Volume 22 No. 1
February 2022
ISSN 1684 5374

Afr. J. Food Agric. Nutr. Dev. 2022; 22(1): 19370-19385 https://doi.org/10.18697/ajfand.106.20040

PROSPECTS IN CULTIVATION AND UTILIZATION OF SPIDERPLANT (*Cleome gynandra* L.) IN SUB-SAHARAN AFRICA: A REVIEW

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ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 22 No. 1
February 2022
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

ABSTRACT

Spiderplant (*Cleome gynandra* L.,) exists as a semi-cultivated, indigenous leafy vegetable in sub-Saharan Africa (SSA). It has a natural habitat in the tropics and sub-tropics. The crop has the potential to contribute to sustainable food and nutritional security. This is due its richness in both macro- and micro-nutrients (minerals, vitamins and essential oils respectively). With its nutritional and ethnopharmacological uses, it is underutilized due to lack of awareness, promotion of production and utilization approaches globally. Globally, poor resource farmers are depending on such crops for income generation from economically fresh or dried spiderplant. Additionally, the potential contribution of spiderplant to pests and disease management can justify the need for its promotion in SSA. Spiderplant remains a primitive vegetable due to lack of the valorization units in Africa, which miss scientific information and indicators to understand how the cultivation and chemical compositions varies. Development of spiderplant in SSA requires all sectors to engage especially the breeders and consumers so that good agronomic traits can be achieved. All the biotic (response to field and storage pests and diseases) and abiotic stressors (nutrient use, salinity, drought) need to be addressed during spiderplant breeding program. Nonetheless, understanding the functional potential of spiderplant rhizosphere microbiome may promote sustainable bio-fertilizer-and-processing products in agriculture and related industries. Through value chain development, and technology transfer programs, the transformation of research efforts on spiderplant on the creation of sustainable collaboration frameworks for stakeholders in industry, innovations can be rapidly disseminated and popularized. Analysis of constraints and opportunities for orphan crops like spiderplant require the action and engagement of sectors such as farmer organizations, researchers, seed companies, traders, policy makers and consumers. This, therefore, justifies the need for promotional efforts through breeding, value chain development as well as development of national frameworks, which support orphan crops in SSA, aligning with the United Nations (UN) sustainable developmental goals (SDGs) in nutrition, health and food security. Little is known in most developing countries of SSA, on the cultivation, production, utilization and marketing of the vegetable across regions. This article examined the opportunities for the production, utilization, constraints as well as the promotional efforts of spiderplant in SSA.

Key words: *Cleome gynandra* L., indigenous vegetable, nutrition, health, production, utilization, breeding, policies

https://doi.org/10.18697/ajfand.106.20040

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 22 No. 1 February 2022 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

INTRODUCTION

Sub-Saharan Africa (SSA) has a wide range of plants among which are leafy vegetables growing in the wild. These wild vegetables have been reported to have high nutritive and medicinal potentials [1, 2]. Yet, there is still high prevalence of malnutrition and micronutrients deficiencies among the low-income poor resource communities. Effective utilization of wild vegetables like spiderplant (*Cleome spp.*), has been proposed as alternative solutions to address the problem of dietary deficiencies in SSA. Their importance is mainly as relish to accompany and complement starch-based diets [3]. They are also known to serve as supplements for food, which have the potential to improve the health status of well-being.

Spiderplant (*Cleome gynandra* L.) is a C_4 *monocotyledoneae* diploid plant in *Capparaceae* or *Cleomaceae* family with thirty, thirty-two, thirty-four and thirty-six (2n=2x=30, 32, 34 or 36) chromosomes depending on the genotype [4]. The plant consists of about 150-200 different *Cleome* species and 50 of them are known to occur in tropics and sub-tropics [1, 2, 4]. Spiderplant is a highly polymorphic herb, which grows up to 150 cm high, and commonly known as Sagati (Kenya), Gasaya (Nigeria), Esobyo or Eshogi (Uganda) and Nyeve or Ulude (Zimbabwe) and cat's whisker, African leafy vegetable or spider flower in English [5]. It is claimed to have originated in southern Asia, Africa and the Central America [6]. In Africa, the plant adapts well under both stable and disturbed ecological conditions.

