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Eco-organic system and silicon-based biostimulant as a strategy for vegetable production under multistress conditions in South Africa: A review

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Abstract

Plants get exposed to multiple stresses throughout their phenological growth stages. At most, these stresses are attributed to single or combined stresses like salinity, water deficits, wounding, mineral deficiencies, potting bag size, soil/root media density and type, soil pH, and the type of production system employed. Multistress factors have been widely reported to reduce the plant growth and development, strength, yield, and quality of horticultural crops globally. In the literature, reports extensively recommended the use of silicon-based biostimulants to improve the growth and development of commercial horticultural plants; however, little has been reported in South Africa on the recovery response mechanisms of beetroot (*Beta vulgaris* L.), lettuce (*Lactuca sativa* L.), tomato (*Solanum lycopersicum* L.), and kale (*Brassica oleracea* L.) grown under multi-stress conditions treated with silicon-based biostimulants, and using the cheaper eco-friendly production systems. In South Africa, most silicon-based biostimulant production companies reserve their novel concoctions as their company secrets; thus, many of the products are never tested in public to ascertain and monitor compliance with the Fertilizers, Farm Feeds, Agricultural Remedies, and Stock Remedies Act 36 of 1947 in South Africa. On the other hand, emerging farmers and smallholder growers are failing to afford existing agricultural insurance options, thereby affecting their yields against the commercially developed farmers. Although the government aids farmers, the assistance does not cover all costs associated with the multistress losses. Some farmers and growers adopted advanced production systems; however, at most, these systems are costly and rely primarily on electricity as a source of power, which is a challenge in South Africa. This paper explains various production systems used by commercial and emerging farmers, and the smallholder growers in South Africa to reduce costs related to multistress losses. Moreover, an alternative eco-organic production system that applies silicon-based biostimulant as a novel idea for commercial vegetables grown under extreme multi-stress conditions is recommended for emerging farmers and smallholder growers in South Africa. Future studies should be based on eco-friendly production systems in vegetable production in line with Sustainable Development Goals, to combat poverty and improve the livelihood of the African countries.

Key words: plant growth regulators, stress factors, soil density, salinity, wounding

Introduction

There is little to no research, investigating the use of silicon-based biostimulants on beetroot (*Beta vulgaris* L.), lettuce (*Lactuca sativa* L.), tomatoes (*Solanum lycopersicum* L.), and kale (*Brassica oleracea* L.) grown under multi-stress conditions in South Africa using eco-organic production systems. Globally, plants are exposed to various stresses such as wounding, which causes mechanical stimuli like an attack by herbivore insects, strong wind, hail, ultraviolet radiation, and harvesting cuts. On the other hand, the soil and water salinity, water deficit, production systems attributes such as soil health, pH, potting bag size and type, substrate type and quality, and nutrition are other key factors affecting crop production (Kloth and Dicke, 2022; Gao *et al.,* 2023). For optimization, many studies have been reported on various vegetable crops with research and development-based production systems in place; however, there are fewer studies on the production of vegetables under novel multi-stress conditions, especially those associated with combined effects of/or wounding, salinity, water deficit, production systems attributes such as soil health, pH, potting bag size and type, substrate type and quality, and nutrition in South Africa.

The use of organic and inorganic chemicals such as osmoprotectants and biostimulants is adopted to improve the tolerance of horticultural crops to multi-stress (Penna and Jain, 2023). However, some of these approaches are expensive, time-consuming, and labour-intensive, and some are associated with some drawbacks, like contributing to environmental pollution (Wazny *et al.,* 2021). In addition, for competitive advantage, most of the companies which commercially sell these chemicals and biostimulants copyright and patent them, mainly to keep the ingredients undisclosed to the public; thus, there are limited scientific reports in the literature to ascertain the effectiveness of these products to be used under extreme multistress conditions. Moreover, another challenge relates to access to the available agricultural insurance for horticultural crops, especially for emerging farmers, and those farmers who fall within the category of subsistence and smallholder farmers. At most, the costs tend to be higher; therefore, the use of novel silicon-based biostimulants may come as an alternative strategy under extreme multi-stress conditions. This paper aimed to review the possible development of alternative eco-organic production systems as a strategy using novel silicon-based biostimulants applied on vegetables grown under extreme multi-stress conditions. Therefore, the next part of the section focuses on the currently adapted production systems used by emerging farmers and smallholder growers in South Africa.

