EVALUATION OF SPIDER PLANT (*Cleome gynandra*) GENOTYPES UNDER DIFFERENT NITROGEN FERTILISER APPLICATIONS IN KIAMBU COUNTY

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Evaluation of Spider Plant (*Cleome gynandra*) Genotypes under Different Nitrogen Fertiliser Applications in Kiambu County

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other university

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DEDICATION

This thesis is dedicated to my late mother Neddy Nabifwo, and my family at large for their unconditional love. God bless you!

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ACRONYMS AND ABBREVIATIONS

ALV	African leafy vegetables
AVRDC	African Vegetable Research and Development Centre
CAN	Calcium Ammonium Nitrate
DAP	Diammonium Phosphate
DAS	Days After Sowing
FAO	Food and Agriculture Organisation of the United Nations
Ha	Hectare
HCD	Horticultural Crops Directorate
kg	Kilogram
KES	Kenya Shillings
NPK	Nitrogen Phosphorus Kalium (Potassium)
MoA	Ministry of Agriculture
SPSS	Statistical Package for Social Sciences
SSA	Sub-Sahara Africa
UN	United Nations
WHO	World Health Organisation

ABSTRACT

Spider plant (*Cleome gynandra* L.) is among the traditional leafy vegetables whose consumption is increasing in Kenya. However, the limited availability of high-yielding genotypes and suboptimal fertiliser use are major causes of low yield, making it difficult for supply to match demand. New genotypes have been developed perhaps whose performance in Kiambu was unknown as well as their response to nitrogen. The objective of this study is to evaluate growth, yield, and preference of eleven spider plant genotypes as influenced by N application in Kiambu County. Field experiments and surveys were conducted during short and long rainfall seasons in 2011–2012 and 2021–2022 in Ruiru and Juja Sub-Counties to evaluate growth, yield and preference attributes of spider plant genotypes under different N rates and forms. In Ruiru, nine genotypes bred at World Vegetable Centre; IP3, MLSF17, MLSF3, P6, UGSF12, UGSF14, UGSF25, UGSF36, and UGSF9 were evaluated. In Juja, two genotypes, JKUAT and Simlaw, were investigated. Genotypes and N factors were investigated. Measurements were taken to quantify growth and yield in terms of height, number of leaves, and leaf area. Plants were sampled five times at 7-day interval. Farmer and consumer surveys — using questionnaires and key informants interviews (KIIs) — were undertaken to determine farmer and consumer preferences for these genotypes. Growth and yield data were analysed in GENSTAT software, and means separated using LSD at $\alpha = 0.05$, while survey data were analysed in SPSS, and genotypes ranked from 1–9 on performance. In Ruiru, the highest plant yields (36.49 and 95.20g) were recorded for plants supplied with 2.3g N/plant while the lowest (33.37 and 78.60g) were 2.6g N/plant in seasons 1 and 2 respectively. Season 1 had a very low yield compared to season 2, with the highest (34.20–40.27g) harvested for MLSF17, P6, UGSF14, UGSF25 and UGSF36 in season 1, and (84.75–94.00g) for MLSF17, MLSF3, P6 and UGSF9 in season 2. For Juja, the tallest plants (65.42–73.50cm) were manure, DAP+CAN, manure+CAN, manure+NPK, and NPK+CAN in season 1, and (82.74–92.60cm) for manure and manure+CAN in season 2. Interaction of fertilisers and genotypes was not significant in both seasons. Largest number of days to flowering (48.86–51.50 DAS) and (42.55–45.33 DAS) were observed for DAP+CAN and manure+CAN for both seasons respectively. Farmer and consumer surveys revealed that MLSF17, P6, UGSF14, UGSF36 and UGSF9 possess desired traits; medium to tall, high leaf area, and a high number of leaves. Simlaw genotype is highly preferred compared to JKUAT. Based on performance and acceptance, it is recommended that genotypes MLSF17, P6, UGSF14, UGSF36 and UGSF9 undergo onward protocol tests for distinctness- uniqueness-stability (DUS), and national performance trials (NPTs) for their release as new varieties, and farmers grow the Simlaw genotype using 2.3g N/plant in manure form or 2.6g N/plant as CAN. This study findings add a significant contribution to the management and production practices that enhance spider plant yield and achievement of the second Sustainable Development Goal (SDG) by 2030.

CHAPTER ONE

INTRODUCTION

1.1 Background Information

Spider plant, *Cleome gynandra*, is one of the African leafy vegetables (ALVs) whose consumption has grown progressively in Kenya. They are renowned for their high nutritional, medicinal and economic potential (Oniang'o *et al*., 2008; Mibei, *et al*., 2012; Onyango *et al*., 2013; Ayua *et al*., 2016; Letting *et al*., 2018; Zorde *et al*., 2020; Mushamaite *et al*., 2022). Consequently, and like other vegetables in general, acceptance of spider plant among farmers and consumers continues to grow. According to the Horticultural Crops Directorate (HCD) of Kenya's annual report 2021, production increased from 35,295 tonnes in 2020 to 36,445 t in 2021 (Table 1.1). Additionally, the area of land under production declined from 4,280 to 3,949 Ha over the same period. However, the yield per hectare increased with the decrease in land area as computed from 8.246 to 9.229 tonnes per Ha, perhaps because farmers continue gaining experience of growing spider plant as well as better access to new knowledge shared by researchers and extension workers (Ojiewo *et al*., 2010; Achiando *et al*., 2013; Odendo *et al*, 2023).

In Kenya, at least 90% of this crop is produced in Nyanza, Western and parts of Rift Valley counties (Table 1.2). The produce is mostly sold in urban and peri-urban centres, with significant quantities consumed locally (Abukutsa-Onyango, 2009). Additionally, it has shown good adaptability to harsh climatic conditions and tolerance to pests and diseases (Prasad *et al*., 2008). However, limited access by farmers to improved varieties and low fertiliser use are major causes of low yield. Thus, access to high-quality seeds is necessary to increase its productivity (Diouf *et al*., 2007, Onyango *et al*., 2013).

As demand for spider plant increases, its role in food security continues to be recognised by funding agencies, policymakers, educators, health workers, and other stakeholders. This increase in demand due to acceptance of existing genotypes as well as new ones attracts new farmers, while the current ones raise acreage and adopt intensive monoculture production systems that use fertilisers, manure, and irrigation. Earlier studies have revealed that spider plant responds well to mineral and organic fertilisers (Agong and Masinde, 2006; Minja *et al.*, 2008). This finding is corroborated by Kujeke *et al.* (2017), who reported a 20% increase in its fresh and dry weight due to fertiliser application. Nitrogen promotes vegetative growth, increasing fresh and dry above-ground biomass in leafy vegetables (van Averbeke *et al*., 2007). Mauyo *et al*. (2008) showed that applying N significantly ($P \leq 0.05$) increased plant height, number of leaves and shoots, and consequently leaf yield. Different N sources such as manure and CAN are also important because they influence spider plant growth and yield (Hutchinson *et al*., 2006; Schoenau, 2006; Ng'etich *et al*., 2012; Onyango *et al*., 2013).

There are various types of spider plant. Mauyo *et al*. (2008) reported the availability of four spider plant genotypes in Kenya ranging from green to purple pigmentation. This polymorphism in pigmentation in stems and petioles is due to differences in the accumulation of anthocyanins in tissues, specifically glycosides and acyl-glycosides that are classified under flavonoids (Mutua, 2015). However, there is inadequate information on difference in agronomic performance across different genotypes. In fact, the breeder (World Vegetable Centre) who provided the seeds did not provide any key characteristics of these genotypes, and all the names were coded. Thus, there was no baseline information available on the genotypes being experimented, and this was a major weakness of this study.

Table 1.1: Production of African Leafy Vegetables in Kenya — 2020–2021

Crops	2020 Area (Ha)	2020 Volume (t)	2020 Value (KES)	2021 Area (Ha)	2021 Volume (t)	2021 Value (KES)	% of Value
Cowpea	79,535	159,386	3,512,308,830	36,018	113,666	3,348,701,203	37.4
African nightshade	6,950	69,254	2,397,810,725	5,917	58,909	1,831,009,726	20.5
Spider plant	4,280	35,295	1,229,098,895	3,949	36,445	1,315,530,681	14.7
Leaf amaranth	3,996	54,813	1,322,286,150	3,237	38,172	831,076,886	9.3
Slender leaf	355	7,107	722,892,977	841	5,605	260,730,596	2.9
Pumpkin leaf	903	6,650	147,623,496	900	3,971	158,159,801	1.8
Jute mallow	672	5,894	309,079,967	657	3,373	155,029,483	1.7
Grain amaranth	453	3,020	178,728,617	511	2,459	127,453,939	1.4
Russian comfrey	75	644	19,460,000	163	1,354	50,321,660	0.6
Vine spinach	193	811	33,530,230	217	1,030	29,476,001	0.3
Malabar spinach	41	593	27,780,000	70	652	23,344,245	0.3
Others	1,487	31,022	350,836,860	1,755	38,030	813,596,889	9.1
Total	**98,940**	**374,489**	**10,251,436,747**	**54,235**	**303,666**	**8,944,431,110**	**100.00**

Source: HCD report (2021**)**

Table 1.2: Performance of Spider Plant in Selected Counties in Kenya — 2020–2021

	2020			2021			
County	Area (Ha)	Volume (t)	Value (KES)	Area (Ha)	Volume (t)	Value (KES)	% of value
Nyamira	752	9,480	358,250,000	820	11,010	319,100,000	24.3
Kisii	639	6,495	280,295,000	441	4,328	276,000,000	21.0
Homabay	572	3,263	90,266,111	520	3,040	115,151,500	8.8
Uasin Gishu	21	179	4,210,000	290	4,259	91,780,000	7.0
Migori	290	1,110	51,078,500	330	1,611	69,684,273	5.3
Narok	179	2,385	62,450,000	189	2,441	63,525,000	4.8
Busia	175	1,721	59,330,000	215	1065	63,000,000	4.8
Bungoma	210	1,135	71,530,001	175	1,990	57,105,875	4.3
Siaya	46	208	10,370,000	77	497	46,780,000	3.6
Bomet	96	1,334	27,040,000	111	1,473	39,400,000	3.0
Kericho	27	448	10,160,000	38	858	34,740,550	2.6
Kakamega	163	408	14,533,530	243	677	20,798,550	1.6
Kisumu	44	281	12,279,000	48	440	19,321,000	1.5
Nandi	42	291	12,394,571	53	358	14,567,282	1.1
Vihiga	304	1,113	32,550,000	59	261	13,630,000	1.0
Machakos	164	615	18,450,000	65	195	5,850,000	0.4
Baringo	40	171	4,320,650	44	158	5,250,000	0.4
Kiambu	20	128	4,660,000	21	114	3,160,000	0.2
Trans Nzoia	42	161	4,974,000	32	146	2,620,000	0.2
Others	454	3,769	98,957,532	178	1,524	54,067,201	4.1
Total	4,280	35,295	1,229,098,895	3,949	36,445	1,315,530,681	100.0

Source: HCD report (2021).

1.2 Statement of the Problem

As part of development, new spider plant genotypes have been developed but evidence in their response to N fertiliser is limited. These farmers face several challenges ranging from production factors, inadequate suitable genotypes, shortage and high cost of N fertiliser, inappropriate application of fertilisers, as well as form and rate of N fertiliser. With regard to performance, different genotypes respond differently to N fertiliser, which in turn influences their acceptance by farmers and consumers. These factors hinder spider plant production thus limiting it to kitchen-garden scale in Kiambu County, where only two genotypes have been collected as landraces (Appendix 1; FAO, 1996). Available genotypes such as JKUAT and Simlaw have limitations in growth, yield, farmer and consumer preference, and geographical location (Masinde *et al*, 2007; Mosenda *et al*., 2020).

Limited access by farmers to different N forms due to unavailability or unaffordability has led farmers to blend different N sources in adequate amounts so as to enhance production (Mushamaite *et al*., 2022). There is a variety of suitable fertilisers for spider plant production ranging from organic and inorganic types. Farmers also apply suboptimal N rates below 2.6g N/plant due to the high costs and unavailability of suitable fertilisers (Masinde and Agong, 2011; Ng'etich *et al*., 2012; Sowunmi and Oyedeji, 2019). The Optimal N range for spider plant production varies widely with soil characteristics, genotype, and geolocation. This N fertiliser applied can also be deficient in other essential minerals or cause nutrient unavailability through soil acidification (Hutchinson *et al*., 2006). The soil nutrient deficiency is a problem because it causes plant stress which induces and exacerbates bolting and leads to low yield (Wangolo *et al*., 2015). Wrong N rates, forms, and unsuitable genotypes exacerbate bolting.

Farmers and consumers have varying preferences for spider plant attributes ranging from morphology, yield, taste, appearance, colour, smell, and texture, which may vary under N application (Croft *et al*., 2014; Odendo *et al*., 2020). Attributes that are not preferred by farmers and consumers include low-yielding and early-flowering genotypes, plain recipes, and N forms which are prone to leaching. This problem can hence be elucidated as a knowledge gap existing in N fertiliser types, rates, genotype performance, and their preferences in Kiambu County. To address these problems, this study evaluated growth, yield, N fertilisers, and preference for genotypes, N fertilisers, and recipes.

1.3 Justification

This study makes an important contribution towards realization of the second Sustainable Development Goal for food security, aimed to end hunger and achieve food security by 2030. In line with this goal, farmer preference and availability of improved, high-yielding genotypes, as well as adequate and right forms of fertiliser use, are essential for increased spider plant production. Increased production is beneficial as it promotes food and nutrition security, creates jobs, and generates household incomes (Ojiewo *et al.*, 2010; Uusiku *et al*., 2010; Odendo *et al*., 2023). According to HCD (2021), a total yield of 36,445 t of spider plant generated a revenue of KES 1,315,530,681 was realised in 2021, compared to 35,295 tonnes harvested in 2020, worth KES 1,229,098,895. This rising trend in yield and revenue shows that increased spider plant production generates higher incomes for farmers (Musotsi, 2017; Odendo *et al*., 2023). On the other hand, HCD (2021) reported that farmers encounter low productivity venturing in new agro-ecological zones which are not suitable for spider plant production. The low yield is also inflicted by climate change (Mushamaite *et al*., 2022) and sub-optimal N application. New genotypes being tested have been developed with different attributes compared to the already established counterparts.

Nitrogenous fertilisers are used in many parts of the world to enhance leafy vegetable yields. Of importance are the form and application rates of the various sources of these fertilisers as they affect the yields of vegetables (Makaza *et al*., 2022). Farmer and consumer preferences for spider plant are gauged on the quantity and quality of the crop, which are also influenced by the form and amount of N supplied to the growing crop (Ng’etich *et al*., 2012; Mohamed, 2020) as well as recipes used for preparation (Habwe *et al*., 2010; Musotsi, 2017). Spider plant grown under adequate N produces high leaf yield and more attractive appearance, thus readily acceptable by farmers and consumers. Nitrogen contributes to amino acids and chlorophyll formation, which produce expanded dark-green foliage. On the other hand, N-stressed plants will be stunted with small, light-weight and chlorotic leaves. This study is therefore important, because it provides requisite knowledge about the N rates and forms as well as farmer and consumer preferences for high-yielding spider plant genotypes, recipes, and fertiliser forms suitable for production in Kiambu County.

1.4 Objectives

1.4.1 Main Objective

To study growth, yield and preference of eleven spider plant genotypes as influenced by N application in Kiambu County.

1.4.2 Specific Objectives

i. To determine the effect of N application on the growth and yield of eleven spider plant genotypes in Kiambu County.
ii. To evaluate the influence of N application on farmer and consumer preference for eleven spider plant genotypes produced in Kiambu County.

1.4.3 Hypotheses

i. Nitrogen sources and rates do not affect the growth and yield of eleven spider plant genotypes produced in Kiambu County.
ii. Farmer and consumer preferences for spider plant are not influenced by genotype attributes and N application.

CHAPTER TWO

LITERATURE REVIEW

2.1 Background Information

Spider plant, *Cleome gynandra* (L.), also known as the African spider flower or cat's whiskers belongs to the family Capparaceae. It originated in Tropical Africa, South East Asia, and Central America (Schippers, 2002; Mabhaudhi *et al.,* 2019), before dispersing over the tropical and subtropical countries in the northern and southern hemispheres by wind and migratory birds (Mavenghahama, 2013; Adeka, 2020). In Africa, it is typically found near human settlements under cultivation or growing naturally. It is produced from 0–2400 metres above sea level (Woomer *et al.*, 2003), with an average temperature range of 18–25°C. It is sensitive to water and N stress. It is day length-neutral with heliotropic behaviour to optimise light use efficiency during the daytime. It grows well in diverse soil types — from deep and well-drained sandy clay to loams— with high organic matter and a pH of 5.5–7.0.