In tropical and sub-tropical countries, as in SSA, more than 40% households are poor and exist on diets composed of staple cereals (maize, wheat, rice, teff), tubers (cassava, yams, cocoyam) and plantains [1, 2]. These food crops are generally low in micronutrients and the poor-resource families tend to suffer from malnutrition and other related ailments [6]. Spiderplant, which has a pivotal role in food security and nutrition, especially for rural people, are the readily available and cheapest source of nutrients [1, 7]. It is a rich source of nutrients comprising proteins, vitamins (A and C) and minerals (calcium, iron and sodium, iodine, iron and zinc) and these are available in limited quantities in most exotic vegetables [8]. Studies in plant biodiversity revealed spiderplant as a novel source of food, feed, protectant, shelter and medicine [9, 10].

However, the productivity of this vegetable is highly interfered seed dormancy, which affect plant establishment, density and yield. Yield of spiderplant plant defined by both leaf yield, which is a function of number of plants per unit area by leaf weight per plant and seed yield [11]. Due to limited knowledge on the agronomic performance under diverse environmental conditions, the medicinal, nutrition and plant protectant properties of spiderplant, could result in reduced adoption on cultivation and utilization globally [6, 10]. Socio-economically, the effect of low climatic conditions hinder the steady supply of fresh spiderplant leaves. For example, winter experiences low temperatures compared to summer, thus result in poor crop growth and development [12, 13]. Resource limited people suffer poor credit facilities and inactive policies which support cultivation, production and utilization of traditional vegetable crops [1, 9]. This manuscript, therefore, focused on spiderplant; it highlighted the opportunities

ajfand SCHOLARLY, PEER REVIEWED
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Volume 22 No. 1 February 2022
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ISSN 1684 5374

for cultivation and utilization, challenges in cultivation and utilization as well as awareness efforts in SSA.

OPPORTUNITIES FOR PRODUCTION AND UTILISATION OF SPIDERPLANT

Nutritional attributes of spiderplant

Spiderplant is a highly nutritive vegetable consumed in most parts of tropical Africa [6]. It occurs as cultivated, semi cultivated, weed, or wild plant having ecological, social, and cultural values in daily food and nutritional requirements [1]. Spiderplant is produced for it leaves stems and flowers developing from aboveground, which are rich in proteins, fibre, vitamins, trace elements and minerals [6, 9]. Although, its taste is quite bitter due to high phenolic compounds, there are unique features obtained through chemical analysis on mineral nutrition to quantify crude fibre, vitamin B and C, zinc and iron. Phenolic compounds are considered essential organic components of minerals and being present in trace amount, which improves the taste of spiderplant [10].

However, food insecurity and malnutrition remains a scourge in SSA [4]. Consideration of indigenous vegetables which are usually rich in minerals (Fe, Zn, Ca) and vitamins (vitamin A, B, C) that are often lacking in the diets of children and pregnant women is imperative [6, 10]. Although, chemical compounds in spiderplant are essential (phenolics, β-carotine, flavonoids, Oxygen Radical Absorbance Compounds), there are unique features obtained through chemical analysis on mineral nutrition to quantify crude fibre, vitamin B and C, zinc and iron [2, 7, 9]. Fresh spiderplant is rich in proteins, minerals and vitamins. These nutrients are lacking in many exotic leafy vegetables consumed in SSA [10], hence, spiderplant may become one of the highly nutritious neglected and underutilized vegetables [5]. The World Health Organization recommended daily intake of about 400g of vegetables and fruits per individual to increase health status [1, 14]. Therefore, the nutritional advantage of spiderplant over other vegetables offers opportunities for its promotion and utilisation. The old generation and poor people in SSA highly depend on and endorse traditional orphan vegetables as relish with nutritional component [3, 9]. Research revealed spiderplant as one of the orphan crops, which alleviate poverty and improve nutritional security [6, 8, 9]. The reason being high agricultural potentiality related to resource use efficiency, easy production and adaptation in different agro-ecological zones in tropical regions [15]. In countries like Mozambique, South Africa and Zambia, spiderplant is ranked and recommended first on their dishes, followed by amaranths, cowpeas (*Vigna unguiculata* L.) and others [3, 6, 12]. This vegetable is consumed as either fresh or dried [15], in such countries as well as east, central and west Africa. Others used the crop to make special dishes at traditional ceremonies in commemoration of ancestors; as well as sharing and demonstrating on production and cooking methods as well as marketing their products [5]. Chemical composition evaluated showed high percentages of minerals and trace elements compared to other exotic vegetables [12]. Table 1 summarizes the nutritional value of spiderplant and calculations were based on the modified analyses by scientists [6, 13, 14].