Common production cultures used by South African horticultural growers

Geoponics system culture: Conventional agricultural systems, also known as geoponic practice, are the first most common and cheapest option for open-field production for most horticultural growers in South Africa. It is known to require a large quantity of irrigation and high-quality irrigating water, IPM and fertilizers, with a relatively marginal return on investment (Macwan *et al.,* 2021). Conventional agriculture has been marked as one of the production systems that causes a wide range of land degradation, especially where farmers do not follow correct cultivation techniques for land cultivation; thereby, leading to negative impacts on the environment and crop production. Some of the negative impacts of conventional agriculture include the high and inefficient use of water, large land requirements, high concentrations of nutrient consumption, and soil degradation (Ma *et al.,* 2023). The rapid growth of the world population should be offset by the same or rather higher rate in the production of food. With the rapid technology change, particularly the 4IR, and the climate change affecting the production systems, most of the emerging farmers and smallholder growers in South Africa need to adapt to the advancing precision production techniques, mainly to sustainably maintain high yields and quality of produce in the country's growing population. However, the advancements of the alternatives come at a high cost per hectare for emerging farmers (Ndhlovu and Mhlanga, 2023).

Hydroponics and soilless culture: The second most common production system adapted by the growers in South Africa is the production under a controlled environment using hydroponics and soilless culture (Combrink *et al.,* 2019). Hydroponics is described as a technique for establishing and growing plants using water-soluble fertilizers without soil. In hydroponic systems, various types of root media are used as a replacement for the highly buffered soil, and this system uses a nutrient solution where the roots are continuously immersed in a nutrient solution (Tüzel *et al.,* 2019). On the other hand, soilless culture cultivation is mostly confused with the hydroponic system; however, the two systems are the same, although with the soilless system, at times plants are cultivated without any root media (Gebereegziher, 2023). Globally, the most common types of hydroponics-related systems include the Nutrient-film technique (NFT), floating culture or deep-water system, lay-fat bag or slab culture, soilless cultivation, substrate culture, trough culture system, static solution culture and aeroponics. However, as illustrated in Table 1, the most used hydroponics and soilless culture systems in South Africa are the NFT, floating culture or deep-water system and trough culture system.

For the two systems, hydroponics and the soilless culture, commercial farmers use synthetic and inorganic fertilizers to formulate the nutrient solutions, which comes at a costly price to farmers. In addition, South African growers and farmers are faced with an energy crisis, where electricity bills are charged at higher prices for farmers and are also unreliable (Erero, 2023). The establishment of a successful production system requires four to six multi-span tunnels of tomatoes to break even; therefore, hydroponics is deemed as a highly demanding system that requires a greater amount of product knowledge, experience, technical skill, and financial investment than many other greenhouse production systems (Combrink *et al.,* 2019); thus, this remains a challenge for emerging farmers and smallholder growers in South Africa. Tüzel *et al.* (2019) and Combrink *et al.* (2005) described various types of hydroponics and soilless culture systems commonly used in South Africa, for example, Table 1 describes a few of these systems with their pros and cons for suitability by emerging farmers and smallholder growers.

