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Research Article

Response of Black Nightshade to Different Cropping Systems and the Effect on Physiological Parameters and Mineral Composition

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In southern African countries, production of indigenous leafy vegetables is commonly practiced at home garden and/or commercial level due to their significant contribution toward eradication of hunger, food insecurity, and malnutrition. Black nightshade (*Solanum nigrum* L.) is among African leafy vegetable (ALV) highly recognised for its pharmacological and nutritive benefits. Several research have shown that ALVs can be cultivated in the open field or greenhouses, however, little information is available on the changes of the agronomical parameters and mineral composition. The aim of the study was to compare the physiological parameters and mineral composition of nightshade grown in the open field vs. greenhouse cropping systems. The results of the study revealed high-leaf area and relative chlorophyll content in the open field conditions while plant height and the number of leaves were reportedly higher under the greenhouse system. Minerals elements such as magnesium, copper, manganese, iron, zinc, and aluminium were significantly higher in the open field cropping system, while greenhouse cultivation recorded higher sulphur and boron. Notably, no significant amount was observed in calcium, phosphorus, potassium, and sodium between open field and greenhouse system. Furthermore, a significant amount of total nitrogen was reported in the open field, however, no significant difference was observed in moisture and ash content for both cropping systems. In conclusion, black nightshade cultivated in open field provided higher leaf chlorophyll, leaf area, and trace elements compared to greenhouse cultivation while macro minerals concentration had no significant difference in both cropping systems.

1. Introduction

Food security, malnutrition, hunger, and poor household livelihood continue to be major challenges in sub-Saharan Africa (SSA) for centuries [1, 2]. According to the sustainable development goals centre for Africa (SDGC/A, 2017) [3], food demand in Africa is expected to increase by over 60% by 2050 due to improvements in healthy nutrition and population growth which is expected to reach 9.7 billion by 2050 [4]. Climate change is predicted to significantly affect arable land health and agricultural output which ultimately magnifies the pressure on agricultural lands to meet the growing food demands [5, 6]. As a result, the increased consumption of African leafy vegetables (ALVs) was reportedly proposed as a key to the sustainable solutions to address the burden of micronutrient malnutrition and hunger among the rural populations of SSA [7, 8]. ALVs are reported to contain higher nutritional benefits in comparison with exotic leafy vegetables [9]. A study by Managa et al. [10], revealed that raw nightshade leaves contain 199 mg/100 g Ca and 12.8 mg/100 g Fe while Chinese cabbage has 27–31 mg/100 g Ca and 0.5–3.5 mg 100 g Fe higher than raw spinach (which contains 99 mg/100 g Ca and 2.71 mg/100 g Fe) and cabbage contains Ca 40 mg/100 g and Fe 0.47 mg/100 g [11]. Consumption of phytonutrient-rich ALVs on a daily basis was recommended by the World Health Organisation, in accordance with the United State Department of Agriculture [12] recommendations of one cup (~237 g) of raw or cooked vegetables, to reduce the global disease burden such as chronic diseases, non-communicable diseases (NCDs), primarily cardiovascular diseases (CVDs), and for Type 2 diabetes and cancer, two cups of raw leafy greens should be consumed every day [13, 14]. Among the ALVs that are commonly consumed in most parts of the rural communities in Africa include but are not limited to; African nightshade (*Solanum* spp.), amaranth (*Amaranthus* spp.), cowpea leaves and pods (*Vigna unguiculata*), spider plant (*Cleome gynandra*), mallow jute (*Corchorus olitorius*), African kale, (*Brassica carinata*), moringa (*Moringa oleifera*), and pumpkin leaves (*Cucurbita muschara*) [15].

Solanum nigrum L. (black nightshade) is a short-lived perennial shrub [16] that has been used for many centuries and is probably the second most popular and distributed ALVs after *Amaranthus* spp. in rural and peri-urban households in Africa [17]. Nightshade has evolved and become an important part of most people's diets over the years in most communities because of their potential contribution to poverty alleviation and nutritional security [18, 19]. Exploiting the potential of nightshade to address the above-mentioned challenges is important due to the anti-oxidative properties nightshade possesses that have the potential to act as a natural source for reducing cellular oxidative damage and suppression of various cancers, diabetes, and cardiovascular diseases [20]. The anti-oxidative properties found in nightshade vegetables are due to the presence of a diversity of secondary metabolites such as polyphenols and ascorbic acid [21], which contributes to positive health benefits [22]. In addition to containing high contents of plant secondary metabolites, nightshade leaves are rich in micronutrients such as β-carotene, folic acid, protein, vitamins C and E, minerals (iron, calcium, and zinc), and dietary fibre [19]. Although the fruits are not edible due to the alkaloid content, they are reported to have high levels of anthocyanins and are used as a natural source of dye or ink by children [23]. On the contrary Bvenura and Sivakumar [24], reported that ripe berries are consumed as a fruit or processed into a bread's spread jam.