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Medicinal attributes of spiderplant

The *Cleomaceae* family, to which the spiderplant belongs, is a very important medicinal family, mainly comprising of herbs or shrubs often with an aromatic smell [16, 17]. It possesses oils that are mostly present in the seed and can be combined together in a ring or straight chain structure in a head to tail form [18]. The oil extracts therefore become valuable in cosmetic, flavouring, fragrance, perfumery, pesticide, and pharmaceutical industries [18, 19, 20]. Abdullah *et al.* [18] and Ayua *et al.* [21] clearly demonstrated that the spiderplant possesses anticancer, antibacterial, antimalarial, antidiarrhoeal, anti-schistomiasis, analgesic and anti-inflammatory properties. The cytotoxicity of the aqueous and ethanolic extracts, respectively, of the aerial parts of spiderplant against two human cancer cell lines, breast (MCF7) and colon (HCT116) adenocarcinoma was evaluated [22]. The findings by Abdullah *et al.* [18] showed high cytotoxic activities recorded against the two tested cell lines and compound 18-hydroxydollabela-8(17)-ene was the most active with the lowest IC_{50} value comparable to those of the anticancer drug doxorubicin [22]. Anti-cancerous property was also studied on Swiss albino mice against Ehrlich Ascites Carannoma. Findings showed that there was increased life span for affected mice by increasing CD4 count to normal level and decreased tumour weight and volume [15].

The antibacterial activity of both the leaves and flowers of spiderplant was investigated against *E. coli, P. vulgaris* and *Ps. aeruginosa* [15, 22]. Most tested bacterial species were inhibited, despite the varying degrees of inhibition observed ranging from 150–550 μg ml^{-1}MIC values. Other studies used the agar-well diffusion and the micro-dilution methods to assess the biological activities of spiderplant [18]. Their results showed that spiderplant has broad spectrum of antimicrobial activity exhibiting moderate activity against pathogenic fungi. The methanolic extract of *C. gynandra* showed anti-malarial activity in treatment and prophylactic in chloroquine sensitive infected mice since the extract has a high activity in both ways in a dose dependent behavior [24]. Additionally, it has been revealed that spiderplant has the anti-diarrhoeal potential following experimental models in rats [25]. The effective inhibitory activity against castor-oil-induced diarrhoea and PGE_{2}- induced enteropooling in rats occurred in gastrointestinal motility in the charcoal meal test in rats [18, 24].

Antischistomiasis activity of spiderplant on experimentally infected mice with *Schistosomamansoni* was evaluated [26, 27]. Results showed a reduction in worm burden (32.46%) and affected the viability of both mature and immature eggs as substantiated by increase in the percentage of dead eggs. Spiderplant extracts have analgesic and anti-inflammatory properties where high analgesic acetic acid-induced writhing and tail immersion tests was recorded at 200 and 400 mg/kg, p.o dosage against yeast-induced pyrexia [25]. Anti-inflammatory effect against carrageenan induced inflammation, induced polyarthritis and antipyretic activity against yeast-induced pyrexia [22, 27]. The ethanolic extract, which was given orally at a dose of 150 mg kg^{-1} body weight for 30 days to the induced arthritic rats per day, stabilized the lysosomal enzyme activities in the plasma and liver [18].