Spider plant is an important African indigenous leafy vegetable, grown on subsistence and commercial scale under intensive and semi-intensive horticultural systems. Spider plant has economic and health benefits which have been explored comprehensively (Kimiywe, 2007; Ojiewo *et al*., 2010; Mushamaite *et al*., 2022). It has vital ethnopharmacological properties like repelling ticks and alleviating fever (Kwarteng *et al*., 2018; Makaza *et al*., 2022).

Different communities in Kenya produce spider plant in various ways. Western Kenya farmers intercrop it in kitchen gardens and use manure (Abukutsa-Onyango, 2007). Production remains small, with farmers being the main guardians of spider plant genetic pools and production skills (Masinde *et al*., 2007; Adebisi *et al*., 2013; Blalogoe *et al*., 2020). Sowing is mainly done by broadcasting and the seeds used are a mixture of varieties (Diouf *et al*., 2007). In Kenya, broadcasting is practised by 20, 40, and 60% of respondents from the Luhya, Luo, and Kisii communities respectively (Abukutsa-Onyango, 2007). Flower buds are regularly removed to encourage leaf growth and extend harvesting duration (Agong and Masinde, 2006; Mutua, 2015).

Leaving flowers intact acts as a sink for assimilates resulting in significantly reduced yield (Mutua, 2015). Farmers apply N to attain higher leaf yield (Agong and Masinde, 2006; Minja *et al.,* 2008), using conventional inorganic fertilisers like CAN for top dressing (Abukutsa-Onyango, 2009). Nitrogen rates between 100–250 kg N/ha (van Averbeke *et al*., 2007) were shown to increase fresh and dry above-ground biomass in spider plant. Spider plant is well-suited to environment-friendly farming systems like intercropping and organic farming (Masinde, 2003).

There are 313 genotypes worldwide (AVRDC, 2008), while Kenya has 128 samples in the Gene Bank (Appendix 1). There are four spider plant genotypes based on pigmentation currently grown in Kenya (Mauyo *et al.,* 2008; Omondi *et al*., 2015). These are green stem-green petiole, green stem-purple petiole, purple stem-green petiole, and purple stem-purple petiole. These colours were referenced in the Royal Horticultural Society (RHS) colour chart (2015) as purple-63A and green-140A, and have been ranked as an attribute in this study. These traits are key influencers of farmer and consumer preferences for spider plant.

2.2 Production Trends and Challenges

Continuing awareness creation on the benefits of spider plant has increased its demand and new entrants join farming to fill the gap. Most new farmers have limited knowledge and experience on best management practices like recommended N fertiliser use and genotype selection, and require appropriate information. Spider plant propagation, for instance, is primarily undertaken via seed, but germination is poor due to dormancy that limits sustainable production (Abukutsa-Onyango, 2007; Onim and Mwaniki, 2008; Ekpong, 2009; Makaza *et al*., 2022). A high seeding rate is required to achieve desired plant population posing a challenge where seed access is limited. The seeds are sourced from commercial seed companies or saved on-farm from previous crops (Onim and Mwaniki, 2008).

Land area under spider plant production declined from 4,280 to 3,949 Ha between 2020 and 2021. Nevertheless, the yield per hectare increased with the decline in land area from 8.246 to 9.229 tonnes per Ha. This is because farmers continue gaining experience of growing spider plant in addition to improved access to new knowledge as shared by researchers and extension workers (Ojiewo *et al*., 2010; Achiando *et al*., 2013; Odendo *et al*, 2023). On the contrary, individual farmers face decreasing productivity in new agro-ecological zones unsuitable for spider plant (HCD, 2021), which is also aggravated by climate change (Mushamaite *et al*., 2022) besides low N fertiliser usage.

Spider plant has high susceptibility to N stress, which has drawn particular interest in studying it. This is because existing knowledge of the effects of N on other plant species may not work for spider plant (Makaza *et al*., 2022). The crop is highly vulnerable to N deficiency stress besides having a limited number of genotypes available for farmers. Nitrogen stress causes significantly low leaf area, reduced dry matter production and bolting in spider plant at a very young age (Wangolo *et al*., 2015; Mushamaite *et al*., 2022).

2.3 Importance of Spider Plant

Spider plant is a valuable resource for food and nutrition security as well as household income generation, whose scientific selection and utilisation of new varieties is ongoing. It plays a significant role in food and nutritional security regardless of socio-economic status, from resource-poor households to affluent consumers (Uusiku *et al*., 2010). Over 98% of respondents grow this vegetable mainly for its nutritional (Appendix 2) and medicinal value (Onyango *et al*., 2013). It provides jobs and a source of income and livelihoods for many people along the value chain (Odendo *et al*., 2023), including seed merchants, farmers, middlemen, transporters, traders, consumers, regulators and processors (Appendix 3). Total spider plant sales in Kenya are worth KES 643 million, while Kiambu County generated KES 10 million (HCD, 2021).

Spider plant biochemical constituents and minerals have medicinal and well-being value against various ailments and disorders, and it is especially recommended for lactating mothers to boost milk production. Achiando *et al.* (2013) reported that consistent feeding on spider plant also shortens labour time, eases childbirth, and expedites post-maternal convalescence. Consumption of this vegetable by expectant women is almost mandatory in some communities in Kenya.

Surveys show that a paltry proportion of children and youth are involved in spider plant farming and consumption, probably because they do not own or have limited access to land. Besides land, they have inadequate capital to invest in real farming, thus prefer migration to urban areas in search for employment. They also engage in other activities for source of income, such as motorbike transport, online jobs, and betting. However, continuing awareness creation and knowledge sharing on social and mainstream media platforms persuade them to get involved and reap the benefits. Increasing consumer awareness of the dietary importance of spider plant has led to a rise in its demand (Ngugi *et al*., 2007; Irungu *et al*., 2008; Amaza, 2009; Chelang'a *et al*., 2013; Senyolo *et al*., 2014; Mushamaite *et al.*, 2022).

2.4 Nitrogen Fertiliser Use

Spider plant farmers apply different fertilisers — organic, mineral, and their mixtures — to optimise growth and yield. Optimal rates and forms of N fertiliser applied are important determinants of its efficacy, yet farmers under-apply due to cost and/or availability issues. As a leafy vegetable, Masinde and Agong (2011); Onyango (2013); and Kujeke *et al.* (2017) reported how critical N is for promoting spider plant vegetative growth by synthesizing chlorophyll and amino acids, and induction of leaf production. Nitrogen delays flowering, prolongs the vegetative phase, and grows dark-green and expanded leaf surface area influencing leaf area index and light interception. Nitrogen deficiency manifests as small, chlorotic foliage and induces stress that predisposes them to bolt and reduced leaf yield (Leghari *et al*., 2016; Mosenda *et al*., 2020). Spider plant bolts under N stress to form seed as a species survival adaptive mechanism (Mutua, 2015; Kujeke, 2017). Accordingly, vegetative growth attributes — height, canopy width, stem girth, branch and number of leaves, chlorophyll content, and leaf yield — improve with increasing N rates. This trend only applies up to a specific threshold beyond which N becomes phytotoxic (Masinde and Agong, 2011).

In a study by Hutchinson *et al*. (2006) in Elgeyo Marakwet County, four levels of manure; 5, 10, 15, 20 t/ha, and four rates of CAN; 100, 200, 300, 400 kg/ha were applied. Results showed that the addition of various rates of manure and CAN significantly improved vegetative growth and increased leaf yield. The yield harvested from plants under manure was higher than CAN. Application of 300 kg/ha CAN led to accumulation of nitrates in young and old plant tissues while manure did not affect the same. Additionally, these high N rates are uneconomical (Mwashasha *et al*., 2013), and undesirable because N metabolites (nitrate and nitrite) above acceptable daily intake (ADI) can have detrimental effects on the health (Luetic *et al*., 2023) of spider plant consumers. On this account, manure is a slow N releaser that results in lower N accumulation in plant tissues.

Nitrogen is a major component of nitrous oxide (N_2O) gas. The greenhouse gas has a high global warming and ozone-depleting potential of 300-fold that of carbon dioxide (Pittelkow, 2013). Thus, fertiliser N requires climate-smart handling practices by farmers to mitigate and reduce N_2O emissions (Mushamaite *et al*., 2022). Right N rate and form, and placement by incorporating in the soil are key considerations for managing wastage, phytotoxicity, leaching, denitrification, volatilisation, and eutrophication by soil testing (Roberts, 2008; Masinde and Agong, 2011; Mwashasha *et al*., 2013; Gong *et al*., 2020). Soil analysis is an important activity undertaken before and after the experiment to determine soil nutrient status, as part of materials and methodology. Excessive N supply is hazardous to human health when consumed since it can surpass the ADI for nitrate of 3.7 mg/kg body weight/day (WHO, 2012; Brkić, 2017). There is inadequate farmer knowledge about optimum N rates and forms for sustainable spider plant production in Kiambu County and beyond, which should be studied.

2.5 Genotypes and Preference Attributes

Farmers and consumers have preferences for different spider plant genotypes, N sources as well as recipes. The preferences are anchored on specific spider plant growth and morphological attributes such as yield, height, number of leaves, leaf size, stem and petiole colour, days to flower and recipes (Masinde and Agong, 2007; Ng'etich *et al*., 2012; Onyango *et al*., 2013; Nair and Maram, 2014; Mutua 2015). Preferences for different attributes were measured using the 9-point hedonic scale (Tuorila *et al*., 2008; Lawless and Heymann, 2013) and the 5-point Likert scale (Wichchukit and O'Mahony, 2015; McLeod, 2019; Sack, 2020). Hedonic/Likert scales are simple, effective data management tools that have been used widely by researchers across different fields. Application of correct N fertiliser rates and forms on suitable spider plant genotypes produces a high yield and is most preferred by farmers. Yield comprises the harvestable weight of spider plant tissues and organs — leaves, tender stems, flowers, and petioles — measured per plant or land area (Ng'etich *et al*., 2012). Yield is an important productivity component because farmers aim to optimise economic benefits from their investments (Muhanji *et al*., 2011; Dinssa *et al*., 2016). The two commonly available spider plant genotypes in Kenya used in this study in Juja Sub-County were JKUAT and Simlaw. Consequently, there are gaps in the limited number of suitable, more N stress-tolerant genotypes that farmers can access for different locations aggravated by climate change. These new genotypes were selected on the basis of suitability to be grown under Agro-Ecological Zone (AEZ) II in Kiambu County. Nitrogen fertiliser forms include different N sources such as manure, CAN, DAP, and NPK (Hutchinson *et al*., 2006). Manure is mostly preferred by farmers because it is more readily accessible on farms in most households, and it is effective when applied in adequate amounts (Mauyo *et al*., 2008; Ng'etich *et al*., 2012). However, the mineral N sources are purchased and may be limiting for low-income farmers due to high costs (Omiti *et al*., 2005). Besides low accessibility by farmers, mineral N sources are susceptible to losses such as leaching and volatilisation (Madan and Munjal, 2009; Onyango *et al*., 2013; Makaza *et al*., 2022).

2.6 Household Characteristics

Farmer and consumer household characteristics influence spider plant production and consumption behaviour. Consumer socio-economic status is important in commodity market assessment since it informs its purchase and consumption patterns (Oniang'o and Shiundu, 2008; Bett *et al.*, 2011; Muhanji *et al*., 2011; Onyango *et al*., 2013). Family attributes such as gender, age, marital status, household size, income, education, and access to land determine whether or not, and to what extent spider plant is produced and/or consumed (Tukei *et al*., 2022). Regarding gender, most of the decision making on spider plant cultivation as well as purchases are made by women as compared to men (Mundua *et al*., 2010; Odendo *et al*., 2023). On age, it has been reported that youth do not prefer spider plant as a vegetable compared with the adults

(Okeno *et al*., 2003). This can be attributed to inadequate cooking skills and the bitter taste of the vegetable which is not appealing to the youthful generation. Accordingly, married consumers are more likely to grow or purchase spider plant due to the obligation to feed their families, unlike those who are single. Married households have a responsibility to provide balanced diets for their families which most likely includes spider plant (Uusiku *et al*., 2010; Musotsi, 2017). There is a possibility that a family with high literacy and income would consume more spider plant as opposed to one without education and income because the former knows its benefits and can afford it. This observation was corroborated by Ngugi *et al*. (2007), Oniang'o and Shiundu (2008), and Muhanji *et al*. (2011) that as demand by spider plant consumers grows, the market prices often rise hindering purchases, especially during the off-season. Additionally, a large household size is likely to consume more spider plant compared with a smaller one. Finally, access to land — a major factor of production — implies that households can cultivate the vegetable for subsistence and sale the surplus (Mwangi and Kimathi, 2006; Figueroa *et al*., 2008; Ekesa *et al*., 2009).

High N fertiliser costs and limited access to high-yielding, stress-tolerant genotypes deter most low-income households from spider plant farming (Mauyo *et al*., 2008; Oniang'o and Shiundu, 2008; Ng'etich *et al*., 2012). Household knowledge of fertiliser rates and forms, and access to suitable genotypes and recipes are inadequate, yet paramount for prudent resource allotment and management for sustainable spider plant production (Okeno *et al*., 2003. Recipes are cooking methods developed and standardised, especially for relatively less known vegetables such as spider plant, to maximise its culinary activity consistent with high quality. Typically, recipe development is a process: cooking ideas are drawn by experts/consumers, and ingredients are selected and sourced (Westling *et al*., 2021). Well-balanced recipes have combination features such as flavour, texture, appearance and nutrients (Musotsi, 2017). Spider plant recipes are normally fortified by adding milk, coconut milk, peanuts, or other leafy vegetables to increase their nutrition content (Uusiku *et al*., 2010) as well as mask bitterness making them taste milder (Abukutsa, 2007; Sharafi *et al*., 2014). A significant proportion of consumers, however, prefer spider plant with this bitter after-taste (Okeno *et al*., 2003; Onyango *et al*., 2013)

CHAPTER THREE

MATERIALS AND METHODS

Field experiments and surveys were undertaken to determine the effect of N and genotypes on growth, yield, and acceptance of spider plant among farmers and consumers. Performance and acceptance are key factors in spider plant value chain that were deliberately selected in this study context. These studies were set up in two Sub-Counties of Ruiru and Juja in Kiambu County of Central Kenya, which is adjacent to the capital city of Nairobi. All these experiments were open-field. Ruiru trials were rain-fed while Juja was under drip irrigation, and were carried out for two seasons each.

3.1 Effect of Nitrogen Rates and Genotypes on Growth

Trials were conducted in Ruiru and Juja Sub-Counties in Kiambu County during short and long rainfall seasons in 2011–2012 and 2021–2022. These two sub-counties were purposively selected to represent the entire Kiambu County, cognizant that Kiambu has a total of 12 sub-counties. These two were chosen due to their strategic location proximal to JKUAT Main Campus, where the researcher is affiliated as well as the research project budgetary constraints The 10-year delay was due to mandatory sabbatical leave taken by the researcher.