Water deficit is the significant abiotic stress that occurs due to the lack of soil water to maintain plant growth and respiration demand and leads to reduced plant water potential (Lin *et al.,* 2023). Water stress can induce various morphological, physiological, and biochemical alterations in plants which involve stomatal variation, leaf expansion, reduced plant growth, and stem elongation (Jain *et al.,* 2019). Water stress causes stomatal closure and an interruption in water flow from the xylem to the surrounding cells, which inhibits cell elongation and affects sensitive physiological processes such as protein synthesis and transportation of nutrients (AL-Quraan *et al.,* 2021). Moisture stress decreases leaf relative water content and stomatal conductance, ultimately resulting in stunted growth (Inoue *et al.,* 2021). Water deficit hinders cell division, roots, and shoot expansion, leading to stunted plants (Jain *et al.,* 2019). Water deficiency affects chlorophyll content by altering chloroplast membranes, causing swelling, and distortion of the lamellae (El-Dakak *et al.,* 2023).

Eco-organic soilless culture: Table 1 clearly illustrates that most of the common alternative production systems employing hydroponics and soilless culture systems used by a successful commercial farmer in South Africa require high establishment costs, more space to break even, high costs to maintain and warrant cheaper and sustainable production systems for emerging farmers and smallholder growers. The Chinese growers have been employing the eco-organic production system for ages (Na *et al.,* 2021; Sallam *et al.,* 2021; He *et al.,* 2023; Jiang *et al.,* 2002), and this type of production system has not received much attention in South Africa. Organic ecological soilless culture is a kind of emerging high-efficient soilless culture mode (He *et al.,* 2023). This production system is not new to agricultural systems; however, with the increasing costs of the production of synthetic and inorganic fertilizers, emerging and smallholder farmers are warranted to seek alternative traditional methods to reduce the costs of production.

According to Sallam *et al.* (2021), the eco-organic soilless culture follows a similar soilless culture, where a nutrient solution is used; however, the electro-conductivity (EC) is countered with the use of liquid effluent or sludge containing high content of nitrogen. Eco-organic type soilless culture system decreases the initial investment and fertilizer cost by up to 60%, improves vegetable quality, and simplifies the rules of operation. The soilless culture technique uses solid fertilizer instead of a nutrient solution to feed crops (Sallam *et al.,* 2021). Recent studies on eco-organic soilless culture demonstrated the cost-effectiveness and recommended it as a solution to compliance with the Fertilizers, Farm Feeds, Agricultural Remedies, and Stock Remedies Act 36 of 1947 in