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Volume 22 No. 1 February 2022
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ISSN 1684 5374

Anti-insecticidal property of spiderplant

The vegetable has a plant protectant characteristic due to its insecticidal and repellent properties [5, 28]. Some secondary metabolites extracted from spiderplant can treat or control aphids (*Aphidoidea spp*.) and thrips (*Thysanoptera spp*) population in horticultural crops as well as *Heliothis armigera* in field crops of cotton [28]. For example, the presence of carvacrol oil, an essential oil containing a repellent compound and extract from mature seeds was found to be toxic to *Heliothis armigera* [3]. Volatile compounds produced include acetonitrite and glucosinolates, which exists *in vivo* with myrosinase enzyme, which hydrolyse glucosinolates [4, 5]. These compounds can suppress ovipositoning of diamond back moth adult in *Brassicae* species. Extracts can be tank-mixed with low dosage of synthetic pesticides to control crop pests [29]. Spiderplant has allelochemical effects assessed through bio-fumigation to suppress *Galinsoga parviflora, Bidens pilosa,* and *Gainsoga ciliate* weeds [28]. Kamatenesi-Mugisha *et al.* [29] studied spiderplant as live mulch in association with snap bean (*Phaseolus vulgaris* L.) and found it reducing thrips incidence compared to conventional pesticides. Intercropping spiderplant with sunnhemp (*Crotalaria juncea* L.), decrease African nightshade (*Solanum spp*), which is a non-edible weed, especially in fertile soils; and recorded the least arthropod damage [30].

Literature showed repellent and acaricidal features of spiderplant on larvae, nymphs and adults of ticks [15, 28]. High nematicidal activity was also reported with 72.7% Abbott's value on *Meloidogyne incognata* [19, 26, 28, 30]. Five percent of spiderplant leaf extract reduce mussel scales (*Lepidoptera piperis* Gr.) [29]. A leaf dipping bioassay method was adapted to assess the insecticidal activity of spiderplant in insect pest management. The result revealed high mortality rate of 3rd instar larvae of cotton leaf worm *(Spodoptera littoralis* L.) indicating anti-feeding effect [28, 30]. High concentration levels of phenolics, flavonoids and tannins were found in spiderplant [31]. These concentrations are useful in organic farming system, conventional agriculture and is recommended for both short and long cycle crops in nematode management [30, 31]. A concoction called *Likong* in Kenya obtained from leaves of spiderplant is orally given to livestock as a way of boosting their immune system [29]. There is need for researchers to explore the potential of spiderplant in livestock production and management as an opportunity for its cultivation, promotion and utilization. For instance, methanol extracts and volatile emissions of aerial parts of *Gynandropsis gynandra* have been shown to have a strong acaricidal effect, especially on the two-spotted spider mite *Tetranychus urticae* as well as on *Rhipicephalus appendiculatus* and *Amblyomma variegatum*, two livestock ticks occurring in Africa [28].

Socio-economic values of spiderplant

Since orphan crops like spiderplant have no traceable trading record internationally, it can play an important role in regional food security [14]. It benefit the communities due to its uniqueness, suitability and adaptabiltiy to the environment in which it has been produced. Studies showed that spiderplant is supplied in abundance during summer season and there is a steady consumption of traditional vegetables during the same period, thus income generating for many spiderplant producers [9]. Nonetheless, informal trade of these traditional crops specifically spiderplant is occurring, but, there

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is no statistical data that indicate how much has been exported or imported locally, regionally, or internationally [4, 12]. A survey by Voster *et al.* [32] reported the monetary values of local vegetables in South Africa, where the spiderplant was considered the first crop with high net income, followed by amaranths (*Amaranths spp*), black jack (*Bidens pilosa* L.), wild jute (*Corchorustridens spp*), *and Chenopodium album.* The SSA, for example Botswana, Malawi, South Africa, Zambia and Zimbabwe countries with well-known spiderplant producers have access to contracts with supermarkets, restaurants, lodges and hotels [9, 19].