Despite safety concerns of this crop, over the years in South African rural communities, the juice of the leaves and berries were used for medicinal purposes to treat various ailments such as headache, ulcer, diarrhoea, wounds, ringworms, and fever among other conditions [25]. Generally, edible parts of black nightshade include soft, tender leaves, fresh shoots, and succulent stems, the vegetable is consumed boiled or fried as a relish [26] with other ingredients, such as cooking oil, tomatoes, onions, peanuts, and even spices, are added to enhance the flavour and aroma [16], however, preparation methods vary depending on the individual's preferences. In South Africa, nightshade is normally cooked on its own and/or with supplementary vegetables such as Chinese cabbage, and *Amaranthus* spp., with an addition of tomato/grounded nuts and/or cooking oil for flavour. The cooking method includes several discarding of boiled extract to reduce the bitter taste. In African countries, the relish of the vegetable is accompanied by the main meal which is the carbohydrates staple such as pap/porridge in South Africa commonly referred to as "vhuswa" by VhaVenda tribe, "vuswa" by VaTsonga tribe of Limpopo Province, ugali in Kenya [27] and yam/coco yam porridge in Nigeria. Due to their highly perishable nature and seasonality, most of the leaves are dried under the sun or in the shade or fermented as preservation practices to increase their shelf life [19] and to use in winter period when in scarcity.

ALVs are primarily grown by smallholder farmers in rural areas and are an important source of food for poor households [28], with minimal use of agricultural inputs [29]. Investing in a crop such as nightshade has additional benefits, as it plays a crucial role in the local economy by generating commercial revenue, thus enhancing the general welfare of the local community [30, 31]. Compared to commercial vegetables, there is a great and/or deal of diversity among ALVs, which makes them suitable for production in the marginal agricultural systems typical of South Africa's rural landscapes. Maseko et al. [32] assessed drought and heat stress tolerance in ALVs and the results showed ALVs adapt to low-water availability and high temperatures. Because of their drought-tolerant and low-agricultural productivity, they can represent an important component of agro-biodiversity under the changing climatic conditions in South Africa [33]. Although their availability throughout the year and affordability makes them an alternative to high-priced off-seasonal vegetables [34], ALVs are not grown commercially on a large scale or sold widely, however, are cultivated, traded, and consumed locally [35]. The less availability of ALVs in the market also leads to questioning the level of consumer's acceptance of these vegetables. Therefore, there is a need for technological, environmental, and agricultural revolution to scale up food production systems to meet modern production efficiency [36] and the demand during the off-season. Commercialisation of ALVs will contribute significantly toward food demands to end hunger and poor nutrition [37] for Africa's growing population at a national level as highlighted in the sustainable development goals in SSA 2017. Furthermore, their availability in the commercial markets will also change consumer perception especially to those residing in the urban areas as these vegetables are considered poisonous, or weeds, in many parts of the world [38].

Production of nightshade and other ALVs in greenhouses has raised considerable interest in recent years as a way to enhance the production and monitor yield. The effects of environmental stress on plants are reported to stimulate the antioxidant compounds production [39]. According to Zhang et al. [40], greenhouses can increase agricultural production such as crop development and high yield per cultivated area if appropriate measures are taken as compared to those grown in the open field systems. Additionally, there is better control of weeds, pests, and diseases with efficient use of water and inputs in the greenhouse condition [41] as a result, crops develop with little risk because of the protective structure which is different from the crops grown in the open field system, which are subjected to uncontrolled environmental changes [42]. Hence, the study analysed *S. nigrum* L. grown in the open field vs. greenhouse cropping systems and the impact on agronomical parameters and mineral composition.

Table 1: Effect of open field vs. greenhouse cropping systems on agronomic parameters of *S. nigrum* L.

Variables	Cropping systems		SEM	LSD (5%)	F probability
	Open field	Greenhouse			
Leaf chlorophyll (SPAD)	103.1[a]	49.0[b]	2.12	8.34	<.001
Leaf area (cm^2)	6214[a]	1217[b]	910.7	3575.6	<.001
Number of leaves	24.3[b]	42.0[a]	1.55	6.07	<.001
Plant height (cm)	52.67[b]	59.67[a]	0.333	1.309	<.001

Note: Means within columns followed by the same superscript were not significantly different ($p \leq 0.01$). SEM is the standard error of means; LSD is the *t*-test least significant difference at 5% level.