Experimental Sites

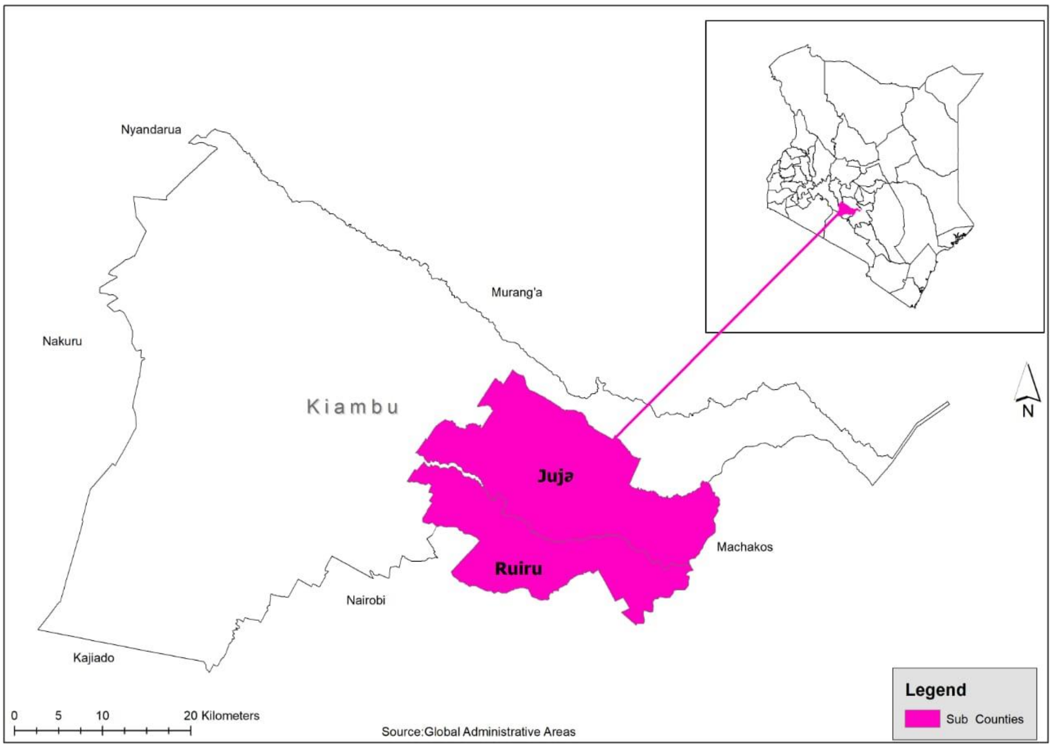

Figure 3.1: Map of Kiambu County Showing Study Sites

3.1.1 Ruiru Sub-County Trial

The trials were conducted on a farmer's field in Tatu Village of Gitothua Ward, Kiambu County (Figure 1) between October–December 2011 and April–June 2012; its geo-coordinates are 1.150˚S, 36.967˚E. This demonstration farm was selected at random from a list of spider plant farmers from this ward, provided from MoA database. The ward is centrally located near Ruiru town and it is easily accessible from JKUAT Main Campus, Thika, Nairobi, and Kiambu Township. This area is categorised under subtropical highland climate by the Köppen climate classification system and receives an average annual rainfall of 1,025 mm. It received rainfall of 256 mm and 543 mm in seasons 1 and 2 respectively. It has an altitude of 1,795 m above sea level with a temperature range of 10–26˚C. The diurnal temperature varied from 15–26 ˚C during the crop season. Soils are typically red on an undulating landscape. Major economic activities are dairy, coffee farming and horticulture (CIDP, 2023).

a) Experimental Design and Layout

Experiments were laid out as split plots in completely randomised block design (CRBD), with three replications (Figure 2). The CRBD was preferred because similar experimental units grouped into blocks or replicates have better control of possible variation emanating from the spatial effects in the field: each block sees each treatment exactly once, thus more precise than a completely randomised design (Kutubi, 2020).

Nitrogen rates were main plots while genotypes were subplots. There were nine genotypes (IP3, MLSF17, MLSF3, P6, UGSF12, UGSF14, UGSF25, UGSF36, and UGSF9) (Plate 1), whereby genotype P6 was the control plot because it grows naturally in this area, and the seeds were sourced locally. These new genotypes which have been developed were chosen for testing on the basis that they had potential to grow in Kiambu County, yet their performance as well as their response to N was unknown.

R1	N1A9	N1A5	N1A2	N1A4	N1A8	N1A6	N1A3	N1A1	N1A7
	N2A7	N2A1	N2A6	N2A2	N2A9	N2A8	N2A3	N2A9	N2A4
	N3A5	N3A3	N3A8	N3A4	N3A7	N3A9	N3A2	N3A6	N3A1
R2	N1A3	N1A8	N1A5	N1A7	N1A6	N1A9	N1A1	N1A4	N1A2
	N2A4	N2A9	N2A2	N2A8	N2A3	N2A5	N2A7	N2A6	N2A1
	N3A6	N3A1	N3A4	N3A7	N3A6	N3A9	N3A8	N3A2	N3A5
R3	N1A1	N1A7	N1A9	N1A5	N1A3	N1A4	N1A2	N1A5	N1A8
	N2A8	N2A4	N2A7	N2A1	N2A2	N2A5	N2A3	N2A9	N2A6
	N3A2	N3A6	N3A1	N3A4	N3A1	N3A8	N3A7	N3A3	N3A5

Figure 3.2: Layout of the Field Trials in Ruiru. Plots are Spaced 1 m Apart.

KEY: N1 = Manure; N2, N3 = CAN treatments; A1— A9 = Genotypes; R1—R3 = Replications

Nitrogen treatments were: N1 = 2.3 g N/plant (100 g/plant cattle manure), N2 = 2.6 g N/plant, and N3 = 5.2 g N/plant that were replicated thrice. These N rates were chosen on the basis of earlier trials and farmer practice. This range commonly used by Sub-Saharan African farmers as well as experiments which were previously done justifying these rates, including the mix of N and manure as optimal (Masinde and Agong, 2011; Makaza *et al*., 2022; Mushamaite *et al.*, 2022). Treatment N1 was well-cured cattle manure representing the farmer practice as control, and was sourced from the same farmer, who also keeps cattle. This manure was analysed for nitrogen and the results showed 2.3% N content. Treatments N2 and N3 were calcium ammonium nitrate (CAN) — a mineral fertiliser. The three replicates were set up concurrently under rainfed conditions, whereby 256 mm and 543 mm of rainfall were received in the first and second season respectively, with a temperature range of 10–26˚C.

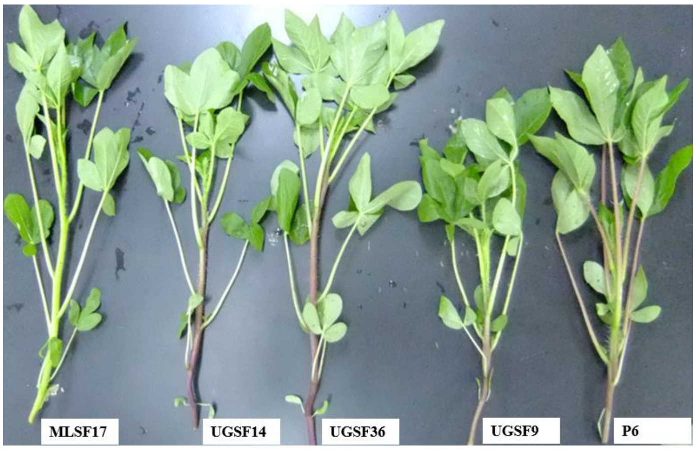

Plate 3.1: Part of the Genotypes IP3, MLSF17, MLSF3, P6, UGSF12, UGSF14, UGSF25, UGSF36, and UGSF9 Evaluated at Ruiru in Season 1

Note: Part of the photo with 4 Genotypes was Omitted Due to Technical Error

b) Soil Testing

Five sampling points were marked in a zig-zag line on the project site. One soil sample was collected from each of the five sampling points to a depth of 15 cm and analysed for N and pH at JKUAT Main Campus. The residual N level before this experiment was 0.04% while the pH was 4.9. This pH was corrected to 6.2 by incorporating calcitic agricultural lime within the soil at 20 g/m^2 and left intact to cure for 28 days before sowing. At the end of season two, soil samples were collected from three random subplots for each N treatment. These three samples were mixed into one aggregate sample, separately for N1, N2 and N3, and analysed, where pH and %N were 6.0, 6.3, 6.2 and 1.7, 0.06, and 0.09 respectively. It should be noted that soil testing is part of the materials and methods.

c) Land Preparation and Agronomic Practices

The land was prepared by clearing and cultivating to a fine tilth. The experimental site for season 2 was laid adjacent to the first site to avoid residual soil N effect and build-up of pests. The subplots were subjected to the same N treatments in season 1 and 2. Three raised beds, each measuring 1.2 m by 30 m served as main plots prepared and subdivided into nine subplots, each subplot measuring 3 m long and spaced 1.0 m apart. Main plots represented N treatments while subplots were genotypes. Manure was applied on the identified subplots and mixed in the soil. Seeds of spider plant were sown by drilling in shallow furrows 5–10 mm deep, spaced 30 cm apart. These furrows were covered lightly with soil and mulched. Seedbeds were watered once daily at the rate of 3 litres/subplot using watering can keeping them at field capacity. The crop was produced under rainfed conditions with 256 mm and 543 mm rainfall received during the crop season 1 and 2 respectively. Termites were controlled by drenching beds with *chlorpyrifos* at 20 ml/litre of water. Weeding and scouting for pests were undertaken constantly.

Thinning was done 21 DAS leaving an intra-row spacing of 10 cm and 90 plants per subplot (30 plants/m^2). The CAN treatments were applied in two splits; the first half soon after thinning, and the second one a fortnight later. Fertiliser was weighed before applying and incorporating it within the soil (Plate 3.2).

Plate 3.2: Application of CAN Fertiliser Treatment in Ruiru

d) Data Collection for Ruiru

Different growth and yield measurements were undertaken. The parameters measured were height, number of leaves, leaf area and yield. The sampling procedure and units of measure are indicated (Table 3.1). Data collection began at 35 DAS, per descriptors for the *C. gynandra* characterisation record sheet (Appendix 4; AVRDC, 2008). Measurements were taken on the same day to minimise differences in plant growth and developmental stage (Dambreville *et al*., 2015). Sampling was done five times at 7-day interval. During destructive sampling for the leaf area, one plant per subplot was randomly sampled from the middle portion of the plot to minimise border effect, and cut at the stem base and the leaves were plucked off. Data were analysed in GENSTAT software at $\alpha = 0.05$.

Table 3.1: Data collection Protocol for Ruiru trial

Parameters	Measurement method/procedure	Frequency	Units of measure
Height	Used tape measure to determine height starting at stem base to apex	Weekly starting 35 DAS	cm
Number of leaves	Total count	Idem	Numeric
Leaf area	Leaf area meter (model *3100 LICOR,* USA)	Idem. Using random number table, plants were identified, uprooted, and leaves plucked	cm^2/plant
Yield	Leaves, young stems and flowers were harvested. Weight divided among plant population/ subplot.	Weekly starting 35 DAS	g/plant

3.1.2 Juja Sub-County Trial

In this trial, only two commonly available genotypes, namely JKUAT and Simlaw were used. Different genotypes were used in Juja because the ones used in Ruiru were available but either did not germinate or germinated poorly. The first trial was set up during cold weather in May–July, while the second was during warm weather in August–October 2022, at JKUAT Main Campus farm under drip irrigation. This site is located in Central Kenya on geo-coordinates 1.0720˚S, 37.0117˚E, at an elevation of 1,417 m above sea level. The mean annual rainfall is 799 mm and received 289 mm during the crop season 1, and 188 mm during season 2. Average annual temperature is 19.6˚C. Diurnal temperature range was 14–24˚C. Soil is predominantly vertisols with pH 6.1 and 0.15% N. Each fertiliser treatment supplied an equivalent and recommended rate of 2.6 g N/plant for optimal growth (Masinde and Agong, 2011; Makaza *et al*., 2022). The only similarities between Juja and Ruiru experiments were the N treatments tested and parameters measured; otherwise, the soils, watering regimes, and genotypes were different. The genotypes were different because the ones tested earlier in Ruiru had very low germination or failed to germinate. The option of Simlaw and JKUAT genotypes was fitting because both are readily available commercially at agro-dealer outlets and JKUAT Main Campus. Therefore, based on these differences in experimental design, it would be statistically illogical to compare the performance of these two sites.

a) Soil chemical properties

To determine the actual amount of fertiliser or manure to be applied, soil testing was carried out, which showed that the soil contained 0.15% N, manure = 2.3% N, while NPK, DAP and CAN = 17%, 18% and 26% N respectively. It was found that 100 g of manure, or 15 g NPK, 15 g DAP, or 10 g CAN supply 2.6% N/plant, all else unchanged. This manure was also sourced from the same farmer who had supplied earlier on in Ruiru. This soil test is described under the materials and methods, and not the results section.

b) Experimental Design

This experiment was laid out as split plots in completely randomised block design (CRBD), with three replications (Figure 3). There were two genotypes — JKUAT and Simlaw — in main plots and eight fertiliser treatments in subplots, namely; manure alone, NPK (17:17:17), DAP, DAP+CAN (26%N), NPK+CAN, manure+CAN, manure+NPK, and control treatment which had zero N applied. These fertiliser treatments are commonly used by spider plant farmers in Kiambu County. Each main plot occupied a full bed, whereby two beds formed one block, and each block was replicated thrice. Blocks and plots were separated by a one-metre space to minimize cross effects. Each subplot area was 1 m^2, having three spider plant rows; spaced 30 cm inter-row and 10 cm intra-row. Apart from CAN, all fertiliser treatments including manure were applied in their respective subplots after randomisation, and incorporated within the soil before sowing. Seeds were mixed with 0.5 kg sand before drilling into 5–10 mm deep furrows and covered lightly with soil. Guard rows of maize were planted around every block. Irrigation was done using a drip system. Thinning was done 21 DAS down to 30 plants/m^2, and the first split of CAN was top-dressed at 1.3g and 2.6g N/plant. Scouting for pests was undertaken and managed accordingly.

REPLICATE	TREATMENTS							
Block 1	Simlaw X Control [0]	Simlaw X (DAP + CAN) [225g+150g]	Simlaw X NPK [450g]	Simlaw X (NPK + CAN) [225g+150g]	Simlaw X (Manure + CAN) [1.5kg+150g]	Simlaw X Manure [3kg]	Simlaw X DAP [450g]	Simlaw X (Manure + NPK) [1.5kg+225g]
	JKUAT X Manure [3kg]	JKUAT X NPK [450g]	JKUAT X DAP [450g]	JKUAT X (NPK + CAN) [225+150g]	JKUAT X Control [0]	JKUAT X (Manure + NPK) [1.5kg+225g]	JKUAT X (DAP + CAN) [225g+150g]	JKUAT X (Manure + CAN) [1.5kg+150g]
Block 2	JKUAT X NPK [450g]	JKUAT X (DAP + CAN) [225g+150g]	JKUAT X Manure [3kg]	JKUAT X (Manure + NPK) [1.5kg+225g]	JKUAT X (Manure + CAN) [1.5kg+150g]	JKUAT X Control [0]	JKUAT X (NPK + CAN) [225g+150g]	JKUAT X DAP [450g]
	Simlaw X (DAP) [450g]	Simlaw X (DAP + CAN) [225g+150g]	Simlaw X (NPK + CAN) [225g+150g]	Simlaw X (Manure + CAN) [1.5kg+150g]	Simlaw X Control [0]	Simlaw X (Manure + NPK) [1.5kg+225g]	Simlaw X NPK [450g]	Simlaw X Manure [3kg]
	JKUAT X (NPK + CAN) [225g+150g]	JKUAT X (Manure + NPK) [1.5kg+225g]	JKUAT X DAP [450g]	JKUAT X Manure [3kg]	JKUAT X (DAP + CAN) [225g+150g]	JKUAT X (Manure + CAN) [1.5kg+150g]	JKUAT X Control [0]	JKUAT X NPK [450g]

Block 3	Simlaw X (Manure + NPK) [1.5kg+225g]	Simlaw X NPK [450g]	Simlaw X Control [0]	Simlaw X (Manure + CAN) [1.5kg+150g]	Simlaw X DAP [450g]	Simlaw X (NPK + CAN) [225g+150g]	Simlaw X Manure [3kg]	Simlaw X (DAP + CAN) [225g+150g]

Figure 3.3: Experimental Design and Treatments with the Plot Separation Distance of 1 metre

Figures in square parenthesis [] are actual fertiliser and manure rates applied per subplot

c) Data Collection for Juja

Three growth measurements were undertaken. Parameters measured were height, number of leaves, and days to flower. The sampling procedure and units of measure are indicated (Table 3.2). Data collection began at 28 DAS, as per descriptors for the *C. gynandra* characterisation record sheet (Appendix 4; AVRDC, 2008). Measurements were taken on the same day to minimise differences in plant growth and developmental stage. Sampling was done five times at 7-day interval until 56 DAS (Plate 3). The time interval of 28 days for collecting growth data of spider plant is justified because it has a lifespan of over 70 days depending on management standards. Leaf area and yield were omitted from Juja trial because both data had been collected in Ruiru trial and was deemed to be sufficient for this study.