A PERSPECTIVE GAPS AND CONSTRAINTS FOR THE CULTIVATION AND UTILISATION OF SPIDERPLANT

Gaps were reported in the cultivation and utilization of spiderplant across all developing countries of SSA. According to Hendre *et al.* [2], the focus on orphan crops like spiderplant can pose a significant challenge like reliable cultivation data, nutritional data, information on breeding technology and data on local and regional markets and value chain. The crop is under-researched and has received little attention although is now gaining more focus as publications are slightly increasing compared to other orphan crops like cowpeas [33]. This under-research may be due to poor funding for the crop development based on web of knowledge during 21st Century, but there is the potential to increase in research, development and commercialization of the crop [16, 17, 28]. To date, the African orphan crops consortium (AOCC), Forum for Agricultural Research in Africa (FARA) as well as African Researchers Network have not yet gathered enough information on spiderplant although partnerships and collaborations can better advocate all policy measures. There are also social biases or non-favourable reputation where the crop is considered a “poor-man’s” crop and consumed traditionally by the minority. In recent years, there is physical invisibility and conservation of spiderplant germplasm both wild, local endemic species and ecotypes, which are disappearing before they are seen for gene banks. Dawson *et al.* [34] revealed that missing data on spiderplant is one of the other major perspective gaps on how fresh or dried vegetables are marketed through local distribution channels that cannot easily be measured by governments or trade organization [35]. Interests in funding the crops such as spiderplant, which is not grown or traded worldwide, decrease its significance. People who consume spiderplant in SSA countries as a traditional food crop are unaccounted for in the global statistics [36]. As a green vegetable gathered wild or from cultivation, perception gap is close to 100 % [2]. The distribution is only to the poor-resource families and cannot support the whole population.

PROMOTIONAL EFFORTS OF SPIDERPLANT IN SSA

Breeding targets

Spiderplant played a significant role in livelihood, nutrition, health and socio-economic lives in SSA [33]. Through a network of international, regional, public and private partnerships and collaborations, a wide genetic diversity of spiderplant can be explored [2, 34]. Studies have revealed different agronomic activities of spiderplant, its adaptability and nutritional composition in different geographical locations whilst

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PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

others explored its genetic diversity [6, 8, 9]. Low genetic variance in quantitative traits were recorded, which were associated with plant height, pod number and length, as well as leaf and seed yield [2, 33]. This revealed the need for more collection and conservation of germplasm since this activity is decreasing, thus in turn, increasing genetic diversity of the crop. Nonetheless, limited National Gene Banks of Kenya, Tanzania and South Africa were reported to be active in the collection and conservation of germplasm [7, 8]. Technologies like reference genome sequence, transcriptome sequence, and re-sequencing accessions/species, using next-generation sequencing (NGS) technology can be used to achieve these targets [27, 33].

Collection and conservation of spiderplant genetic resources will widen the genetic diversity pool and rigorous studies on morphological and molecular characterization can ascertain a wide range of accession for cross breeding programs to improve beneficial traits. Also, yield and agronomic related traits such as delayed senescence, longer vegetative growth period can be developed [37]. Nonetheless, there is low exploitation and few literatures on spiderplant nutritional traits [7, 8], these studies revealed the bitterness taste of the crop, which is associated with phenolic compounds (contain one or more aromatic groups and hydroxyl groups) [4, 6]. Therefore, crop improvement should be geared towards the reduction of the concentrations of these compounds without compromising its nutritional and medicinal properties. Understanding the genetic variation of polyphenols and bitterness on spiderplant lightens the breeding programs when screening, which has impact on nutritional and medicinal value of crop [13, 16]. Nutrient-rich and low anti-nutritional factors especially through bio-fortification is very significant on high yielding genotypes breeding. As a result, the rate, intensity and degree of adoption of spiderplant by both local and regional communities in SSA can increase. Spiderplant, an orphan crop, is generally well adapted to tropical and subtropical environmental conditions; provided with sufficient information and data on economically important pests and diseases, effective field and greenhouse screening and laboratory techniques can be developed for identifying resistant or tolerant genotypes.