2. Material and Methods

2.1. Experimental Areas. The open field trial was carried out at Itsani Matieni village, found in Thulamela Local Municipality under Vhembe District (Latitude: −22°9′47.86″; Longitude: 30°47′27.6″) with 550 m altitude, Limpopo Province, South Africa. The planting took place in the summer season when temperatures ranged between a minimum of 26 and a maximum of 32°C and annual rainfall of ±500 mm in October–March [43]. The experiment lasted for 4 months (October–December 2021) for both cropping systems. As described by Mthimunye et al. [44], the greenhouse pot experiment was conducted at the Science Campus, Horticultural centre, at the University of South Africa, Florida (GPS coordinates −26°9′29.274″; 27°55′17.663″). The minimum and maximum air temperature inside the greenhouse ranged from 7.4 to 44.9°C. During the planting period (October–December 2021) the average relative humidity was 68% inside the greenhouse.

2.2. Treatments. S. nigrum L. seeds were obtained from a reputable seed supplier. In both cropping systems, direct sowing in sandy loam soil was used as a planting method. The potting plant of 20 cm in diameter, with a height of 17.5 cm, and 20 cm width were laid at 0.3 m by 0.25 m inter- and intrarow spacing, respectively, as prescribed by Managa and Nemadodzi [43] with crop density established at 30 plants per 7 m^2. Cultivation was done without fertilisers as adopted from Van Rensburg et al. [45]. In both trial sites, plants were irrigated every 2 days, and weeding done as and when the need arose.

2.3. Sample Preparation. Healthy edible leaves of black nightshade from each cultivation system were randomly collected between 60 and 95 days (8-leaf stage) as prescribed by Medoua and Oldewage-Theron [46]. Thereafter, the collected leaf samples were transported to the laboratory at the University of South Africa. To preserve the leaves from spoilage, wilting, and yellowing, leaves were placed in an ice-packed cooler box. Leaves were detached, thoroughly washed with running water to discard the unwanted particles, and air dried at room temperature (30 ± 2°C) for 4 days until crisped according to Kachiguma et al. [47] and ground with a 500 W blender, (Russel Hobbs), manufactured in Shangai, thereafter used for nutritional analysis.

2.4. Agronomic Parameters. True leaves without defects were counted randomly and the leaf area calculated following a liner equation according to Mârzoca et al. [48] using the below formula:

Leaf area $(cm^2) = 0.52 \times (L \times W)$

Where: 0.52 = leaf shape coefficient; L = length of leaf (cm); W = width of leaf (cm) measured at half-length.

Leaf chlorophyll content was measured using a spectrophotometer (Konica Minolta SPAD-502 PLUS Chlorophyll Meter, 2 × 3 mm, −9.9 to + 199.9 SPAD) the non-destructive approach method was used to determine leaf chlorophyll in fresh, healthy edible leaves in (SPAD units) as described by Bvenura and Afolayan [49] and Zhang et al. [50]. Furthermore, plant height was measured with a tape measure as prescribed by Managa and Nemadodzi [43].

2.5. Chemical Analysis. Nutritional traits of leaves such as total nitrogen, moisture, ash, and minerals were determined by chemical analysis at the Agricultural Research Council Institute for Soil, Climate, and Water located in Pretoria, South Africa. Determination of total nitrogen was done following a dry combustion method as described by Matejovic [51] and Nemadodzi et al. [52]. A standardised method of the AOAC [53] was used to determine the ash, moisture content, and minerals composition such as phosphorus, potassium, calcium, magnesium, sodium, aluminium, iron, zinc, manganese, sulphur, boron, and copper.

2.6. Statistical Analysis. One-way analysis of variance (ANOVA) was used to obtain data from black nightshade grown in the open field and greenhouse cropping system with a software of Genstat 64-bit Release 20.1 Where differences were significantly observed, the mean separation was carried out using least significant difference test at 5% level.