Table 3.2: Data Collection Protocol for Juja Trial

Parameters	Measurement method/procedure	Frequency	Units of measure
Height	Used tape measure to determine height starting at stem base to apex	Weekly starting 28 DAS	cm
Number of leaves	Total count	Idem	Numeric
Days to flower	Duration after sowing	Once until the first flower bud opens	DAS

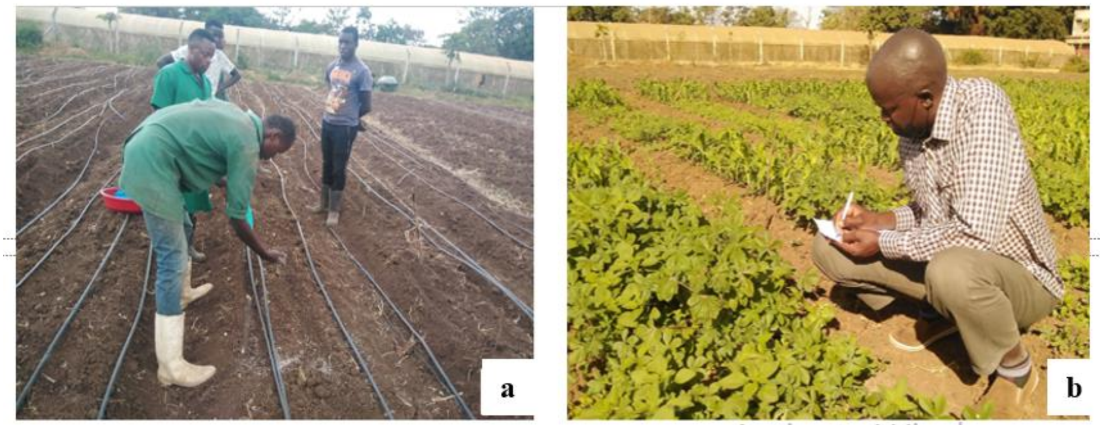

Plate 3.3: Trial Site in JKUAT: a - Planting; b - Data collection

d). Growth Computation and Statistical Analysis

Growth entails an irreversible physical change in size, which can be manifested in terms of height, number of leaves, weight, and leaf length, among others. Growth was computed for two-time points; namely, 28 and 56 DAS in Juja (Table 3.2), and, 35 and 63 DAS in Ruiru (Table 3.1) respectively, by subtracting the initial measurement from the final one as per equation (1).

$$\mathrm{Gr} = \mathrm{H_f} - \mathrm{H_0} \qquad \text{(Equation 1)}$$

Where;

Gr = Growth

H_f = Last measurement

H_0 = Initial measurement

Derived growth data were analysed in GENSTAT at $\alpha = 0.05$.

3.2 Genotype Preference Surveys

3.2.1 The Study Sites

Preference surveys were conducted in Ruiru and Juja Sub-Counties, Kiambu County, Kenya. Kiambu was selected for these studies because vegetable production is an important economic activity in this county due to its proximity to Kenya's capital city, Nairobi, a major market for spider plant. This market supplies plant produce to consumers of diverse socio-economic status from different backgrounds and preferences, with typical continuous mobility in and out of the city. Not only does spider plant produced in Ruiru end up in Nairobi, but it is also supplied in Juja, Thika, Kiambu Township, and other surrounding areas. The bulk of spider plant supplied to Nairobi is sourced from Western Kenya and Nyanza Regions.

3.2.2 Ethical Considerations

Ethics in this study entailed the moral principles which guided what to do and vice versa. These guidelines were followed as documented by Smith (2003), Greaney *et al*. (2012) and Mumtaz *et al*. (2013). Accordingly, the researcher obtained permission to carry out this study based on the procedures laid down in various authorization bodies. First, approval was sought from the JKUAT Board of Postgraduate Studies which certified all aspects of ethics in carrying out research. Second, consent from the Kiambu County Director of Agriculture was sought. Third, the researcher sought consent from respondents after clearly explaining the research purpose and confidentiality of the information thereafter. Finally, the researcher thanked the participants after these interviews, and carefully documented the points raised.

3.2.3 Data Sources

Primary and secondary data were used in both Ruiru and Juja studies. Secondary data were collected from MoA annual reports, government records and published journal papers. Data was collected using semi-structured questionnaires administered to farmers and consumers (Appendix 5, 6) and KIIs. Data on spider plant attributes — leaf colour, number of leaves, height, stem and petiole colour, freshness, flavour — and socio-demographic variables — age, income, gender, education level, marital status and household size — of respondents were collected. Enumerators were positioned next to traders where they interviewed every second and willing vegetable customer.

A simple random sampling procedure was used to select these 100 farmers in Ruiru. Both farmers and consumers were asked to rank their attributes of choice (both intrinsic and extrinsic) for this vegetable on the 9-point hedonic scale. Average scores and their standard errors were analysed at $\alpha = 0.05$ (Appendix 7).

3.2.4 Sampling Technique

The first preference study was held in Ruiru, targeting farmers and consumers in Kiambu County, whereby a multistage sampling technique was applied. In stage one, Ruiru and Juja Sub-Counties were purposively selected due to their proximity to Nairobi, and are considered producers of ALVs including spider plant.

Determination of sample size was based on equation (2), (Kothari, 2004).

$$n_0 = \frac{Z^2\mathrm{pq}}{\mathrm{e}^2} \quad \text{(Equation 2)}$$

n_0 is the sample size,

p is the proportion of the population (50%) containing farmers and consumers. This is chosen because the proportion of the population producing and consuming this ALV is unknown.

q is 1-p,

Z is the standard variation of 1.96 given a confidence level of α = .05 and,

e is the acceptable precision level of 6.93%

Since it is difficult to determine the real-time actual number of people in this study area due to continuous migration, it is assumed that 50% of this population produces and consumes spider plant. The acceptable precision of 6.93% was selected because of this small sample size, thus a higher confidence level of these results.

1.96x1.96x0.5x0.5/0.0693x0.0693 = 200

Systematic random sampling was used to select 100 farmers and 100 consumers in the selected sub-counties/markets. Both primary and secondary data were used in the study. Primary data were collected by trained enumerators who were recruited from within the area of study due to their familiarity with the local language. Data were collected with the aid of a semi-structured questionnaire administered to spider plant producers and consumers by enumerators. Secondary data were collected from MoA annual reports in Kiambu County, government records and published journal papers.

3.2.4.1 Consumer Preference Survey

Four major open-air market centres — Juja, Ruiru, Kahawa West, and Githurai — were purposively selected for the study because of the availability of a large number of spider plant consumers (Ayieko *et al*., 2005). Semi-structured questionnaires were administered to 100 consumers, thus targeting 25 respondents from each market

(Appendix 6). The respondents were selected on site as they came to purchase spider plant. Enumerators were strategically positioned next to traders where they interviewed every second and willing vegetable customer. Information about the market, respondent household characteristics, spider plant attributes, and preference for different recipes were collected.

3.2.4.2 Farmer Preference Survey

Farmers were asked to indicate their preference attributes during the purchase of seeds. Data on spider plant attributes (height, number of leaves, stem and petiole colour, yield, farm-gate price), socio-demographic variables (age, income, gender, education level, marital status and household size of the respondents) were collected for the study (Appendix 5). Farmer selection was done in collaboration with Kiambu County MoA using a simple random sampling procedure to obtain 100 producers in the area. Farmers were interviewed by enumerators on their farms.

Plate 3.4: a, b - Farmers Undertaking Spider Plant Evaluation at the JKUAT Trial Site

3.2.4.3 Recipe Preference Survey

This study sought to elicit consumer perceptions of three recipes. Consumer responses were based on their previous encounter and recipe utilisation. These recipes were; plain spider plant, spider plant + amaranth + peanut and spider plant + milk. Average preference scores were recorded using the 9-point hedonic scale (Tuorila *et al*., 2008), where 1 means 'dislike extremely' and 9 represents 'like extremely' (Table 4.4.3).

For the Juja site, a total of 15 KII respondents (Mumtaz *et al*., 2013) comprising 7 females and 8 males, who were spider plant farmers with >5-year production experience undertook on-site evaluation and filled out a semi-structured questionnaire. The questionnaire was logically designed according to the guidelines of Bird (2009), Vanclay *et al*. (2013), Hammersley (2015) and, Artal and Rubenfeld (2017). Respondents had in-depth know-how of the spider plant value chain and voluntarily offered to participate. Only two known spider plant genotypes (JKUAT and Simlaw) were used under eight N treatments. These two genotypes were selected because; Simlaw genotype is the default genotype commercially available in the agro-dealer outlets in Kenya, while JKUAT was developed by researchers from the Department of Horticulture and Food Security, and it is also available for sale at the same university. Parameters evaluated were height, number of leaves, and stem and petiole colour. The questionnaire had three parts: 1 - General information (area of residence, gender); 2 - Household characteristics (size, income, education, marital status); 3 - spider plant attributes (height, number of leaves, stem/petiole colour).

The 9-point psychometric hedonic scale analysis (Lawless and Heymann, 2013) was used: 1=Dislike extremely; 2=Dislike very much; 3=Dislike moderately; 4=Dislike slightly; 5=Neutral; 6=Like slightly; 7=Like moderately; 8=Like very much; 9=Like extremely. The feedback was discussed among these farmers and responses were recorded.

3.2.5 Data Analysis

For Ruiru, data were analysed using descriptive statistics with the aid of Excel and STATA version 11 software.

In Juja, data were analysed using the composite sampling formula below (equation 3).

$$\sum_{i=1}^{n} \frac{[(f.s)_1 + (f.s)_2 + \cdots + (f.s)_{nth}]}{n} \qquad \text{(Equation 3)}$$

Where, f = frequency of each hedonic scale score (no. of respondents)

s = hedonic scale score (ranking 1–9)

n = total number of respondents

With regard to the surveys, the 9-point hedonic scale, and Likert scale analyses were used. The Hedonic scale ranged from ‘Dislike extremely’ to ‘Like extremely’ as described by Wichchukit and O'Mahony, 2015; Lawless and Heymann, 2013; and Sack, 2021. The 5-point Likert scale analysis was used to determine differences among genotypes, ranging from ‘Least preferred’ to ‘Most preferred’ (McLeod, 2019).

CHAPTER FOUR

RESULTS

4.1 Effect of N Fertiliser Application on Growth and Yield of Nine Spider Plant Genotypes in Ruiru

Different N rates are expected to promote growth and development of spider plant in terms of height, leaf area, and number of leaves at varying levels. Credibility of these results to a large extent also depends on the actual N content of the manure, which was 2.3% N. These experiments were conducted in open field. Differences in the field conditions were controlled through border plants, randomisation, and sampling was deliberately done around the middle of the plots. To assess the treatment effect, initial and final measurements were taken, and the difference recorded as growth over the trial period.

4.1.1 Height

The effect of N application showed significant differences in plant height for both seasons. The highest plant height (79.63 and 86.33 cm) were sampled from plants supplied with 2.3g N/plant in seasons 1 and 2 respectively, while the lowest (58.89 and 76.59 cm) were recorded for plants treated with 2.6g N/plant (Table 4.1). There were significant differences in plants supplied with 5.2g N/plant against those of 2.3g N/plant and 2.6g N/plant in season 1. However, the trend was different in season 2 where plants supplied with 5.2g and 2.3g N/plant were statistically similar.

Table 4.1: Plant height, Number of Leaves and Leaf Area of Spider Plant as Influenced by N Application in Two Seasons (S1 and S2) at Ruiru

N Rates	Height (cm)		Number of leaves		Leaf area (cm^2)	
	Season 1	**Season 2**	**Season 1**	**Season 2**	**Season 1**	**Season 2**
2.3	79.63a	86.33a	69.52a	78.40a	1604.00a	1914.00a
2.6	58.89c	76.59b	59.22c	60.30b	1168.00b	1370.00b
5.2	63.44b	85.59a	65.26b	59.20b	1187.00b	1507.00b
p-value	***	***	***	***	***	***
$LSD_{0.05}$	**3.841**	**4.32**	**3.61**	**11.75**	**110.10**	**175.20**

Means followed by the same letter within a column are not significantly different at 0.05% probability level.

Season 2 had double the rainfall rate of 543 mm compared to 256 mm in season 1. It is therefore possible that higher soil moisture (field capacity) promoted N uptake together with other nutrients, which promoted growth in terms of height in season 2. On the other hand, treatment 2.6g N/plant may have been leached, leaving behind suboptimal N levels. The implication is that spider plant needs adequate moisture during the growing period for maximum yield, which can also be supplemented by irrigation (Mosenda *et al*, 2020).

4.1.2 Number of Leaves

Application of different N rates on plant number of leaves revealed significant variation among the different N rates for both seasons. The highest plant number of leaves (69.52 and 78.40) were recorded for plants supplied with 2.3g N/plant in seasons 1 and 2 respectively. The lowest number of leaves (59.22 and 59.20) were recorded for plants treated with 2.6g and 5.2g N/plant in seasons 1 and 2 respectively (Table 4.1). There were significant differences in the number of leaves across the 3 N rates in season 1, but the trend was different in season 2 whereby plants supplied with 2.6g and 5.2g N/plant were not significantly different. The number of leaves per plant is a genetic function. However, N rate influence leaf size.

4.1.3 Leaf area

There were significant differences in leaf area due to the application of different N rates for seasons 1 and 2. The highest plant leaf area (1604 and 1914 cm^2) was observed for plants supplied with 2.3g N/plant in seasons 1 and 2 respectively whereas the lowest (1168 and 1370 cm^2) were for plants treated with 2.6g N/plant (Table 4.1). Significant differences were revealed in plants supplied with 2.3g N/plant against those of 2.6g and 5.2g N/plant in both seasons, implying that plants supplied with 2.6g and 5.2g N/plant were statistically similar. Therefore, increasing the N rate beyond 2.6g N/plant did not have added advantage in terms of leaf area.

4.2 Effect of Genotypes on Growth and Yield of Spider Plant in Ruiru, Kiambu County

4.2.1 Height

The effect of different genotypes on plant height showed significant differences among genotypes for both seasons. The tallest genotypes (74.22 – 78.44 cm) were MLSF17, P6, and UGSF36 in season 1, and (82.89 – 88.89 cm) for MLSF17, P6, UGSF12, UGSF14, UGSF36, and UGSF9 in season 2. The shortest genotypes (55.78 – 62.22 cm) were IP3, UGSF12, and UGSF25 in season 1, and (75.78 – 79.22 cm) for IP3, MLSF3, and UGSF25 in season 2 (Table 4.1.2).

4.2.2 Number of Leaves

There were significant differences in the number of leaves among genotypes for both seasons. The genotype with the highest number of leaves (77.00) was IP3 in season 1 as well as all the genotypes except UGSF25 in season 2. UGSF9 had the smallest number of leaves (56.67) in season 1, and UGSF25 in season 2 (Table 4.2). These results compare well with the existing genotypes, considering the wide genetic diversity of spider plant coupled with the effect of different AEZ.

4.2.3 Leaf Area

Genotypes significantly differed in plant leaf area in season 1. Genotypes with the highest leaf area (1341 – 1503 cm^2) were IP3, MLSF17, MLSF3, UGSF14, and

UGSF36 in season 1. In season 2, all the genotypes tested did not differ (1523 – 1812 cm^2), except UGSF25 which was the lowest at 1256 cm^2. Genotype UGSF25 also had the lowest plant leaf area (1093 cm^2) in season 1 (Table 4.2). Height is not necessarily a good indicator for spider plant performance, especially the genotypes with spread or prostate habit. But researchers have also reported a general positive correlation of yield with height in most erect genotypes.

Table 4.2: Growth in Terms of Height, Number of Leaves and Leaf Area of Spider Plant as Influenced by Genotypes in Two Seasons (S1 and S2) at Ruiru

Genotype	Height (cm)				Number of leaves				Leaf area (cm^2)			
	Season 1		Season 2		Season 1		Season 2		Season 1		Season 2	
IP3	55.78d	±2.78	79.22b	±7.65	77.00a	±6.91	70.28a	±7.96	1341a	±148.56	1625a	±166.81
MLSF17	78.44a	±3.41	88.89a	±2.67	58.22c	±2.76	76.60a	±5.93	1503a	±66.56	1812a	±85.66
MLSF3	64.44c	±2.90	77.00b	±8.72	65.22b	±4.42	62.23a	±10.82	1367a	±108.41	1658a	±184.84
P6	74.22a	±3.64	83.78a	±9.20	60.00c	±4.65	72.15a	±8.83	1239b	±157.39	1639a	±204.32
UGSF12	60.89c	±6.47	82.89a	±6.35	67.67b	±11.74	69.90a	±8.83	1208b	±84.96	1643a	±148.23
UGSF14	66.78b	±2.28	84.67a	±7.48	67.00b	±6.76	68.14a	±5.61	1386a	±137.46	1523a	±166.23
UGSF25	62.22c	±2.69	75.78b	±5.09	61.56c	±4.43	55.20b	±4.93	1093c	±44.03	1256b	±58.30
UGSF36	76.11a	±2.67	87.11a	±5.74	68.67b	±6.92	60.74a	±9.96	1473a	±103.01	1641a	±149.22
UGSF9	67.00b	±5.95	86.22a	±8.43	56.67d	±12.50	58.70a	±10.83	1267b	±106.93	1579a	±159.14
$LSD_{0.05}$	**6.65**		**7.49**		**6.26**		**20.35**		**190.70**		**303.40**	
p-value	***		**		***		**		**		**NS**	

Means followed by the same letter within a column are not significantly different at 0.05% probability level.