In addition, little is known in terms of regeneration and multiplication of the spiderplant from its different tissues as well as the media and hormones needed [27]. Therefore, biotechnological studies are needed to reveal and develop the protocols which induce rapid shoot and root development. During this process, transgenic studies can be explored through either physical, chemical or *Agrobacterium*-mediated transformation [28]. This may help to understand the transformation efficiencies within spiderplants and scientists can have a deep view of the plant's cell biology [2, 8]. Assessments on spiderplant's sister leafy vegetables such as *Brassica spp* on heat and drought tolerance can help to facilitate genetic characterization of these traits through prescreening of lines for further verification in the field [16, 33]. Salt tolerance breeding should be considered in breeding programs, since it is one of the continuous abiotic factors posing detrimental effect to most crop production. This should be carried out on spiderplant to understand its anatomical and physiological responses as well as specific ion toxicity and nutrition status as a strategy to find options which detoxify superoxide radicals [10, 13, 37]. Strategies for biotic and abiotic stresses should integrate both management and breeding technologies [38]. The breeding

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February 2022
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ISSN 1684 5374

programs seek to develop new high-yielding genotypes adapted to a wide range of climatic conditions in SSA and assessing the impact of agronomic practices on desired traits in critical aspects of multi-environment tests. Nevertheless, an understanding of the functional potential of the rhizosphere microbiome associated with spiderplant should be addressed as biological agents effective against spiderplant phytopathogens. The microbiota will improve spiderplant crop growth and development through production of phyto-hormones to allow the crop withstand heat, salt or drought stresses as there might be adequate nutrient supply. Therefore, Table 2 gives a summary of some of the significant traits, which can be developed as a promotional strategy of spiderplant in SSA and Africa-wide.

Value chain development, marketing and processing

There is a strong value chain in support of rural development and food security achieved through research value chain, production, agro-processing and marketing. The strategic intervention on spiderplant can make it more commercially competitive by genetic improvement. There is the need for transformation of research efforts on spiderplant. This should focus on concreting spiderplant productivity and maybe attained through collaborational frameworks with different stakeholders. Nonetheless, innovations in line with promotion of this crop can be rapidly achieved, leading to dissemination and popularization of the crop globally. Analysis of constraints and opportunities for orphan crops like spiderplant require the action and engagement of multidisciplinary and multi-stakeholders which include farmer organizations, researchers, seed companies, traders, policy makers and consumers.

Technology transfer and/or capacity building programs are required as a strategy to promote spiderplant where promotional campaigns, which emphasize the nutritional/health benefits and commercial opportunities. The creation and practices of best post-harvesting management, addressing issues on appropriate harvesting time, drying, packaging and branding, which ensure long shelf-life, need to be practiced.

Policies

The wide spread adoption of spiderplant is low; despite the efforts to improve dissemination of the plant by a wide range of institutes globally. These institutes are taking the initiatives towards research and development as well as capacity building where they train the lead African scientists to develop high yielding, nutritious, and climate-resilient orphan crop cultivars that meet African farmer and consumer needs [2, 8, 19]. In addition, these institutes implement such policies towards promotion and strengthening the utilization of spiderplant globally. Sogbohossou *et al.* [37] reported the importance of good seed stewardship, which can promote the use of the spiderplant seed across all farmers in SSA. One of the innovations in SSA is the use of government agricultural program schemes and national extension to ensure food self-sufficiency which provides access to credits. Implementation of sound policies for instance, making it compulsory for every seed company in the region to produce at least one traditional seed variety in order to increase seed availability and accessibility of these crops should be encouraged. Countries like Tanzania have national policies and local interventions with intense bearings on the opportunities and constraints that affect the nation but not towards food security and nutrition [12]. Also, at least one third of leafy vegetables produced for both local and international market in SSA countries should be traditional and/or orphan crops. The policies should also advocate for awareness campaigns, which promote the adoption of bio-fortification to alleviate the micronutrient deficiency in well-being.