3. Results

3.1. Agronomic Parameters. The significant influence of open field vs. greenhouse cropping systems on the agronomic parameters and chlorophyll content (SPAD units) of black nightshade is shown in Table 1 and Figure 1 below. The leaf chlorophyll content, leaf area (cm^2), number of leaves, and stem height (cm) showed significant difference ($p \leq 0.01$) between the two-cropping conditions. *S. nigrum* grown in an open field exhibited the highest leaf chlorophyll of 103.1 SPAD values and a larger leaf area of 621.4 cm^2 (see Table 1). On the contrary, greenhouse grown *S. nigrum* attained the lowest chlorophyll content of 49 SPAD values and leaf area of 121.7 cm^2. Furthermore, the findings demonstrated that the two-cultivation system differed significantly ($p \leq 0.01$)

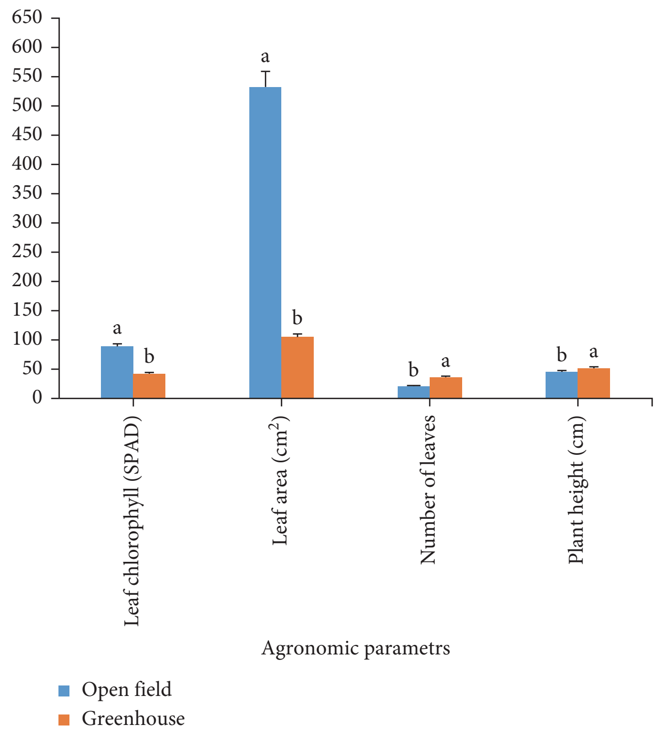


FIGURE 1: Effect of open field vs. greenhouse cropping systems on agronomic parameters of *S. nigrum* L. Bars with similar alphabetic letters for cropping system are not significantly different at $p \leq 0.01$ according to Fisher's LSD test.

TABLE 2: Proximate analysis composition of *S. nigrum* L. grown in open field vs. greenhouse cropping systems.

Nutrient (%)	Cropping systems		SEM	LSD (5%)	*F* probability
	Open field	Greenhouse			
Total nitrogen	6.197^{a}	2.707^{b}	0.0474	0.1860	<.001
Moisture	4.17^{a}	4.95^{ab}	0.687	2.698	0.467
Ash	12.97^{ab}	13.03^{a}	0.176	0.693	0.802

Note: Means within columns followed by the same superscript were not significantly different ($p \leq 0.01$). SEM; LSD at 5% level.

on the growth of nightshade in terms of the number of leaves and plant height, whereby greenhouse condition had the highest number of leaves 42 and longer plant height of 59.67 cm as compared to the open-field grown plants which resulted in fewer leaves 24.3 and lower stem height 52.67 cm as shown in Table 1.

The comparison of agronomic parameters measured and recorded on nightshade grown in the open fields and greenhouse cultivated are shown in Figure 1.

3.2. Proximate Composition. The available moisture and ash concentrations in *S. nigrum* grown in the open field and greenhouse cropping systems were not significantly ($p \leq 0.01$) different from each other as shown in Table 2.

Proximate constituents of *S. nigrum* cultivated in two environmental conditions did not differ significantly ($p \leq 0.01$) as illustrated in Figure 2, however, total nitrogen was observed at the highest concentration of 6.197% under open-field growing conditions as compared to the greenhouse cropping system with a lower concentration of 2.707% of total nitrogen.

3.3. Minerals. The macro mineral contents of *S. nigrum* grown in the open field vs. greenhouse cropping systems such as C, P, K, and Na content were not significantly ($p \leq 0.01$) different as shown in Table 3. On the contrary, magnesium content was recorded as the highest (0.6940%) in open-field grown plants, while the highest (1.503%) sulphur content was observed in greenhouse-grown plants. The trace elements found in *S. nigrum* were significantly different ($p \leq 0.01$) among the cultivation systems. Notably, open-field cultivation system exhibited significantly ($p \leq 0.01$) higher contents of trace elements such as copper, manganese, iron, zinc, and aluminium. However, the available boron content was significantly ($p \leq 0.01$) higher in *S. nigrum* greenhouse grown than in the open-field cultivation system. Therefore, the trace elements of open-field crops are superior compared to the greenhouse-grown crops.