4.2.4 Yield

The effect of N application rates on yield was insignificant in season 1, but significant in season 2. There were significant differences in yield for plants supplied with 2.3g N/plant against those of 2.6g N/plant and 5.2g N/plant in season 2 (Table 4.1.3). There was interaction between season 1 and 2 in terms of yields, whereby season 1 were very low compared to season 2. The genotypes have high genotypic variation implying that they are still genetically unstable. The genotypes also have environmental variation because less rainfall experienced in season 1 limited the N availability for spider plant uptake from the soil solution. Nevertheless, the results fall within the yield range of existing genotypes depending on the level of management practices such as fertiliser application, irrigation, and inherent traits.

Table 4.3: Yield Means of Spider Plant across Genotypes as Influenced by N Application in Two Seasons (S1 and S2) at Ruiru

N Rates	**Yield (g/plant)**			
	Season 1		**Season 2**	
2.3	36.49a	±0.89	95.20a	±2.75
2.6	33.37a	±1.64	78.60b	±1.66
5.2	35.87a	±1.46	76.80b	±2.10
$LSD_{0.05}$	**3.506**		**5.34**	
p-value	**NS**		******	

Means followed by the same letter within a column are not significantly different at 0.05% probability.

Yield differed significantly among the various genotypes in both seasons. The highest plant yields (35.09 – 40.27 g) were recorded for genotypes MLSF17, P6, UGSF14, UGSF25, and UGSF36 in season 1, and (88.10 – 94.00 g) for genotypes MLSF17, MLSF3, P6, and UGSF9 in season 2 respectively. The lowest plant yields (31.59 – 33.52 g) were recorded for genotypes IP3, MLSF3, UGSF12, and UGSF9 in season 1. and (73.1 g) for the genotypes IP3, UGSF12, UGSF14, UGSF25 and UGSF36 in season 2 respectively (Table 4.4).

Table 4.4: Yield of Spider Plant as Influenced by Genotypes in Two Seasons (S1 and S2) at Ruiru

Genotypes	**Yield (g/plant)**			
	Season 1		**Season 2**	
IP3	32.33b	±1.10	75.70b	±4.76
MLSF17	39.37a	±2.14	91.00a	±3.08
MLSF3	31.65b	±2.50	94.00a	±4.57
P6	40.27a	±1.98	88.10a	±4.71
UGSF12	33.52b	±2.60	78.60b	±5.37
UGSF14	37.87a	±1.80	80.70b	±4.63
UGSF25	35.49a	±1.29	79.00b	±3.06
UGSF36	35.09a	±2.83	83.10b	±4.41
UGSF9	31.59b	±3.00	91.70a	±5.39
$LSD_{0.05}$	**6.07**		**9.25**	
p-value	*		**	

Means followed by the same letter within a column are not significantly different at 0.05% probability level.

4.3 Effect of Fertilisers and Genotypes on Spider Plant Growth in Juja

Eight fertiliser forms, namely; manure, DAP+CAN, manure+CAN, manure+NPK, NPK+CAN, DAP, NPK, and control were tested against two genotypes – Simlaw and JKUAT in Juja.

4.3.1 Height

The effect of genotypes had significant differences in height for both seasons. Genotype JKUAT had a higher plant height (61.50 cm) compared with Simlaw genotype (55.93cm) in season 1. In season 2, Simlaw genotype had a higher height (67.30 cm) than JKUAT (61.60 cm) (Table 4.5). The N factor was the nitrogen treatment means.

Table 4.5: Growth in Terms of Height of Two Spider Plant Genotypes as Influenced by N Application in Two Seasons (S1 and S2) at Juja

Genotype	**Height (cm)**			
	Season 1		**Season 2**	
JKUAT	61.50a	±4.17	61.60b	±6.09
SIMLAW	55.93b	±3.52	67.30a	±6.45
$LSD_{0.05}$	**4.04**		**4.93**	
CV (%)	**11.7**		**13.0**	
p-value	**		*	

Means followed by the same letter within a column are not significantly different at 0.05% probability level.

Fertilisers significantly influenced variation in plant height among genotypes for both seasons. The eight fertiliser treatments were selected because they the most commonly applied by spider plant famers. The highest height (66.93 – 73.50 cm) were determined for manure, DAP+CAN, manure+CAN, manure+NPK, and NPK+CAN in season 1, and manure and manure+CAN (89.30 – 92.60 cm) in season 2. Control had the lowest height (23.23 and 10.10 cm) in seasons 1 and 2 respectively (Table 4.1.6). Besides the genotypic traits, fertiliser forms also influenced spider plant growth. Manure is a slow-release and it is less vulnerable to leaching. It also has other elements besides N (Appendix 9) that benefit the plant. Diammonium phosphate (DAP) can cause soil acidification if uapplied inappropriately, making nutrients in the soil unavailable to the plant.

Table 4.6: Growth in Terms of Height of Two Spider Plant Genotypes as Influenced by Fertilisers in Two Seasons (S1 and S2) at Juja

Fertilisers	Height (cm)			
	Season 1		Season 2	
Manure	73.50a	±5.44	89.30a	±4.39
Control	23.23d	±0.63	10.10d	±0.92
DAP	48.20c	±3.56	41.30c	±2.98
DAP+CAN	67.28a	±1.79	79.20b	±3.14
Manure+CAN	72.52a	±6.20	92.60a	±2.42
Manure+NPK	66.93a	±1.32	81.20b	±4.75
NPK	49.45b	±2.49	40.50c	±1.51
NPK+CAN	68.58a	±3.38	81.30b	±5.18
$LSD_{0.05}$	**8.08**		**9.86**	
CV (%)	**11.7**		**13.0**	
p-value	*******		*******	

Means followed by the same letter within a column are not significantly different at 0.05% probability level.

4.3.2 Number of Leaves

The effect of genotypes on the spider plant's number of leaves was significant in season 2, but not significant in season 1. Presence of adequate soil moisture in season 2 enhanced N uptake from the soil solution unlike season 1. Simlaw genotype had a higher plant number of leaves (61.20 cm) compared with JKUAT (53.80 cm) in season 2 (Table 4.7). Besides genetic traits, the results indicate that genotype JKUAT may be better adapted to tolerate drought conditions than Simlaw genotype.

Table 4.7: Growth in Terms of Number of Leaves of Two Spider Plant Genotypes as Influenced by N Application in Two Seasons (S1 and S2) at Juja

Genotype	Number of leaves			
	Season 1		Season 2	
JKUAT	37.46a	±2.79	53.80b	±4.92
SIMLAW	37.08a	±2.63	61.20a	±6.09
$LSD_{0.05}$	**3.7**		**4.93**	
CV (%)	**16.8**		**13.2**	
p-value	**NS**		*******	

Means followed by the same letter within a column are not significantly different at 0.05% probability level.

The effect of fertilisers had significant differences in the number of leaves for both seasons 1 and 2. A higher number of leaves (39.50 – 46.00) was realized for manure, DAP, DAP+CAN, manure+CAN, manure+NPK, and NPK+CAN in season 1, while it was manure+CAN (87.00) in season 2. Control demonstrated the lowest number of leaves (10.50 and 9.30) for seasons 1 and 2 respectively (Table 4.8).

Table 4.8: Growth in Terms of Number of Leaves of Two Spider Plant Genotypes as Influenced by Fertilisers in Two Seasons (S1 and S2) at Juja

Fertiliser	**Number of leaves**			
	Season 1		**Season 2**	
Manure	46.00a	±2.43	76.30b	±5.65
Control	10.50c	±0.60	9.30f	±0.33
DAP	39.50a	±2.59	39.80d	±2.17
DAP+CAN	41.17a	±4.29	68.00c	±3.50
Manure+CAN	42.00a	±3.53	87.00a	±3.68
Manure+NPK	43.67a	±2.40	75.00b	±4.42
NPK	33.00b	±3.18	33.20e	+0.86
NPK+CAN	42.33a	±3.19	71.00b	±3.86
$LSD_{0.05}$	**7.39**		**8.95**	
CV (%)	**16.8**		**13.2**	
p-value	***		***	

Means followed by the same letter within a column are not significantly different at 0.05% probability level.

4.3.3 Days to Flower

The effect of different fertilisers on plant days to flower showed no significant differences in seasons 1 and 2. This observation implies that regardless of the fertiliser form supplied, the genotypes flowered at same time (Table 4.9).

Table 4.9: Growth in Terms of Days to the Flower of Two Spider Plant Genotypes as Influenced by N Application in Two Seasons (S1 and S2) at Juja

Genotype	Days to flower (DAS)	
	Season 1	**Season 2**
JKUAT	45.08a	39.21a
SIMLAW	45.67a	39.83a
$LSD_{0.05}$	**1.32**	**1.39**
CV (%)	**4.9**	**6.0**
p-value	**NS**	**NS**

Means followed by the same letter within a column are not significantly different at 0.05% probability level.

The influence of fertilisers had significant differences on plant days to flower for both seasons. The longest time taken to flower (50.50 – 51.50 DAS) and (44.33 – 45.33 DAS) were observed for DAP+CAN, and manure+CAN for seasons 1 and 2 respectively. Control (34.83 and 30.00 DAS) had the shortest days to flower in both seasons (Table 4.10).

Table 4.10: Growth in Terms of Days to Flower of Two Spider Plant Genotypes as Influenced by Fertilisers in Two Seasons (S1 and S2) at Juja

Fertilisers	Days to flower (DAS)			
	Season 1		**Season 2**	
Manure	47.50b	±0.76	41.33b	±0.67
Control	34.83e	±0.75	30.00d	±0.86
DAP	41.33c	±1.02	35.83c	±0.95
DAP+CAN	50.50a	±0.76	44.33a	±0.84
Manure+CAN	51.50a	±0.89	45.33a	±1.02
Manure+NPK	48.00b	±1.29	41.67b	±1.43
NPK	40.67d	±0.80	35.33c	±0.84
NPK+CAN	48.67b	±0.42	42.33b	±0.42
$LSD_{0.05}$	**2.64**		**2.78**	
CV (%)	**4.9**		**6.0**	
p-value	***		***	

Means followed by the same letter within a column are not significantly different at 0.05% probability level.

4.4 Genotype Preference Survey

4.4.1 Consumer Survey

4.4.1.1 Household Socio-Economic Characteristics

Table 4.11 shows socio-economic characteristics of spider plant consumer households. The average age for consumers was 42.2 years with the youngest aged 18, while the oldest was 71. This trend indicates that spider plant consumers belong to the older respondents unlike the youth (18–35). Concerning marital status, married consumers dominated the consumption of spider plant, where 64.95% were married, 20.62% were single and 14.43% were either widows or widowers.

Among the consumers, 32.0% had a diploma education, with an illiteracy rate of 9%. The same respondents also had an income with 37.1% earning between KES 30,000–50,000 per month. Consumers who earned less than KES 10,000 per month were 9.0%. The average household size was five members with a minimum of one and a maximum of 12 (Table 4.11).

Table 4.11: Socio-Economic Characteristics of Consumer Households

Variable	Category	Frequency	%	Mean	Max	Min	N
Age	-	-	-	42.2	71	18	100
Household size	-	-	-	5.48	12	1	100
Gender	Male	12	12.0	-	-	-	-
	Female	88	88.0	-	-	-	-
	N	100	-	-	-	-	-
Marital status	Married	63	65.0	-	-	-	-
	Single	20	20.6	-	-	-	-
	Widow/er	14	14.4	-	-	-	-
	N	97	-	-	-	-	-
Education	No education	9	9.0	-	-	-	-
	Primary	17	17.0	-	-	-	-
	Secondary	29	29.0	-	-	-	-
	Diploma	32	32.0	-	-	-	-
	Degree	9	9.0	-	-	-	-
	Postgraduate	4	4.0	-	-	-	-
	N	100	-	-	-	-	-
Income*	<10,000	9	9.3	-	-	-	-
	10,000 – 20,000	12	12.4	-	-	-	-
	20,001 – 30,000	20	20.6	-	-	-	-
	30,001 – 40,000	19	19.6	-	-	-	-
	40,001 – 50,000	17	17.5	-	-	-	-
	50,001 – 60,000	9	9.3	-	-	-	-
	>60,000	11	11.3	-	-	-	-
	N	97	-	-	-	-	-

*1 USD = 107 KES

4.4.1.2 Spider Plant Preference Attributes

Table 4.12 shows consumer preference for spider plant attributes. Consumers highly consider the freshness of spider plant before making their purchase choices. Freshness was the most highly ranked attribute of spider plant with an average score of 8.58. Fresh spider plant leaves were highly preferred by 91.9% of the consumers compared to the preserved leaves. Tasty spider plant was preferred by consumers with an average score of 8.3 on the 9-point hedonic scale. Consumers preferred green leaves of spider plant at 52.0% compared to purple leaves. On the hedonic scale, leaf colour received a high ranking at an average score of 8.3. Spider plant with large leaves size were highly preferred compared to those with small leaves size at 54.0%. Leaf texture had the least ranking score compared with all the other attributes with an average of 7.04

at the 9-point hedonic scale rating. Nevertheless, consumers preferred spider plant with rough leaves at 62.6% compared to smooth leaves at 37.4% (Appendix VII; Table 4.12).

Table 4.12: Consumer Preference for Spider Plant Attributes

Variable	Category	Frequency	Percent (%)
Leaf texture	Smooth	37	37.4
	Rough	62	62.6
	N	99	
Size of leaves	Small (<10 cm^2)	0	0.0
	Medium (10–20 cm^2)	46	46.0
	Large (>20 cm^2)	54	54.0
	N	100	
Colour of leaves	Green	52	52.0
	Purple	48	48.0
	N	100	
Freshness	Fresh	91	91.9
	Preserved	8	8.1
	N	99	

4.3.1.3 Recipe Preference Survey

Table 4.13 shows acceptance score for three spider plant recipes. These recipes were selected from existing literature and interviews with random respondents from different communities in Kenya. The most preferred recipe by consumers was spider plant plus amaranth, with an average score of 8.28 on the 9-point hedonic scale. The least-ranked recipe was spider plant plain, with an average score of 1.6. Similarly, the mixture of spider plant and milk was highly preferred with a ranking average of 8.04 (Table 4.13).

Table 4.13: Preference Score for Spider Plant Recipes

Variable	Min	Max	Mean	N
Spider plant plain	1	9	1.60	100
Spider plant				
+ Amaranth	5	9	8.28	100
+ Peanut				
+ Milk	5	9	8.04	100

4.4.2 Farmer Survey

4.4.2.1 Farmer Socio-Economic Characteristics

Table 4.14 shows farmer household socio-economic characteristics. The proportion of women among spider plant farmers was 53.0% compared to their male counterparts at 47.0%. The average age for the spider plant farmers in the current study was 43.4 years. The youngest farmer was aged 19 whereas the oldest was aged 65. This indicates that spider plant farmers, similar to consumers, belonged to the adult age bracket as compared to the youthful age bracket (18–35). Regarding marital status, 72.0% of the spider plant farmers were married.

Regarding education, 32.0% of the farmers had diplomas while the illiteracy rate was 9.0%. Concerning income, 43.0% of respondents earned between KES 30,000 to KES 50,000 per month. The farmers who earned less than KES 10,000 per month were 11% of the sampled respondents. The average household size was six members, where the minimum household size was three members while the maximum was 11. The average size of land owned by farmers was one acre, with the minimum acreage being 0.5 while the maximum landholding was 2.6 acres. Consequently, this land was owned on a freehold basis at 63.7% while 33.3% of the sampled farmers leased land for spider plant production. Among the farmers, 61.9% have a farming experience of more than two years. The average farm gate price per kilogram of spider plant leaves harvested was KES 19.47 while the minimum at KES 15.00, and maximum at KES 25.00 (Table 4.14).