CONCLUSION

Spiderplant has central important roles to the ecosystem. Its potential to health and alleviating malnutrition, hidden hunger especially for the resource poor farmers has been documented as this may increase in socio-economics of many livelihoods in most developing countries of SSA. Since the agronomic practices of spiderplant are the same as other exotic vegetables, it can be incorporated in smallholder farming and food systems. Efforts to develop lines through collection, conservation and exploration in breeding programs can help to further develop spiderplant. Nonetheless, gender inclusiveness in breeding programs can help to augment various strategies for the benefit of farmers. Sound policies, which support production of traditional vegetables such as spiderplant should be implemented. Demonstration plots should be done such that farmers can visually appreciate the similarity of yield, related agronomic performance and consumers' preferences between accessions. Considering high existing nutritional profiles, spiderplant provide a wide range of more nutritious food options for consumers and therefore have an obvious role in a food-system-diversification approach to improve diets. The mechanisms by which spiderplant support nutritional improvements can involve combinations of diversification and bio-fortification, as any change to an individual crop which can influence the balance of incentives for production and consumption of other crops compared to that crop. Understanding how the consumption and production of one crop influences the consumption and production of other crops is therefore an important research question in food systems. With its numerous benefits, spiderplant has the potential of becoming a major vegetable if well developed and promoted.

ACKNOWLEDGEMENTS

We would like to extend our gratitude to Mrs.T. Kujeke (Horticulturalist) and Knowledge Transfer Africa for valuable contribution during the preparation of this manuscript.

Table 1: Nutritional value of spiderplant per 100g edible plant portion

Status	Energy (KJ)	Protein (g)	Fats (g)	Carbohydrates (g)	Fibre (g)	Vitamin C (mg)	Crude Protein %	Ash %	Ca^{2+} (mg)	K^{+} (mg)	Fe^{2+} (mg)
Boiled/Dried	34	4.2	0.4	5.2	1.2	89.6	1.5	1.9	135	94	3.4
Raw/Fresh	41	4.8	1	6.3	1.3	89.6	1.5	3	288	111	6

Adapted from: Gonye *et al.* [6], Sogbohossou *et al.* [13] and WHO [14].

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Table 2: Breeding targets for spiderplant as a promotional strategy in SSA

Traits	**Current**	**Nutritional target**	**Medicinal target**	**Feed formulations**
Yield	3.2 t ha^{-1} [37, 39]	≥5 t ha^{-1}	≥5 t ha^{-1}	≥5 t ha^{-1}
Anti-nutrient factors (Phenolics, phytates, tannins, sarponins,oxalic acids, cynide)	7 mg $100g^{-1}$, <0.48%, >4%, >0.36% [1, 6, 40]	<7 mg $100g^{-1}$, >0.48%, 0.04-3.74%, >0.36%, >0.3%, >0.17% respectively	<7 mg $100g^{-1}$, >0.48%, 0.04-3.74%, >0.36%, >0.3%, >0.17% respectively	<7 mg $100g^{-1}$, >0.48%, 0.04-3.74%, >0.36%, >0.3%, >0.17% respectively
Vitamins (B and C)	1.1 µg/100g and 88.9 mg/100g respectively [1, 40]	1.5-2.5µg, ≥65 mg [34, 35]	1.5-2.5µg, ≥65 mg [34]	1.5-2.5µg, ≥65 mg [35]
Minerals (Fe^{2+}, Zn, Ca^{2+})	4.2 mg/100g, 3.6 mg/100g, 288 mg/100g [6, 7, 37]	15 mg, 15 mg, 1100 mg (35)	15 mg, 15 mg, 1100 mg [37]	15 mg, 15 mg, 1100 mg [6, 35]
Pest/Disease resistant	Moderate – high [31, 33]	High	High	High
Heat tolerant	Low [13]	Moderate-High	Moderate-High	High
Drought tolerant	Low 13, 40]	High	High	High
Salinity tolerant	Low	High	High	High
Days to maturity	45-60 [6, 37]	≥60 days for heat and drought escape	≥60 days	≥60 days
Consumer preferences	Fairly bitter [10, 20]	Low bitterness	Low bitterness	Low bitterness
Preference by birds	High [10, 40]	low	low	low
Nutrient use efficiency	High response to high NPK applications [2, 6]	High response to low NPK applications	High response to low NPK applications	High response to low NPK applications
Seed viability	65-75% [10, 11, 12, 15]	100%	100%	100%

*Calculations are based on daily intake ratio (DIR)

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ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 22 No. 1
February 2022
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

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