paper is part of the first author's MSc thesis literature review at the Department of Agriculture, PNG University of Technology, PNG. The authors are grateful to PNGSTS and PNGUoT for the research grants for the sweet potato project. We thank the anonymous reviewers whose inputs improved the quality and the contents of the manuscript.

Declaration of Competing Interest

The authors declare that no competing financial or personal interests that may appear and influence the work reported in this paper.

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