Table 4.14: Household Socio-Economic Characteristics

Variable	Category	Frequency	%	Mean	Max	Min	N
Land size	-	-	-	1.13	2.6	0.5	100
Price/kg of spider plant (KES)*	-	-	-	19.47	25	15	100
Age	-	-	-	43.4	65	19	100
Household size	-	-	-	5.59	11	3	100
Gender	Male	47	47.0	-	-	-	-
	Female	53	53.0	-	-	-	-
	N	100	-	-	-	-	-
Marital/S	Married	72	72.0	-	-	-	-
	Single	18	18.0	-	-	-	-
	Widow/er	10	10.0	-	-	-	-
	N	100	-	-	-	-	-
Education	No education	9	9.0	-	-	-	-
	Primary	17	17.0	-	-	-	-
	Secondary	29	29.0	-	-	-	-
	Diploma	32	32.0	-	-	-	-
	Degree	9	9.0	-	-	-	-
	Postgraduate	4	4.0	-	-	-	-
	N	100	-	-	-	-	-
Income*	<10,000	11	11.0	-	-	-	-
	10,000 –	13	13.0	-	-	-	-
	20,000	18	18.0	-	-	-	-
	20,001 –	20	20.0	-	-	-	-
	30,000	23	23.0	-	-	-	-
	30,001 –	9	9.0	-	-	-	-
	40,000	6	6.0	-	-	-	-
	40,001 –	100	-	-	-	-	-
	50,000						
	50,001 –						
	60,000						
	>60,000						
	N						
Land ownership	- Freehold	63	63.6	-	-	-	-
	- Communal	3	3.0	-	-	-	-
	- Leasehold	33	33.3	-	-	-	-
Farm experience	- 3 months	5	0.1	-	-	-	-
	- 6 months	14	14.4	-	-	-	-
	- 12 months	18	18.6	-	-	-	-
	>24 months	60	61.9	-	-	-	-
	N	97	-	-	-	-	-

*1 USD = 107 KES

4.4.2.2 Farmer Preference Attributes

Table 4.15 shows farmer preference for different spider plant attributes. These attributes were selected based on the farmer experiences and feedback from this study, as well as the referenced wider literature. The number of leaves was ranked highest among spider plant preference attributes. The mean score on the 9-point hedonic scale was 8.9 with a minimum score of 7 and a maximum of 9. The results indicate that farmers consider the number of leaves as an important attribute before selecting the variety of choice for planting. Consequently, 99.0% of farmers indicated that they preferred spider plant genotypes with more leaves. The second highly ranked attribute of spider plant genotypes by farmers was their height at 8.4 on the hedonic scale. Tall spider plant genotypes were most preferred by farmers at 62.6%. The colour of the stem was highly ranked with a mean score of 6.7, 50.5% of the farmers sampled indicated they preferred green stem colour while 49.5% preferred the genotypes with purple stem colour.

The colour of the petiole had a mean score of 6.3 on the hedonic scale while the colour was preferred on an equal basis at 49.5% for both green and purple. Genotypes with green stem-green petiole were more preferred at a 4.6 mean score compared to those with purple stem-purple petiole which had a mean score of 4.3 on a hedonic scale. The least preferred genotypes were those having green stem-purple petiole and purple stem-green petiole at a mean score of 3.4 and 3.3 respectively (Appendix VIII; Table 4.15), because they were perceived to have a mild flavour (smell and taste).

Table 4.16 shows farmer preference for genotypes and fertiliser. To interpret the results, the scores in the table can be matched and compared with their respective keys, thus define their acceptance levels. The values in brackets show the level of data dispersion by the respondents, whereby 1 is the lowest and 4 was the highest. The KII survey revealed that Simlaw genotype was preferred over JKUAT genotype in terms of the number of leaves at all N fertiliser treatments. Nitrogen fertilisers DAP+CAN and manure+CAN had the lowest variability range of 1 under Simlaw genotype on the hedonic scale out of the observed maximum of 4. This lowest range of 1 implied that these two fertiliser treatments had the lowest dispersion, implying that they were clearly distinct: all 15 respondents selected this particular score. Fertiliser DAP+CAN had the highest mean score on the 9-point hedonic scale at 8.87 (Like extremely) while control was 1.0 (Dislike extremely). The results also imply that these two fertilisers had the highest farmer preference. The trend was similar to height apart from manure+CAN, where JKUAT genotype had a mean score of 8.4 (Like very much) against Simlaw genotype at 7.8 (Like very much). Manure+NPK had the lowest range of 1 for height also under Simlaw genotype on the hedonic scale. Simlaw genotype stem and petiole purple colour was preferred over JKUAT across the different fertiliser applications. Simlaw genotype was ranked as an all-purple stem-purple petiole indicating that the genotype did not have a green colour and was not evaluated as such (Table 4.16).

Figure 4.1 shows farmer preference for Simlaw and JKUAT genotypes using 5-point Likert scale. Regarding these two genotypes, 86.7% of famers liked extremely Simlaw genotype compared with 13.3% for JKUAT. However, 66.7% of these farmers like moderately the JKUAT genotype over Simlaw with 33.3%. A total of 15 respondents took part in this KII survey.

Table 4.15: Farmer Preference for Spider Plant Attributes

Variable	**Category**	**Frequency**	**Percent (%)**
Height	Short (<30 cm)	1	1.0
	Medium (30–60 cm)	36	36.4
	Tall (>60 cm)	62	62.6
	N	99	
Number of leaves	A few (≤30)	1	1.01
	More (>30)	98	99.0
	N	99	
Colour of stem	Green	50	50.5
	Purple	49	49.5
	N	99	
Colour of petiole	Green	49	49.5
	Purple	49	49.5
	N	98	

Table 4.16: Spider Plant Farmer Genotype Preference per Treatment

		Mean farmer genotype preference per treatment							
Attribute	**Genotype**	**Manure**	**Manure + CAN**	**Manure+ NPK**	**NPK+ CAN**	**DAP+ CAN**	**DAP**	**NPK**	**Control**
Number of leaves	Simlaw	8.73 (2)	8.73 (1)	8.80 (2)	8.53 (2)	8.87 (1)	6.93 (3)	5.67 (3)	1.00 (0)
	JKUAT	7.80 (3)	8.53 (2)	6.87 (3)	7.80 (3)	6.20 (2)	4.20 (4)	4.27 (4)	1.00 (0)
Height	Simlaw	8.67 (2)	7.80 (2)	8.86 (1)	8.20 (2)	8.47 (2)	4.30 (3)	5.07 (3)	1.00 (0)
	JKUAT	6.80 (3)	8.40 (3)	7.67 (2)	6.33 (4)	7.40 (3)	4.73 (3)	4.40 (3)	1.00 (0)
Stem colour	Simlaw	8.53 (2)	7.33 (3)	8.27 (3)	8.60 (2)	8.67 (2)	8.20 (3)	7.73 (2)	7.33 (2)
	JKUAT	6.33 (3)	8.40 (3)	4.86 (3)	5.33 (3)	5.60 (3)	7.40 (3)	4.27 (3)	5.00 (3)
Petiole colour	Simlaw	7.80 (3)	4.86 (3)	8.27 (3)	8.67 (2)	8.53 (2)	8.53 (3)	7.60 (3)	8.80 (1)
	JKUAT	5.33 (3)	8.40 (3)	5.80 (3)	4.27 (3)	4.26 (3)	5.13 (3)	6.20 (3)	7.67 (3)
Purple stem-	Simlaw	8.73 (2)	8.53 (3)	8.06 (3)	7.93 (3)	8.53 (2)	7.00 (3)	8.00 (3)	7.87 (3)
Purple petiole	JKUAT	6.07 (4)	5.33 (3)	4.27 (4)	7.00 (3)	6.20 (4)	4.80 (3)	7.67 (3)	5.93 (3)
Green stem-	Simlaw	-	-	-	-	-	-	-	-
Green petiole	JKUAT	4.20 (3)	7.07 (3)	6.07 (4)	5.27 (3)	7.93 (3)	3.07 (5)	3.87 (3)	3.13 (3)
Purple stem-	Simlaw	-	-	-	-	-	-	-	-
Green petiole	JKUAT	6.67 (4)	4.20 (5)	5.20 (3)	4.13 (4)	3.33 (3)	5.60 (3)	5.60 (3)	3.33 (3)
Green stem-	Simlaw	-	-	-	-	-	-	-	-
Purple petiole	JKUAT	6.27 (4)	8.00 (3)	4.13 (4)	6.60 (3)	5.26 (4)	3.13 (2)	6.47 (4)	4.53 (4)

Values in parentheses show data range on hedonic scale.

KEY: 1.00 – 1.44= Dislike extremely 3.45 – 4.44= Dislike slightly 6.45 – 7.44= Like moderately

1.45 – 2.44= Dislike very much 4.45 – 5.44= neither like nor dislike 7.45 – 8.44= Like very much

2.45 – 3.44= Dislike moderately 5.45 – 6.44= Like slightly 8.45 – 9.00= Like extremely.

- = No data (Simlaw genotype is all Purple stem-Purple petiole colour)

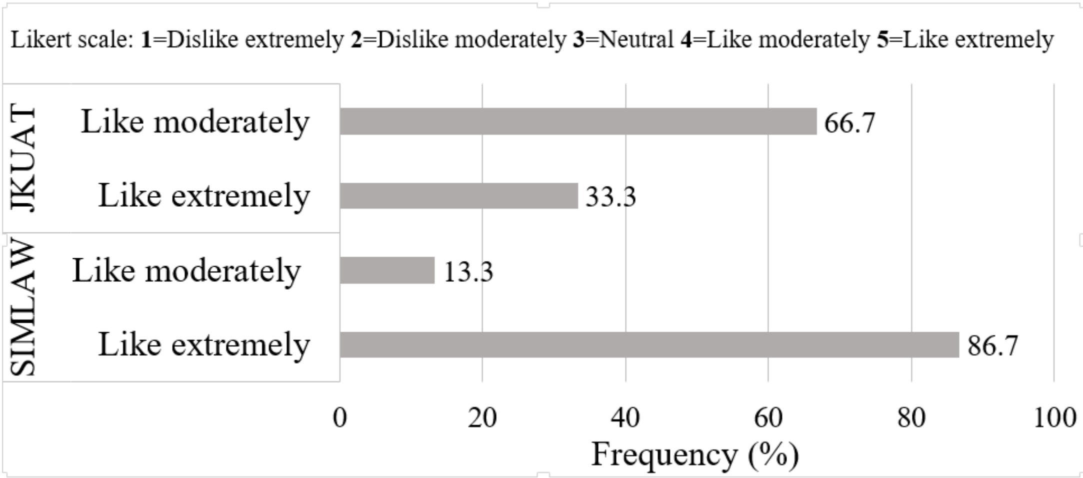

Figure 4.1: Overall Farmer Preference for Simlaw and JKUAT Genotypes

n=15; 7 female, 8 male

CHAPTER FIVE

DISCUSSION

5.1 Effect of N Rates and Nine Genotypes on Growth of Spider Plant in Ruiru

Different N rates and genotypes had different effects on the growth of spider plant that were exhibited in terms of height, number of leaves, leaf area, and days to flower. These attributes were selected and classified as key on the basis of existing literature as well as farmer experiences.

5.1.1 Height

Height is an important trait for erect genotypes in spider plant production because it has a positive correlation to yield (Masinde and Agong, 2007; Ambika, 2014). All eleven genotypes tested in this study were erect: other genotypes may have prostate or spreading growth habit. Genotypes MLSF17, P6, UGSF14, UGSF36, UGSF9 were tallest while IP3, UGSF25 were shortest. Masinde *et al*. (2005) documented that tall genotypes compete more effectively for sunlight than the short ones producing more biomass and yield. By default, MacDonald and Gill (2009) found that tall genotypes form large, vigorous root systems increasing the ability of spider plant to extract rhizosphere N and other nutrients. Related studies conducted on other plant species corroborate this finding that the yield of erect spider plant genotypes is highly influenced by height. For instance, Masinde and Agong (2011) found tall *Solanum nigrum* genotypes have more leaves than shorter ones, translating to a higher leaf area per plant. Additionally, Mboyerwa *et al*. (2022) and Ciftci *et al*. (2004) documented similar results where height was a major factor accounting for high *Oryza sativa* and *Cicer arietinum* yield. This positive plant height association implies that the farmer-preferred medium to tall spider plant genotypes (Table 4.4.2) have a higher potential to yield more than the short ones (Houdegbe *et al*., 2022).

Manure (2.3g N/plant) had the highest plant height while 2.6g N/plant was the lowest. Well-cured, decomposed manure was applied and incorporated in the soil before sowing and performed better than CAN (2.6g and 5.2g N/plant) on growth in height, which could be due to the effects of the resulting humus in the soil. Humus contributed to increased soil organic matter content, which has also been documented to have numerous benefits that promote spider plant growth and development, but does not have immediate effect. Similar results on the merits of manure have been reported by different scientists, such as Ng'etich *et al*. (2012) and Sowunmi and Oyedeji (2019). This observation is also supported by Hutchinson *et al*. (2006) and Mohammed (2020) who found that the presence of humus improves soil texture making it porous, thereby facilitating gaseous exchange in the rhizosphere. Additionally, humus enhances soil water infiltration rates, water holding capacity, and cation exchange capacity which helps buffer soil pH (Yami and Shrestha, 2005). These soil factors play a key role in promoting plant growth in terms of height. A corroborative finding made by Wright and Lenssen (2013) shows that humic substances such as humin, fulvic acid, and humate promote shoot growth by increasing plant height and nutrient uptake. Unlike manure, mineral fertilisers such as CAN are prone to leaching. However, wide variation in the N content of manure is an important shortcoming, thus manure should be analysed to determine adequate quantities before application (Risch *et al*., 2019).

Genotypes MLSF17, P6, UGSF36, and MLSF17, P6, UGSF36, UGSF12, UGSF14, UGSF9 had the highest height in seasons 1 and 2 respectively (Table 4.1.2). In contrast, IP3, UGSF12, UGSF25, and IP3, MLSF3, UGSF25 had the lowest height in seasons 1 and 2 respectively. No prior information on genotype characteristics was provided by the breeder (World Vegetable Centre) as a matter of policy. The significant difference in the height of genotypes in response to the same N application rates is probably due to genetic variations in nitrogen use efficiency (NUE) and/or inherent characteristics among the genotypes. Being the most imperative nutrient for plant growth and development (Leghari *et al.,* 2016), different genotypes possess different genetic abilities (Kiebre, 2017) to utilise N for growth in height: the primary nutrient which constitutes many organic compounds, nucleic acids and protein compounds (Madan and Munjal, 2009; Blalogoe *et al*., 2020). Spider plant height is an important farmer preference attribute having a positive correlation to yield. Growth in height is proportional to N rate, otherwise, spider plant under N deficiency is usually stunted with low yield (Ambika, 2014). This finding was confirmed by Ng'etich *et al*. (2012) and Kujeke *et al*. (2017) who reported that availability of N encourages spider plant stem elongation which is correlated to intense vegetative growth leading to increased yield. This observation was confirmed from this study where medium to tall genotypes yielded more. However, contradictory opinions have been documented by different researchers where height was shown to predispose spider plant to lodging (Gastal *et al.*, 2002; Mutua, 2015). While this argument on spider plant height is believable, it can also be understood in the context of inherent genotype characteristics.

5.1.2 Number of Leaves

The spider plant leaf is the flattened, palmate, green organ that forms the primary site of photosynthesis. Thus, high number of leaves translated to large surface area for photosynthesis that availed the requisite resources for growth and biomass production. The number of leaves is an important attribute for this research since the leaf formed the main spider plant yield component. Holding other factors such as leaf size constant, the genotypes with high number of leaves yielded more and vice versa. In this study, manure had a significantly high plant number of leaves while 2.6 and 5.2g N/plant were low in both seasons. This finding conforms to Ng'etich *et al*. (2012) that adequate manure application increased spider plant growth traits such as the number of leaves. The three N rates (2.3, 2.6, 5.2g N/plant) number of leaves were all significant in season 1 while only manure was significantly different in season 2 with those of both 2.6 and 5.2g N/plant remaining statistically similar (Table 4.1.1). This result implies that higher N rates above 2.6g N/plant were taken up by the plants but luxuriously assimilated without meaningful increase in the number of leaves, being an inherent characteristic. Similarly, there is the possibility that the mineral fertilisers lost more N through leaching unlike manure which is less susceptible (Hutchinson *et al*., 2006).