Table 1. Common hydroponic and soilless culture employed in South Africa

Hydroponic and soilless culture type	Yield and quality parameters based on the system	Citation
Nutrient-film technique (NFT)	A kind of hydroponic growth method known as the nutrient-film technique involves suspending plant roots in a thin layer of nutrient solution that circulates through small channels. The channels are positioned on a slope so the nutrient solution can be fed at one end and drained, collected in a return pipe at the opposite end and returned to the reservoir tank. The advantage of this system is that one can rely primarily on the gravity of the slope for feeding the plants, making it lesser in energy requirement for feeding as gravity is employed. In a study conducted on lettuce, the results showed no significant effect of the treatment on the number of leaves 0-20 days after planting and root length. Nutrient solution temperature +10 °C gave the best response to the number of leaves, plant height, root volume, and fresh weight of green lettuce plants. On spinach (*Spinacia oleracea* L.), the yield was significantly increased, where the 90-day harvest was revealed to be the highest yield compared to the control. Although the two studies have revealed NFT to be a successful production system, the disadvantage of the system is at most its design, which is a closed system, requiring a high caution on disease control associated with the feeding water or the recirculating nutrient solutions.	Vincentdo and Surantha (2023) Farooq *et al.* (2023) Combrink *et al.* (2005)
Floating culture or deep-water systems	Compared to the NFT, the floating or deep-water hydroponic systems have a reservoir of nutrient solution where plants are floated while the roots hang freely in the nutrient-rich solution. Successes of using the floating systems have been employed commercially, for example: on a pakcoy cultivation growth (*Brassica rapa* L.), the floating raft hydroponic system resulted in a higher number of leaves, better stem development, longest roots and higher fresh mass compared to the control. In addition, the results further showed that the design of spray bar pumps can minimize oxygen deficiency in floating raft pakcoy plants with a dissolved oxygen level value. The highest plant height, shoot and root fresh weights, stem diameter, and fresh biomass were obtained from an EC level of 25 mS cm^{-1} when *Salicornia perennis* Mill. was grown on floating systems. Studies quoted have revealed the successes associated with the floating system; however, the construction of this system may be deemed cost-efficient for the home grower using wooden frames lined with plastic or other watertight containers. This may not be the case for emerging and smallholder growers in South Africa as erecting a system of this nature on a larger scale, and high establishment costs are required.	Gerlach *et al.* (2023) Puspitahati and Andica (2023) Esra and Tuzel (2023)
Trough culture system	The trough culture system is another common system used by South African growers, and it involves growing plants in sloped troughs like NFT on benches filled with either gravel or sand. This system differs from the NFT as it employs the sub-irrigation system to feed the plants. At most, this system is associated with the ebb-and-flood system, where the primary idea is to recycle and recirculate the feeding water. Successes associated with this system include the improved nutritional composition in okra (*Abelmoschus esculentus* L.) leaves and pods regardless of the growing condition. In addition, okra pods grown under trough culture system micro-plot enhanced the accumulation of quercetin 3-galactoside and quercetin 3-galactoside-7-glucoside. In a study conducted on comparing the ebb-and-flood system, it was found that the water supply time consumption of the U-type troughs was the lowest, accounting for 34.48% of that of the control troughs, and the rate of the T-type troughs was the second lowest, accounting for 55.7% of that of the control troughs; the variation in the water retention process was negligible, at<0.5%. In addition, experiments indicated that the U-type troughs supplied water at the highest rate and exhibited a high substrate water content, and it was determined that the U-type troughs achieved the highest irrigation efficiency, which was higher than that of the control troughs, and the lowest energy consumption, accounting for 18.57%-20.28% of that of the control troughs. The two studies exhibited the success of the trough culture system; however, as with the NFT, the disadvantage of the system is at most its design, which is a closed system, requiring a high caution on disease control associated with the feeding water or the recirculating nutrient solutions.	Gavri *et al.* (2023) Mokgalabone (2023) Sharma *et al.* (2023) Singh (2023) Zheng *et al.* (2022)

South Africa (Table 2). However, it is unknown how plants will respond under multistress conditions when grown using the eco-organic culture combined with silicon-based biostimulants. Therefore, the next section focuses on the common environmental abiotic stress factors affecting horticultural plants.

Common multistress factors affecting horticultural plants in South Africa

In nature, plants encounter an unpredicted combination of different stresses (biotic and abiotic) rather than a single stress, which presents an integrated reaction (Srinivasan *et al.,* 2022). Stresses can be grouped into three categories; single cell stress, multiple cell stress and combined cell stress (Pandey *et al.,* 2017). These stresses can be associated with herbivory, water scarcity/drought, high salinity, extreme temperatures, and soil mineral and pH deficiencies. For example, a critical feature of mechanical wounding can lead to water deficit stress, thus, the combination of water deficit stress and mechanical wounding increases the reactive oxygen species levels (Naveen *et al.,* 2023).

Observation from several studies also revealed that the molecular and metabolic responses to multi-combined factors are unique and cannot be extrapolated from plant response to individual stress (Kiremit *et al.,* 2023). Plant tolerance to abiotic stresses depends on factors such as the timing, duration, frequency, and intensity of stress as well as the affected tissues and the crop's development stages (Venugopalan *et al.,* 2022). In addition, Tadele and Zerssa (2023) reported that combined stresses cause severe damage to plants, and integrated treatments using silicon-based biostimulants may be a better strategy for mitigating the detrimental effects of these combined stresses.