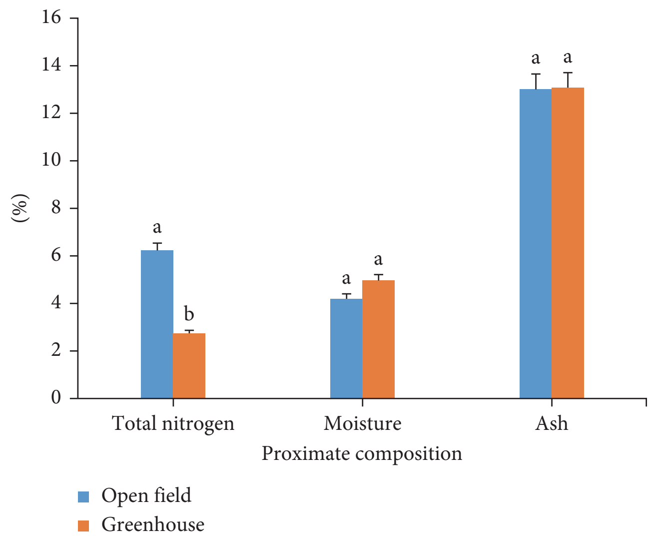


FIGURE 2: Proximate composition of *S. nigrum* grown in open field vs. greenhouse cropping systems. Bars with similar superscripts for cropping systems are not significantly different at $p \leq 0.01$ according to Fisher's LSD test.

TABLE 3: Variation in mineral composition of *S. nigrum* L. in the two cropping systems: open field and greenhouse.

Nutrient	Cropping systems		SEM	LSD (5%)	*F* probability
	Open field	Greenhouse			
Macro minerals					
Calcium (%)	1.183^{a}	1.017^{ab}	0.0145	0.0570	0.001
Phosphorus (%)	0.6143^{a}	0.5213^{ab}	0.01088	0.04270	0.004
Magnesium (%)	0.6940^{a}	0.4073^{b}	0.00475	0.01865	<.001
Potassium (%)	3.900^{ab}	4.570^{a}	0.1288	0.5056	0.021
Sodium (mg/kg)	350.3^{ab}	465.6^{a}	11.49	45.11	0.002
Sulphur (%)	0.634^{b}	1.503^{a}	0.0297	0.1166	<.001
Trace elements					
Copper (mg/kg)	16.97^{a}	12.87^{b}	0.488	1.915	<.001
Manganese (mg/kg)	78.93^{a}	24.97^{b}	0.211	0.828	<.001
Iron (mg/kg)	882^{a}	139^{b}	32.9	129.2	<.001
Zinc (mg/kg)	59.90^{a}	37.27^{b}	1.314	5.160	<.001
Boron (mg/kg)	27.03^{b}	37.27^{a}	0.636	2.497	<.001
Aluminium (mg/kg)	672^{a}	68^{b}	21.2	83.4	<.001

Note: Means within columns followed by the same superscript were not significantly different ($p \leq 0.01$). SEM; LSD at 5% level.

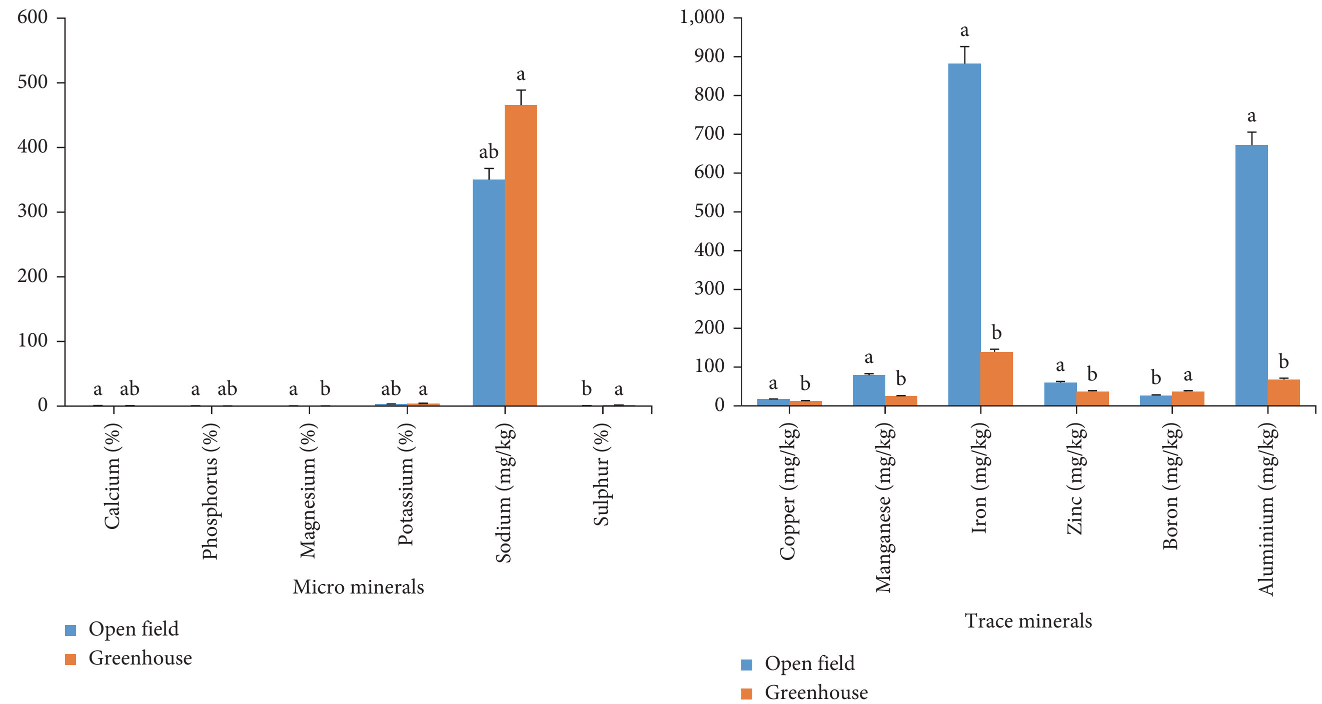
Figure 3 below shows the level of mineral composition found in black nightshade grown in the open fields vs. greenhouse cultivated.