The leaf is the main component of spider plant yield, thus high farmer preference is given to genotypes with high foliage cover. Studies have shown that adequate N rates produce a high number of leaves because N influences the induction and growth of leaves through its role in cell division, expansion, and elongation (Onyango, 2002; Masinde and Agong, 2011), besides being the primary constituent of chlorophyll which assimilates carbon dioxide through photosynthesis. However, other researchers counter-report that the plant number of leaves is an inherent function which differs among genotypes (Kiebre, 2017; Blalogoe *et al*., 2020), an observation which the findings of this study also conforms with. The trade-off in the number of leaves and their size has been reported (Masinde and Agong, 2011) at given N rates. Accordingly, genotypes might have many but small leaves and low yield, thus not preferred by farmers. High N rates result in more foliage biomass with an appealing dark-green colour. Farmers and consumers have a high preference for genotypes with a high number of large and green leaves as opposed to chlorotic ones growing under N deficiency (Mundua 2010; Croft *et al*., 2014)

Different genotypes had varying numbers of leaves in a given N rate. IP3 had a significantly high number of leaves while MLSF17, P6, UGSF25 and UGSF9 had the lowest number in season 1 (Table 4.1.2). However, genotypes were not significantly different in season 2 probably due to cold weather that slowed mineralisation and metabolic process including N uptake. This observation implies that a given N rate does not directly influence the plant's number of leaves, which is a genetic function that varies from one accession to another (Blalogoe *et al*., 2020). This inference confirms Tang *et al*. (2020) finding that high N application increases plant leaf area mainly by aggregating leaf size through an increased rate of leaf expansion in *Aconitum kusnezoffii*, while the number of leaves remained constant. However, this deduction contradicts Joy-Pearse and William (2011) who documented that application of N also increased the rate of production and number of leaf primordia in *Lolium perenne* and *Festuca arundinacea*, and Mera *et al*. (2009) on *Hibiscus sabdariffa*.

5.1.3 Leaf Area

Leaf area is a measure of leaf size, commonly expressed as leaf blade surface area or leaf length from the leaf apex to the base. Genotypes and N treatments with high leaf area also had high yields, possibly due to their proportionate surface area available for photosynthesis. Results from this study showed that manure had the highest plant leaf area while 2.6g N/plant had the lowest for both seasons. Additionally, the leaf area for manure was statistically different from both 2.6 and 5.2g N/plant (Table 4.1.1). The observation can be probably due to the effect of manure on soil moisture retention in the root zone, compared to CAN. This inference matches with Ng'etich *et al*. (2012) that adequate manure application increased spider plant growth traits such as leaf area. Both rates of mineral fertiliser (2.6 and 5.2g N/plant) were statistically similar in terms of leaf area, implying the additional N above 2.6g N/plant was possibly lost through leaching and plant luxury uptake (Mushamaite *et al*., 2022), thus did not affect the leaf area.

The leaf is the most important organ for plants to transform solar energy into biological energy through photosynthesis. Leaf area affects spider plant biomass production and growth through its role in light intervention and photosynthesis (Masinde *et al*., 2005; Funk *et al*., 2013; Onoda *et al*., 2014). Availability of N results in larger leaf surface areas where more carbohydrate metabolites are synthesised (Madan and Munjal, 2009), and varies among spider plant genotypes because it is a genetic function (Blalogoe *et al*., 2020; Zorde *et al.*, 2020). Smaller leaves are produced when the number and/or size of cells are decreased (Horiguchi *et al*., 2006; Gonzalez *et al*., 2010) as a result of reduced cell multiplication and expansion. Leaf surface area increases with an increase in N rate, which increases plant photosynthetic efficiency. This finding conforms to Conversa and Elia (2019) who documented a significant increase in *Lactuca sativa* biomass due to increasing N rate, and Masinde *et al.* (2009) report that plant biomass increases with N supply in *Solanum nigrum* as long as N remains below phytotoxic rate. Since genotypes with medium to big leaves are highly preferred by farmers due to high yield implications (Onyango 2013), an increment in the leaf area can lead to increased leaf biomass (Huang, 2019).

Different genotypes respond differently to N rates, probably due to variations in NUE as influenced by genetic code and environment. Application of 5.2g N/plant predisposes spider plant to N luxury uptake and ultimate phytotoxicity. Excessive N application delays spider plant physiological maturity (Zhang *et al*., 2021), and results in plush plants with soft tissues susceptible to lodging (Gastal *et al.*, 2002; Mutua, 2015). In contrast, N phytotoxicity is manifested by a decreased growth rate, stunted root systems and smaller necrotic leaves, and possible plant necrosis (Palada *et al*., 2005).

In a related study, Lemaire *et al*. (2005) and Tang *et al*. (2020) showed a positive linear correlation between shoot N composition and leaf area in *Medicago sativa* and *Aconitum* spp respectively, irrespective of the growing environmental conditions.

5.1.5 Yield

Yield is the harvestable weight of spider plant tissues and organs which includes leaves, tender stems, flowers and petioles, either measured per plant or unit land area. In this study, the yield level per plant varied significantly depending on N rate and form applied as well as genotype grown. Genotypes also responded differently in terms of yield to the varying N rates and forms depending on their NUE level. In this study, there was no significant difference in yield among the three N rates (2.3, 2.6, 5.2g N/plant) in season 1. However, the yield for manure (2.3g N/plant) was significantly different compared to those of 2.6 and 5.2g N/plant in season 2 (Table 4.1.3). Manure applied in adequate amounts contains an appreciable potassium content that positively impacts NUE which augments photosynthesis (Derossia *et al.*, 2008; Han *et al*., 2016; Appendix 9). The fact that there was no significant difference between 2.6 and 5.2g N/plant might be an inference that the extra N above 2.6 g was probably wasted by leaching and plant luxury uptake since it did not affect yield.

During the experiment period in 2011 and 2012, the total rainfall for season 1 was 256 mm while season 2 was 543 mm respectively. The difference of 287 mm between the two crop seasons is a significant amount of rainfall considering that the spider plant is an AEZ III crop and drought-sensitive (Masinde and Agong, 2011). Season 2 yield was more than 2-fold that of season 1 partly because more rainfall (287 mm) was received, and the soil moisture was optimum for N uptake. Under these optimum conditions in season 2, manure was possibly more exhaustively mineralised, thus releasing N more efficiently for spider plant uptake (Risch *et al*., 2019).

Different spider plant genotypes under the same N application rates had significantly different yields for both seasons. The highest yields were recorded for MLSF17, P6, UGSF14, UGSF25, UGSF36 and MLSF17, MLSF3, P6, UGSF9 for season 1 and 2 respectively (Table 4.1.4). The high yield difference among genotypes results from the fact that these genotypes have optimal NUE: the ability of different genotypes to absorb, assimilate and utilise soil N for maximum yields, and are categorised as low, optimal and excessive. The lowest yields were harvested for IP3, MLSF3, UGSF12, UGSF9 and IP3, UGSF12, UGSF14, UGSF25, UGSF36 for seasons 1 and 2 respectively (Table 4.1.4). Thus, these genotypes have comparatively low NUE (Leghari *et al*., 2016; Gong *et al*., 2020).

This study sought to improve NUE by recommending spider plant production best fertiliser management practices. These include climate-smart approaches that reduce N losses in terms of over-application and greenhouse gas emissions (Roberts, 2008; Leghari *et al*., 2016; Haroon *et al*., 2019) in spider plant farming. Split N application enhances NUE by reducing losses due to leaching, volatilisation and denitrification (Madan and Munjal, 2009; Singh, 2010). Consequently, the mineral fertilisers — DAP and NPK — performed as well as the manure when top-dressed with CAN (Table 4.1.1).

5.2 Effect of Fertiliser and Genotypes on Spider Plant Growth in Juja

Different N rates and fertilisers had different effects on the growth and yield of spider plant genotypes, which manifested in terms of height, number of leaves, and days to flower.

5.2.1 Height

The findings of this study showed that spider plant height was significantly dependent on manure and CAN as opposed to DAP, NPK, and control. These minerals such as phosphorous and potassium have different roles in spider plant growth, and it may be inaccurate to indicate that the crop did not depend on those nutrients. Nonetheless, the context of this study is that N enhances harvestable leaf biomass. Manure had the tallest height (Table 4.1.5) compared to DAP and NPK probably due to the presence and influence of humus on soil organic matter, structure and moisture conservation (Ng’etich *et al*., 2012; Mohammed, 2020; Makaza *et al*., 2022). This finding agrees with Hutchinson *et al*. (2006), Mauyo *et al*. (2008), and Love (2014) who reported that manure is less prone to leaching and available for plant uptake longer than mineral fertilisers if applied in adequate quantity. There was a reduced growth rate for height possibly because DAP and NPK N amount applied at sowing was dwindling 42 DAS due to spider plant uptake and losses such as leaching. Thus, to achieve high yields, DAP and NPK required top dressing by CAN to perform more or less like manure (Table 4.1.2).

Both Simlaw and JKUAT genotypes showed high responses to manure and CAN, thereby underscoring the significance of NUE when the N application is split. It is documented that top-dressing CAN as a split application of N significantly enhances NUE (Madan and Munjal, 2009; Singh, 2010). Genotypes performed better under adequately applied manure because it is a source of multiple nutrients ranging from major, minor, and trace elements, namely; N, P, K, Ca, Mg, Na, Mn, Fe, Al, Zn, Cu (Han *et al*., 2016; Appendix 9). Manure increases soil organic carbon and total N when continuously added to the soil (Kim *et al.*, 2011), thus improving soil fertility, nutrient use efficiency, and plant productivity. Manure breaks down slowly releasing nutrients over an extended time, and it is less susceptible to N denitrification, leaching and/or volatilisation compared to CAN, DAP, and NPK (Ng'etich *et al*., 2012). Nonetheless, mineral fertilisers are preferred by spider plant farmers since they are fast-acting and less bulky to handle (Love, 2014; Mushamaite *et al*., 2022). Lastly, manure-humus promotes soil life and health by enhancing the activity of beneficial organisms and microbes (Schoenau, 2006) for instance, nitrifying bacteria, and mitigating climate change (Mushamaite *et al*., 2022).

5.2.2 Number of Leaves

In this study, the number of leaves per plant differed among spider plant genotypes produced under the same N rate but different fertiliser forms. Genotype Simlaw had a significantly higher number of leaves per plant compared to JKUAT with 61.20 and 53.80 respectively (Table 4.1.7). The number of leaves is a genetic function (Kiebre, 2017), but it is also influenced by the environment (Mera *et al*., 2009; Joy-Pearse and William, 2011; Blalogoe *et al*., 2020; Tang *et al*., 2020). In a study on different spider plant genotypes by Love (2014), manure outperformed mineral fertiliser treatments in plant height and leaf yield. However, this study confirmed that DAP and NPK top-dressed with CAN performed as well as manure as a result of improved NUE (Table 4.1.2). This is confirmed because manure, DAP, DAP+CAN, manure+CAN, manure+NPK, and NPK+CAN had the highest number of leaves. This finding agrees with Makaza *et al*. (2022) that adequate manure N application remains available for spider plant uptake for a longer period since it is less prone to environmental loss. A similar longevity effect is also achieved when N is applied in splits (Madan and Munjal, 2009).

5.2.3 Days to Flower

The results revealed that N rates had a major influence on the timing of spider plant flowering. Additionally, the effect of different fertilisers varied significantly in terms of days to flower for both seasons. The highest number of days to flower were recorded for DAP+CAN and manure+CAN, but there was no significant difference between genotypes JKUAT and Simlaw. Genotypes flower earlier or later depending on the N rate and fertiliser form applied (Wangolo *et al*., 2015). Timing and intensity of flowering is an important physiological process marking the end of the vegetative phase and setting in the reproductive stage with a significant reduction in leaf production (Kriedemann *et al*., 2010; Wangolo *et al*., 2015). High N application delays anthesis in spider plant and vice versa, thus leading to higher yield (Mutua, 2015). This observation conforms to Zhang *et al*. (2021) who showed that high N application for yield optimisation in *Oryza sativa* leads to postponed flowering time. In this study, genotypes JKUAT and Simlaw exhibited an equal response to N fertilisers, and it can be deduced that both genotypes have a statistically similar NUE (Table 4.1.9).

In this study, the control flowered 14 – 16 days earlier than CAN (Table 4.1.10). However, manure and CAN took the longest duration to flower because of the continuous N availability for the genotypes uptake, hence minimising N deficiency stress (Makaza *et al*., 2022). Bolting is a function of N stress that transforms immature spider plant into the reproductive phase for the species' survival (Pingping *et al*., 2017). Spider plant is highly susceptible to bolting when exposed to N stress, flowering at the expense of yield as manifested in this study for control, DAP and NPK. Probably DAP and NPK underwent N losses during the early stage of spider plant growth due to leaching (Makaza *et al*., 2022). Spider plant is prone to bolting which is undesirable because it causes yield loss (Wangolo *et al*., 2015). Nitrogen is used for amino acid and protein synthesis (Madan and Munjal, 2009; Huffman, 2020), thus delaying bolting when applied at adequate rates. Nonetheless, different spider plant genotypes have varying responses to N stress which predisposes them to bolt. Thus, the new spider plant genotypes are highly preferred by farmers if late flowering to prolong the harvest duration (Ng'etich *et al*., 2012; Mutua, 2015).

Interaction is an important concept of data analysis whose presence or absence is essential for accurate data interpretation. Results showed that the effect of the interaction of fertilisers and genotypes was significant on plant height in season 1, but not season 2, and it was not significant on number of leaves and days to flower in both seasons (Table 4.1.11). This interaction on plant height implies that the conflated effect of genotypes and fertilisers is greater when these two independent variables act together (Gonzalez and Cox, 2007). It can also be deduced that these genotypes and fertilisers would have a statistically similar effect on the number of leaves and days to flower whether combined or applied independently (Wang *et al*., 2011).

5.3 Genotype Preference Surveys

In this survey, farmers and consumers had varying preferences for spider plant which were in turn influenced by their household characteristics as well as the genotype attributes. Preference referred to the making of food choices based on what one enjoyed most, and found most satisfying, affordable, and healthy based on body needs and desires (Tuorila *et al*., 2008; Vabø and Hansen, 2014; Musotsi, 2017). Thus, these preferences are the primary determinants of dietary intake and behaviour (Croft *et al*., 2014; Nair and Maram, 2014; Spence, 2015; Gido *et al*., 2017). In this context, preference entails spider plant attributes, recipes, visual, and sensory (smell and taste) when cooked and fresh or dried.

5.3.1 Consumer Preference

5.3.1.1 Household Characteristics

Socio-economic characteristics of household decision makers were key determinants influencing preference for nitrogen and genotypes in Kiambu County. The results of this study showed that age, income and education are key determinants of choice across the households sampled (Table 4.4.1). There was positive response with higher level of education in the sampled population understood the benefits of spider plant consumption while those with income afforded to purchase it whenever they desired to do so. Similar results to these were reported by a number of researchers including Mundua (2010) and Tukei *et al*. (2022). This survey revealed that most consumers were aged 42–71 years, and 45% of respondents had a higher education level of diploma plus. Additionally, 37.12% of them had an income of KES 30,000 – 50,000 per month. This finding on age of consumers agrees with most studies that have linked spider plant consumption with the increase in age, especially the middle class, who are literate and who have interacted with it for a long time and are fully aware of its health benefits and can afford it (Okeno *et al*., 2003; Uusiku *et al*., 2010). Results show that spider plant consumption in the urban and peri-urban areas is becoming a preserve of the rich (Mwangi and Kimathi, 2006; Masinde and Agong, 2011) because households of five members for instance, earning less than KES 10,000 monthly would strain to buy 1.0 kg retailing up to KES 80 off-season.

This survey also established that most consumption was by women at 53% and men 47%, noting that it is nearly mandatory to feed on spider plant when expectant (Mundua, 2010; Odendo *et al*., 2023). This inference agrees with the various studies cited, where spider plant is highly recommended for expectant and lactating mothers (Amaza, 2009; Chelang'a *et al*., 2013; Senyolo *et al*., 2014). Eating this vegetable is also considered a stimulant which reduces dizziness and nausea during pregnancy (Riang'a *et al*., 2017).