Salinity and water deficit as moisture stress factors: Several studies suggest that salinity-related signalling may act even before biophysical changes in cells occur (Rout *et al.,* 2023). It is well understood that the signalling pathways that cause plants' responses to various stresses are highly interconnected on multiple levels. Plants have evolved diverse stress-responsive signalling pathways and defense mechanisms to adapt to drought and salinity stresses. Plants can use multiple stress perception and signal transduction pathways, which can crosstalk at various points along the pathway signalling (Ma *et al.,* 2020). When

Table 2. Common eco-organic soilless culture employed globally

Eco-organic culture type	Yield and quality parameters improved	Citation
Organic cultivation systems (eco-friendly planting strategy)	On rice (*Oryza sativa* L.), organic cultivation increased grain 2-AP and amylose contents by 21.19–26.10% and 4.51–7.69 %, respectively, compared with inorganic cultivation. The results of untargeted flavoromics showed that organic cultivation caused the absence of 56 volatiles and the exclusive presence of 10 new volatiles compared with inorganic cultivation.	Shaoyi *et al.* (2023)
Eco-organic friendly practices (poultry manure and mineral fertilizers)	On cucumber, the cultivation system enhanced the growth and productivity integration of poultry manure and mineral fertilizer.	Sallam *et al.* (2021)
Eco-organic-chemical mix fertilised (Combination of organic and chemical fertilisers)	On sugarcane (*Saccharum officinarum* x *spontaneum*), the eco-organic-chemical mix fertilizer along with the plant growth promoting rhizobacteria increased the yield (18%), and sucrose yield (12%).	Paungfoo-Lonhienne *et al.* (2020)
Eco-organic friendly practices (manures and biofertilizers)	In a study conducted on potatoes, organic potato (*Solanum tuberosum* L.) production was reported to be efficient with a yield of 45 tons per hectare in the Netherlands following appropriate scientific eco-organic friendly practices with an emphasis on organic nutrient supply through available manures and biofertilizers.	Ojha and Saha (2016)
Various organic fertilizers raios	Results on tomato varieties revealed that using different types of organic manure increased the yield and quality parameters of tomato varieties. For instance, the growth parameters of tomato varieties revealed that the chicken manure significantly impacted the sun cherry variety's leaf area, the Isabella F1 variety's plant height and root length, Lelord's fresh and dry weight of the roots, and the Sadia F1 variety's fresh and dry weight of the leaves. The Isabella F1 variety's stem diameter expanded noticeably after being treated with agro-fish pellets. When treated with agro-fish pellets, the sun cherry tomato cultivar produced more blossoms and fruits.	Kalbani *et al.* (2016)
Vermicomposts, chick compost, and horse compost	Vermicompost increased the yield and the Vitamin C content when compared to other treatments on tomatoes. Vermicompost had the highest sugar/acid ratio, available N and P contents in soil and increased the activities of acid phosphatase, catalase and urease in soil compared to the other treatments.	Yang *et al.* (2015)
Mineral and organic fertilization	Compared to lucerne (*Medicago sativa* L.) fertilized with mineral fertilizer, the dry mass yield of lucerne fertilized with dung was 15.9% greater. The lucerne crop was more stable when fertilized with organic matter, according to the sustainable yield index. The nitrogen in dry root mass/nitrogen in dry aboveground mass ratio and plant available nitrogen was higher in plants treated with manure.	Vasileva and Kostov (2015)
Eco-organic soilless culture	Organic cultivation substrates could increase lettuce yield compared with the control (sand soil with sheep manure and Me-Ting substrate from Taiwan).	Song *et al.* (2013)
Eco-organic soilless cultivation system	In melon (*Cucumis melo* L.) the cultivation system showed a greater potential in yield and quality than the control in Ningxia.	Cao *et al.* (2011)
Eco-organic soilless culture system	Results on cucumber (*Cucumis sativus* L.) showed that dry swine waste (166.7g $NHnH_2PO_4$) at 16.7g per plant and dry swine waste 100g ($NH_4H_2PO_4$) at 10g per plant had the higher plant growth, chlorophyll content, carotenoidse content and photosynthesis rate compared to the nutrient solution treatment.	Gao *et al.* (2006)

drought and salinity occur concurrently, plants can exhibit strategic defense responses that differ from the response to either individual stress (Ma *et al.,* 2020). However, in addition to dehydration, plants suffer from ionic stress during long-term salt exposure, which causes leaf senescence and photosynthesis impairment (Ma *et al.,* 2020). Heavy roots may accumulate more chloride when subjected to long-term salinity stress (Khetsha and Sedibe, 2015; Sedibe *et al.,* 2013).