The concentration levels of the trace elements are shown in Figure 3(b) (see below) where black nightshade grown in the open field had a significantly high Fe and Al as compared to the greenhouse cultivated.

4. Discussion

The lack of quality seeds has been a major hindrance to sustainable production and utilization of African indigenous leafy vegetables [54, 55]. Moreover, marketing of African indigenous leafy vegetables has been poorly organised, leading to significant product losses in transit or markets [56]. Exploring different cultivation systems is a promising method to promote utilisation and commercialisation via urban fresh-produce markets of these vegetables [19] while positively contributing toward food production and nutrition security [57]. Studies on the production of different African nightshade species in the open field are available, however, currently, no studies are available in the scientific literature on the comparison of cultivation of *S. nigrum* L. in the greenhouse vs. open-field cultivation system which makes the current study the first to conduct such comparison.

Chlorophyll is reported to be responsible for the green colour in fruits and vegetables [58]. Higher chlorophyll value of 60.34 SPAD units were recorded for *S. nigrum* in the trial conducted in the field by Bvenura and Afolayan [49] which is within the range of 103.1 SPAD units recorded in the current



(a) (b)

Figure 3: (a) Micro minerals of *S. nigrum* grown in open field vs. greenhouse cropping systems. Bars with similar superscripts for cropping system are not significantly different at $p \leq 0.01$ according to Fisher's LSD test. (b) Trace minerals of *S. nigrum* grown in open field vs. greenhouse cropping systems. Bars with similar superscripts for cropping system are not significantly different at $p \leq 0.01$ according to Fisher's LSD test.

study. However, when comparing results of similar studies conducted on different variety of nightshade in the greenhouse by other authors, the current chlorophyll values of 49.0 SPAD obtained in the greenhouse grown *S. nigrum* are in agreement with those reported by Bvenura and Afolayan [49] who reported 49.49 SPAD values. Concurrently, a study conducted in the greenhouse by Prehl [59] reported chlorophyll content values between 30 and 40 SPAD units in young *S. nigrum* plant leaves. On the contrary, Masinde et al. [60] reported higher chlorophyll values of between 40 and 70 SPAD units in the greenhouse-grown *Solanum villosum*. Notably, destructive or non-destructive chlorophyll methods determination may give different results. In the present study, SPAD-502PLUS that measures the absorbance in two wavelengths (400–500 and 600–700 nm) was used to measure the relative chlorophyll concentration in the leaves, therefore it is assumed that an increase in absorbance wavelength can be an indication of higher chlorophyll units in open-field grown *S. nigrum* as compared to the other open-field grown vegetables. Although no fertilisers were applied in the current study, several studies have reported that high-chlorophyll content in the plant cells are an indication of high nitrogen and therefore a good nutrient status of the plants [61, 62]. However, in our study, low-chlorophyll content observed in greenhouse-grown plants may be linked to fertiliser deficiency and high humidity and temperatures [63]. A study by Okello et al. [64] reported that *Solanum scabrum* had a higher leaf area of 304.45 cm^2 under greenhouse cultivation subjected to the different levels of irrigation water stress. Notably, the leaf area yielded by Ogembo Oyaro et al. [65] ranged from 120 to 130 cm^2 on two different African nightshades grown in a greenhouse is in accordance with the results of the present study. On the contrary, the results of leaf area (304.45 cm^2) obtained by Okello et al. [64] are higher than leaf area of 121.7 cm^2 obtained from the current study under the greenhouse condition. Leaf area development is directly related to the yield of African nightshades since the edible part is the leaf [64]. Evaluation of leaf area is an important parameter in understanding crop growth and yield potential, photosynthesis, water and nutrient use, and light interception [66]. A plant's growth is usually decreased by reducing cell elongation, which results in smaller cells and, consequently, a smaller leaf area. Wang et al. [67] reported that when comparing plant potential, the number of leaves is a vital factor to observe.