Wounding and herbivory as morpho-physiological stress factors: Herbivorous insects are a major biotic stress threat due to their variability in attacking the plant. Plant mechanical wounding is an uncomplicated and measurable procedure to study the effects of mechanical stimulation and is also known as simulated herbivory because researchers use automated means such as razors, needles, hemostats, punchers, fine-grained sandpaper for wounding leaves and so on to generate damage patterns in plant tissues like those caused by insect species (Meents *et al.,* 2020; Cunha *et al.,* 2023). However, several studies revealed differences between natural herbivory and artificial because of the recognition of insect salivary compounds (Guan *et al.,* 2022). Plant wounds cause cell wall integrity loss, nutrient loss, and dehydration (Chen *et al.,* 2020). Midribs are the key veins necessary for the transport of water to leaves, therefore their injury leads to secondary water desiccation stress different from wounding stress in leaves (Wang *et al.,* 2023).

Nutrient deficiency as a growth and development stress factor: Phosphorus deficiency is a major abiotic stress that limits plant growth and crop productivity throughout the world (Jalal *et al.,* 2023). It is associated with highly weathered soils, a high capacity to fix phosphorus in forms that are generally unavailable to plants, and low fertilizer use particularly in areas commonly inhabited by resource-poor farmers. Phosphorus plays a critical role in energy reactions in the plant. Deficits can influence essentially all energy-requiring processes in plant metabolism (Lu *et al.,* 2023). Phosphorus stress early in the growing season can restrict crop growth, which can carry through to reduce final crop yield. Plants respond to phosphorus deficiencies by adaptations that increase the likelihood of producing some viable seed. The adaptations increase the ability of the plant to access and accumulate phosphorus and include modification of rhizosphere pH, diversion of resources to root production, increased root proliferation in high-phosphorus regions, and formation of associations with vesicular-arbuscular mycorrhizae (Peterson, 2020).

Soil pH, density, and pot size as growth and development stress factors: Human activities, irrational fertilization, intensive farming, and atmospheric deposition contribute to the formation of acid soils, leading to reduced plant yields and quality (Liu *et al.*, 2023). Additionally, climate change, characterized by high rainfall, releases weak acidic compounds, further acidifying the soil. Soil acidity, with a pH below 5.5, limits nutrient

Table 3. Commercially available silicon-based biostimulants as declared on the labels

Silicon-based biostimulant Product	Yield and quality parameters improved	Citation
Si-NPs (Si nanopowder)	The results presented proof of the stress-relieving properties of the silicon-stabilized hybrid lipid nanoparticles and are a proof-of-concept for the use of the phyto-courier nanotechnology in horticultural applications, and this was shown on tomato in this study.	Guerriero *et al.* (2023)
Silica SiO_2/Sodium silicate ($NaSiO_3$)	Silicon enhanced the quantum yield of photosystem II and chlorophyll content in potatoes (*Solanum tuberosum* L.).	Wadas and Dębski (2022)
Silicon (Sitam™)	The number of grains per pod and biomass was increased significantly at the 1% level by silicon application on canola (*Brassica napus* L.).	Payman *et al.* (2022)
Si biostimulant (SiO_2)	Silicon-based biostimulant to be demonstrated to improve growth and development of watermelon (*Citrullus lanatus* (Thunb.) Matsum. & Nakai).	Bantis *et al.* (2022)
Si-based biostimulant formulation (Omnia Group Ltd.)	Si-based biostimulants could alleviate salinity stress in tomato plants through modulation of the primary metabolism involving changes in the tricarboxylic acid cycle, fatty acid, and numerous amino acid biosynthesis pathways, with further reprogramming of several secondary metabolism pathways such as the phenylpropanoid pathway, flavonoid biosynthesis pathways including flavone and flavanol biosynthesis on tomatoes (*Solanum lycopersicum* L.)	Chele *et al.* (2021)
Optysil	Optysil had a significant effect on above-ground plant biomass and leaf area in the warm and arid growing season.	Wadas (2021)
Sika (72% silicic acid, Siben Ltd) and Potassium silicate ($NaSiO_3$)	Results in this study showed that the Si (v/v) at 0.5 and 1.5% Si (v/v) improved the plant height, number of leaves and chlorophyll contents of tomatoes grown under salinity stress.	Ghani *et al.* (2021)
Agribooster™	Silicon improved growth and yield parameters such as the chlorophyll and carotenoid content of onions (*Allium cepa* L.)	Rangwala *et al.* (2019)
Sodium silicate ($NaSiO_3$)	Si influenced the antioxidant system of barley (*Hordeum vulgare* L.).	Vega *et al.* (2019)

availability for plants, causing deficiencies in phosphorus, nitrogen, potassium, calcium, and magnesium, while increasing toxicities of hydrogen, aluminum, and manganese (Khoshru *et al.,* 2023; Moloantoa *et al.,* 2023; Peterson, 2020). Acidic soils also inhibit root growth and decrease the activity of beneficial soil microorganisms (Xie *et al.*, 2023).

Particle size distribution is vital in describing a material's physical characteristics and its suitability for plant growth. Bulk density measurement is crucial for understanding other substrate characteristics such as aeration space, total porosity, and available water (Liao *et al.,* 2022; Sekaran *et al.,* 2022). Low total porosity and substrate volume require precise irrigation management to avoid water deficit (Bañón *et al.*, 2022). Increasing bulk density reduces porosity and aeration space while increasing available water and remaining water in the substrate. Substrate density and potting size influence root formation, leading to densely branched and matted root systems in small pots (Çekin *et al.,* 2023).

Silicon-based biostimulant as an alternative strategy to grow plants grown under multistress: Several research studies have been conducted, most of them focused on the genetic modification of crop plants to achieve more crop resilience against abiotic stress factors such as water deficit, soil acidity, phosphorus deficiency and other related stress. However, there has been a swift shift in modern agriculture focusing on more organic, eco-friendly, and long-lasting systems to improve crop yield. As such, extensive research into the use of microbial and non-microbial biostimulants has been at the core of agricultural studies to improve crop growth and development, as well as to attain tolerance against several biotic and abiotic stresses. Silicon biostimulant is one of the alternative solutions to crop production such as beetroot, lettuce, tomatoes, and kale grown under multi-stress conditions in South Africa. Silicon can be applied as a biostimulant through foliar spraying, incorporation into the soil, or fertigation. The foliar application of silicon is more effective than the soil application (Wadas, 2021). The beneficial effects of foliar silicon application on plant growth under stress conditions have been reported on for several agricultural and horticultural plants, including rice, wheat, canola, sugar beet, tomato, cucumber, and onion (Wadas, 2021). There is insufficient knowledge of the effect of silicon on beetroot, lettuce, tomatoes, and kale grown under multistress. However, recent studies on the effects of silicon-based biostimulants are recorded in Table 3, corroborating the potential effects of the stimulant on multistress plants using eco-organic systems.

To enhance the growth of commercially viable vegetables in South Africa under severe multistress conditions, research should prioritize the efficacy of silicon-based biostimulants. Specifically, investigations should focus on eco-organic production systems for beetroot, lettuce, tomato, and kale. Key studies should include: (i) Assessing optimal application concentration, frequency, and type of silicon-based biostimulant for tomatoes in eco-organic soilless culture; (ii) Evaluating the efficacy of silicon-based biostimulants in enhancing the growth and yield of tomatoes under combined pruning and salinity stress; (iii) Examining the impact of silicon-based biostimulant concentrations on the recovery of lettuce under multi-abiotic stress in an eco-organic soilless culture.

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