From our study, greenhouse-grown *S. nigrum* had the highest leaf numbers (42) recorded as compared to those recorded in the open field (25) per plant. Similar results were reordered in other ALVs such as *Amaranthus hypochondriacus* grown in the greenhouse condition where 44.8 leaves per plant were recorded after 98 days of planting while 26.1 leaves per plant were observed in the open field after 78 days of planting [68]. Smaller leaves of *S. nigrum* recorded in the open-field cropping system could be attributed to greater leaf hydraulic conductance responsible for photosynthesis [69] hence larger leaf area of 621.1 cm^2 was recorded in the open field. *S. nigrum* grown in the greenhouse system had a significant plant height of 59.67 cm which concurs to a greater extent with those by Kimaru et al. [70] who reported a 60-cm plant height of root-knot nematode non-inoculated *S. nigrum* plants grown under the greenhouse conditions. A study conducted by Bvenura and Afolayan [49] of black nightshade grown in a glasshouse reported the highest plant height of 54.33 cm, however, inorganic fertilisers were applied. In the study by Okello et al. [64] two varieties of nightshade measurements on plant height and *S. scabrum* variety exhibited taller plants (40.17 cm) under the greenhouse cultivation with different levels of irrigation. Benard et al. [71] reported the highest plant height 51 cm of African nightshade grown in the greenhouse where different concentration of superabsorbent polymers was applied. On the other hand, open-field plant height in our study resulted in a lower height of 52.67 cm compared to the greenhouse. Kirigia et al. [23] conducted an open-field study where plants height of 56.3 cm was recorded in African nightshade after 90 days of planting which surpassed the plant height reported from the present study. According to Kannan and Kulandaivelu [72], the decrease in plant height under the open-field cultivation can be attributed to low-cytokinin transportation from roots to shoots and/or an increase in the quantity of the phytohormone called abscisic acid. Deficiencies of abscisic acid hormone negatively cause change in cell wall extensibility which leads to a decline in photosynthetic enzyme concentration and reduce the plant growth [73]. Moreover, Anjum et al. [74] demonstrated that influence of environmental factors such as water stress and drought stress affects both elongation and expansion of the plant growth. Stress to the plant and more leaf senescence is reported to inhibit the efficiency of the translocation and assimilation of the photosynthetic products [75] and might have caused a reduction in plant height in the present study. It should be noted that environmental conditions and plant age at harvest influence variations in the chemical compositions of leafy vegetables, including the quantity of compounds that are useful and harmful to humans. In this study, both open field and greenhouse growing conditions showed lower moisture content of 4.17% and 4.95%, ash content of 13.97% and 13.03%, respectively, and there were no statistical differences observed between the two cropping systems. Low moisture is vital to protect dried samples from microbial infestation which negatively impacts physicochemical and shelf life [76]. In this study, the moisture content was low because the leaves were dried before analysis and the efficacy of the drying method used could have influenced the moisture content. Because the moisture content percentage was found in the dry milled samples, it indicates that freshly harvested leaves will contain a higher amount of moisture content [77]. High values of ash content have been reported to relate high-mineral composition [78]. The ash content of 10.18% recorded by Akubugwo et al. [31] is within the range of ash content obtained in this study regardless of the growing conditions. Ash content of other ALVs such as *Zanthoxylum zanthoyloides Herms*, *Vitex doniana* Sweet, and *Adenia cissamploides Zepernic* of Ebonyi State of Nigeria ranged from 8.74%to 5.12% [77] which is within the same range as the present study under the open-field cultivation. A study by Schmidt [79] comparing the yield and nutrition composition of tropical leafy vegetables, Solanum melanocerasum had the highest total nitrogen contents ranging from 6.04%to 6.74%, the results obtained are in accordance with that of the current study where 6.19% of total nitrogen was obtained under the open-field grown *S. nigrum*.

Quintaes and Diez-Garcia [80] reported that minerals in food are required for diverse metabolic functions. Although there were no significance differences noted among the macro minerals such a sodium, potassium, and calcium, they were noted to be the most abundant macro minerals in *S. nigrum* irrespective of the growing condition ranging from 465.6to 350.3 mg/kg, 4.570% to 3.900%, and 1.183% to 1.017%, respectively. Open-field grown black nightshade in this study showed higher magnesium content than greenhouse grown. On the contrary, higher sulphur content of *S. nigrum* was recorded in the greenhouse cultivation system. According to Raskh [81], high-calcium content in the leaves is significant due to the calcium needed by the cells in the body. More than 99% of calcium in the body is used as a structural component of bones and teeth [82, 83]. The calcium content in the leaves suggests that their consumption can increase the calcium level in the body and help in blood clotting process [84]. Moreover, Cochavi et al. [85] reported that calcium plays a major role in root system development associated with a better water and nutrient uptake in crops. Trace minerals such as iron, zinc, manganese, aluminium, and copper concentration were noted to be abundant in the open-field grown *S. nigrum* compared to the greenhouse cultivation system. Significant concentration of boron was higher in greenhouse condition. Sodium, iron, copper, and zinc obtained from the present study in open field and greenhouse conditions are within the same range as other ALVs such as *Amaranthus* hybridus and *Galinsoga parviflora* reported in the study conducted by Kissanga et al. [86]. Zinc content of 62.1 mg/kg reported from a field study conducted by Kirigia et al. [23] is within the range of zinc concentration of 59.90 mg/kg in the current study. According to Oboh et al. [22] zinc is involved in chlorophyll synthesis, which is important for the photosynthesis. Low concentration of zinc content in the greenhouse cropping system may be attributed to diversion of this mineral toward plant development. Khader and Rama [87] and Mamboleo et al. [88] reported that during fruit initiation and development, some metabolites for the cellular synthesis and growth substances are translocated from the leaves, stems, and roots to the developing fruits. Iron and magnesium play a major role in the metabolic processes that take place in human system and regulation of blood and is essential in the formation of haemoglobin and controlling of anaemia [89]. Jansen et al. [90] investigated the accumulation of aluminium in leaves of 127 species of *Melastomataceae*, 970 mg/kg in *Memycylon* spp. was reported which is a bit higher (672 mg/kg) to that obtained in this study under the open field condition. Kröppl et al. [91] measured the amount of aluminium in various tea powders (green, black, herbal, and fruit), which showed statistically significant differences in aluminium content of tea powders. Green and black tea contain high amount of aluminium 910 ± 31 and 760 ± 36 mg/kg, respectively. The findings reported by Kröppl et al. [91] are within the range of the current study. At high levels, aluminium inhibits prenatal and postnatal brain development in humans and animals, as it is highly neurotoxic [92, 93]. According to Schmidt [79], 100 g of leaves from the *Brassica* spp. and *Solanum* can be expected to add over 0.1 g of oxalate-free calcium and 3–4 mg of iron. Moreover, consuming ALVs by children, and pregnant women is reported to provide approximately 50%–75% toward the recommended daily intake of >400 g. Van Jaarsveld et al. [94] revealed that the abovementioned can prevent NCDs and micronutrient deficiencies such as vitamin A, iron, and zinc. From the current study, it was noted that *S. nigrum* can be a great source of essential minerals required to solve the risks of mineral deficiency in SSA [95]. Furthermore, the findings show that not only the type of plant substantially influences the mineral contents, but the location and the type of cropping system used play a huge role.

5. Conclusions

The findings revealed that the growth of black nightshade and mineral composition is highly influenced by the environmental (open field/greenhouse) conditions. Leaf chlorophyll content and leaf area on open-field cultivated performed better than the greenhouse grown. On the contrary, the leaf number and plant height were significantly higher in the greenhouse. The proximate analysis and essential macro minerals did not significantly differ among the two cultivation systems. However, it is worth noting that the higher concentrations of trace minerals were obtained in the open-field grown *S. nigrum*. The use of different cropping systems is important to close the gap of seasonality in black nightshade and increase consumers' demand for high quality and healthy vegetables while contributing to food security and income generation. Moreover, choosing a suitable condition, temperature, correct fertiliser, rate of application, and harvesting stage of ALVs are important. Future studies will include the use of advanced technological tools such as nuclear magnetic resonance and liquid chromatography-mass spectrometer to determine if different cropping systems will have an influence on the release of metabolites by the black nightshade.

Data Availability

All the necessary data are included in the manuscript. If required, additional data supporting this research article are available from the corresponding author.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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