5.3.1.2 Spider Plant Attributes

Results of this study confirmed that consumers highly consider spider plant freshness before making their purchase choices compared to the preserved leaves. (Table 4.4.2). This observation was attributed to the perception that fresh leaves contain more nutrients in their natural and raw form than their preserved counterparts. Consumers also preferred tasty spider plant because they were appetizing with a high sensory quality. Consumers preferred the green leaves of spider plant compared to purple leaves. This is so because, according to a follow-up discussion, the green leaf colour is commonly perceived to be fresher and richer in vitamins (Mushamaite *et al*., 2022). Spider plant with large leaves was highly preferred compared to those with small leaves since large leaves are heavier and likely to yield more. Leaf texture had the least ranking score compared with all the other attributes that were evaluated. Nevertheless, 37% of consumers preferred spider plant with rough leaves unlike the smooth ones because they have matured and are strong-flavoured (Musotsi, 2017).

5.3.1.3 Recipe Preference

The outcome of this survey revealed that consumers had preferences for different spider plant recipes. Consumers preferred the spider plant plus amaranth recipe, with an average score of 8.28 on the 9-point hedonic scale. Similarly, the mixture of spider plant and milk was highly preferred with a ranking average of 8.04. The least ranked recipe was spider plant plain, with an average score of 1.6. (Table 4.4.3). Compared to the plain spider plant recipe, the added ingredients such as milk and peanut enhanced the vegetable's visual attributes and flavour besides its nutritional status, thus the high consumer preference.

The current study evaluated three recipes that possessed three key food preference attributes – texture, appearance, and flavour (aroma and taste) (Table 4.4.3). Rough leaf texture or chewiness was preferred over smooth one probably because roughness is associated with maturity. Mature spider plant has adequate fibre that aids digestion and most phytochemicals that boost flavour (Belitz *et al.*, 2009) are optimal. This high fibre content in leaves enables farmers to dry and preserve them more effectively (Kimiywe *et al.*, 2008).

Cooked spider plant appearance is critical concerning consumer preference considering that most consumers only buy food that they are familiar with, and their visual appeal influences their choices (Nair and Maram, 2014; Vabø and Hansen, 2014). Low spider plant consumption is attributed to limited information on recipe preparation (Habwe *et al.*, 2010; Musotsi, 2017), which is exacerbated by Teherani-Krönner (2011) finding that food preparation is perceived as commonplace thus, cannot be considered a scientific research problem. Kimiywe (2007) and Gido *et al.* (2017) found that more people are willing to consume spider plant if informed on preparation and cooking techniques.

Spider plant consumers prefer milk added or combined with other vegetables like amaranth and *Solanum nigrum* to neutralise bitterness by making it taste milder

(Abukutsa, 2007; Vorster *et al*., 2007; Musotsi, 2017) and enhance flavour (Belitz *et al*., 2009) since the plain serving is bitter-tasting and not appealing to the consumers (Sharafi *et al*., 2014; Adeka, 2020). However, some consumers appreciate the bitter aftertaste and prefer eating them as such (Mauyo, 2008; Musotsi, 2017).

Peanut ingredient contains many beneficial compounds and nutrients such as proteins, polyphenols, fibres, antioxidants, minerals and vitamins. Thus, it is added as an ingredient to many types of foods to harness these benefits (Arya *et al*., 2016). This inference on ingredients agrees with Abukutsa (2007) who reported that the spider plant is usually mixed with other vegetables like *Vigna unguiculata*, *Ocimum basilicum* and/or *Solanum nigrum* for improved palatability and nutrition composition. Plain spider plant was the least preferred recipe possibly due to its perceived low sensory quality and visual appeal, low nutritional content and bitter taste (Adeka, 2020). It also appears brown similar to over-cooked vegetables, thus may not be as delectable to most consumers.

5.3.2 Farmer Preference

The study established farmer preference attributes for spider plant. The preferred attributes by farmers were expected to guide breeders on the breeding traits on genotypes of relevance.

5.3.2.1 Spider Plant Attributes

This survey showed that socio-economic characteristics of farmers are important before, during and after varietal release. This is important since the adoption of new spider plant genotypes by farmers would be influenced by their socio-demographic characteristics. This inference also conforms to the finding by Bett *et al*. (2011) and Muhanji *et al*. (2011) who studied the hedonic pricing model in agricultural and indigenous vegetable value chains in Kenya. Farmers are the first users of the newly developed genotypes, thus have a direct link to consumers; hence hold vital information on which attributes the consumers prefer in spider plant.

Gender influenced the production and consumption of spider plant at the household level. From these results, more women were involved in decision-making on spider plant farming at 53% as opposed to 47% of the men (Table 4.4.4). This result conforms to the findings of Abukutsa-Onyango (2009), Mundua (2010) and Odendo *et al*. (2023) that most spider plant farming activities and consumption decisions are executed by women. Another finding that most spider plant farmers fell under the adult age bracket could be justified by land ownership. Generally, few youth are likely to own land and those who own may not be interested in farming spider plant (Okeno *et al*., 2003). Among the farmers, 72% were married, thus the obligation to produce food to feed their families and generate income (Uusiku *et al*., 2010; Musotsi, 2017; Odendo *et al*., 2023). Most of these farmers are experienced spider plant growers, who have adequate indigenous technical knowledge of agronomy, varietal traits, medicinal uses and preservation (Achiando *et al*., 2013).

Farmers had preferences for different spider plant genotypes based on various traits. The number of leaves, size, and height were ranked highly by farmers since both have a positive correlation to yield (Masinde and Agong, 2007; Ambika, 2014) (Table 4.4.5). Regarding stem and petiole colour, these pigments are anthocyanins also known to have significant health benefits (Onyango *et al.*, 2014).

Genotypes had varying preferences among farmers based on different traits. The genotype Simlaw was highly preferred over JKUAT genotype by farmers in Juja because it had bigger and more uniform plants with an appealing purple stem and purple petiole colour (Figure 4). This observation agrees with Nair and Maram (2014) and Spence (2015) that spider plant colour and size influence farmer and consumer preferences. Manure and CAN were the most preferred N fertiliser forms that had the biggest plants with the most uniform height, leaf size, and were late flowering.

5.4 Study Challenges and Limitations

There were several challenges encountered during this study, as follows;

i. Low seed germination rate - There was less than 50% germination for the JKUAT genotype. Germination was even lower for the genotypes sourced from the Gene Bank of Kenya (GBK). The implication is that a high seed rate is required to attain the desired 30 plants/m^2 density, which is a significant challenge where seed availability is limited.

ii. Erratic weather aggravated by climate change - Rainfed season 1 in Ruiru received 256 mm of rainfall down from the expected 400 mm. Consequently, there was a significant loss in yield of more than 2-fold compared to season 2.
iii. There were limited cases of pests: *Tetranynchus urticae*, *Myzus persicae* and termites infestation that was below the economic threshold. However, they were managed accordingly by spot-application of a miticide and insecticide respectively.
iv. Biased feedback from three respondents during surveys - Outlier questionnaires were discarded after data validation with reference to MoA data. From the literature review, such anomalies were expected and was addressed by having five extra questionnaires separately for consumer and farmer surveys.
v. Seed and Plant Varieties Act (2012) of Laws of Kenya prohibiting farmers from trading or sharing indigenous vegetable seed. It is stipulated that farmers shall only plant certified, hybrid spider plant seeds sourced from registered agro-dealers.

Besides these challenges, there are factors expected to limit the application of the results of this study results. These include;

i. Location/AEZ - Besides representing Kiambu County, these results are also expected to apply in the entire AEZ II and III, the latter AEZ being the natural spider plant habitat. Locations outside these AEZs would possibly limit the application of these results.
ii. Soil type - The results are expected to apply to vertisols or any other soil types with similar physical and chemical characteristics. Different soil types would be expected to limit the application of these results.
iii. Irrigation/rainfed - Due to unpredictable rainfall patterns, rainfed production can limit the application of these results as opposed to farming under irrigation.
iv. Genotype characteristics and seed availability - The genotypes in this study are expected to perform the same way under a similar growing environment.

However, apart from JKUAT and Simlaw genotypes, seed availability for the new genotypes is limited and can be accessed at the GBK.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

This study evaluated the performance of spider plant genotypes produced under different N rates and forms with regard to growth, yield and preference among farmers and consumers in Kiambu County. Thus, besides possessing high-yielding attributes, these recommended genotypes are also the ones preferred by farmers and consumers. It is noteworthy that some of these genotypes manifested desirable traits such as yield, which competed favourably with the control. Nonetheless, high genotypic and phenotypic variation among the two seasons insinuates that the genetic structure of these genotypes is still changing and they are genetically unstable.

6.1 Conclusion

Nitrogen rates and forms significantly affect the growth parameters of spider plant genotypes. Application of 2.3 g N/plant manure significantly increased growth and yield compared to 2.6 g and 5.2 g N/plant. Nonetheless, where farmers want to use CAN or cannot access adequate manure, they apply no more than 2.6 g N/plant. Manure, Manure+CAN, Manure+NPK, DAP+CAN, and NPK+CAN were superior and most preferred by farmers compared to DAP and NPK stand-alone. The fertiliser combinations had superior height, number of leaves, and highest days to flower.

Genotypes MLSF17, P6, UGSF14, UGSF36 and UGSF9, treated with (i) above had the highest relative plant height, leaf area, and yield compared to other genotypes. These findings also conform to the farmer survey results in Ruiru for these five genotypes vis-à-vis the number of leaves, height, and colour. There is a positive correlation between plant height, number of leaves, leaf area, and yield. Spider plant recipes with milk, amaranth and peanut were highly preferred compared to their plain counterpart. Concerning the genotypes, Simlaw is highly preferred by farmers compared to JKUAT.

6.2 Recommendation

Considering the findings of this study, there may be no sufficient evidence to conclusively release the genotypes as varieties because of distinct-unique-stable (DUS) and national performance trials (NPT) requirements. However, it is recommended that genotypes MLSF17, UGSF14, UGSF36 and UGSF9, undergo the next step of variety release test for production in Kiambu County, using fertiliser combination in 6.1 (ii) above, at the rate of 2.3 – 2.6g N/plant, and grow the genotype Simlaw over the JKUAT. Further studies are also recommended to conclusively confirm the findings of this project.

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APPENDICES

Appendix I: Number of Spider Plant Accessions in Kenya

No	Genus	Species	District of collection	Number of accessions	Year of collection
1	Cleome	gynandra	Baringo	5	1992; 1994; 1995
2	Cleome	gynandra	Bomet	1	1993
3	Cleome	gynandra	Busia	24	1991; 1992; 2004
4	Cleome	gynandra	Butere-Mumias	1	2004
5	Cleome	gynandra	Elgeyo Marakwet	5	1990; 1994; 1995
6	Cleome	gynandra	Homa Bay	1	2000
7	Cleome	gynandra	Kakamega	1	1995; 2004
8	Cleome	gynandra	Kericho	3	1992
9	Cleome	gynandra	Kiambu	2	2001
10	Cleome	gynandra	Kilifi	3	1992; 2001
11	Cleome	gynandra	Kisii	2	1991; 2001
12	Cleome	gynandra	Kisumu	5	2001; 2002; 2014
13	Cleome	gynandra	Kitui	1	1990
14	Cleome	gynandra	Koibatek	1	1995
15	Cleome	gynandra	Laikipia	2	1994
16	Cleome	gynandra	Lugari	1	2004
17	Cleome	gynandra	Makueni	1	1992
18	Cleome	gynandra	Marsabit	1	2006
19	Cleome	gynandra	Meru	1	2014
20	Cleome	gynandra	Migori	2	2000; 2014
21	Cleome	gynandra	Msabweni	1	2013
22	Cleome	gynandra	Nandi	1	1992; 1995
23	Cleome	gynandra	Narok	1	1993
24	Cleome	gynandra	Nyamira	39	2013
25	Cleome	gynandra	Siaya	10	1991; 2001; 2004;2014
26	Cleome	gynandra	Suba	1	2000
27	Cleome	gynandra	Tana River	1	1995
28	Cleome	gynandra	Trans Nzoia	1	1991
29	Cleome	gynandra	Uasin Gishu	3	1992; 1995
30	Cleome	gynandra	Vihiga	6	2001; 2004
31	Cleome	gynandra	West Pokot	1	1992
Total Accessions collected				128	

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22/08/2019.

Ndungu Kirai.

Appendix II: Nutritional And Chemical Composition of *Cleome gynandra* Leaves (% or mg/100 Edible Parts)

Nutrient	Range of values
Moisture content (%)	81.8 - 89.6
pH	5.8
Crude protein (%)	3.1 - 7.7
Crude fibre (%)	1.3 - 1.4
Carbohydrates (%)	4.4 - 6.4
Ether extract (%)	0.4 - 0.9
Total ash (%)	2.1 - 3.0
Potassium (mg)	410
Calcium (mg)	213 - 434
Magnesium (mg)	86
Sodium (mg)	33.6
Phosphorus (mg)	12
Iron (mg)	1 - 11
Zinc (mg)	0.76
Copper (mg)	0.46
β-carotene (mg)	6.7 - 18.9
Ascorbic acid (mg)	127 - 484
Oxalate (mg)	8.8
Total phenolics (mg)	520 - 910

Appendix III: Kenyan Dried ALVs at a Grocery Outlet at Kent, England

Appendix IV: Key Descriptors for C. gynandra

Gynandropsis gynandra	
Days to emergence	4-8
Seedling vigour	very strong - very weak
Days to 50% flowering	17 - 35
Plant type	erect - semi-erect
Plant height (cm)	25-71
Stem colour	green - red
Stem pubescence	glabrous - abundant
Stem diameter (cm)	1.0 - 3.8
Branching habit	upright - spreading
Primary branches (no.)	2-7
Leaf colour	green - brown
Leaf pubescence	glabrous - abundant
Leaf length (cm)	1.7 - 6.6
Leaf width (cm)	0.8 - 2.2
Disease susceptibility	medium - resistant
Pest susceptibility	medium - resistant
Lodging	none - nearly 100%
Flowering tendency	low - high
Position of fruit	top - throughout
Fruit length (cm)	6.4-11.1

Source: AVRDC, 2008

Appendix V: Questionnaire for Farmers

The general objective of this research is to determine farmer preferences towards spider plant in Ruiru Subcounty, Kiambu County. The information gathered from this survey will be treated with highest level of confidentiality. The information from this study will inform other stakeholders and inform the process of policy development concerning spider plant seed selection, production and marketing in Kiambu County.

SECTION A: GENERAL INFORMATION

Questionnaire No………………………..

1. Name of enumerator……………………………………………………………………….
2. Date …………………………………
3. Gender of the respondent

Male ☐ Female ☐

SECTION B: HOUSEHOLD CHARACTERISTICS

4. Please fill the table below relating to the respondent.

Age of respondent in years	**Marital status** 1) Married 2) Single 3) Widow/ widower 4) Other Specify)…	**Highest level of education.** 1) No formal education 2) Primary 3) Secondary 4) Diploma 5) Degree 6) Post-graduate 7) Others (Specify)…	**Relationship to the household head.** 1) Son 2) Daughter 3) Father 4) Sister 5) Others	**Household size** (indicate the total number of members in the household)	**Monthly income (Ksh)** 1) No income 2) Less than 10,000 3) 10,001 – 20,000 4) 20,001 – 30,000 5) 30,001 – 40,000 6) 40,001 – 50,000 7) 50,001 – 60,000 8) Above 60,001

1 of 3

5. (a) Do you own land?

☐ Yes ☐ No

(b) Which type of ownership?

Leasehold ☐ Freehold ☐ Communal ☐ Others ☐

(c) What is the land size in acres? …………

SECTION C: SPIDER PLANT ATTRIBUTES

6. For how long have you been growing spider plant?

☐ Three months ☐ Six months ☐ One year ☐ More than two years

7. At what price do you sell one kilogram of spider plant (Ksh)? ....

8. Indicate by a tick your attributes of preference when selecting spider plant accessions/varieties for planting in the table below and rank them in order of importance using a scale of 1 – 9, where;

1=Dislike extremely, 2=Dislike very much, 3=Dislike moderately, 4=Dislike slightly, 5=Neutral, 6=Like slightly, 7=Like moderately, 8=Like very much, 9=Like extremely.

ATTRIBUTE	**Preference (indicate by ticking √)**	**RANKING SCORE**								
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Height										
Number of leaves										
Colour of stem										
Colour of Petiole										

9. Indicate your preferred attribute parameters for the spider plant accession for planting.

Attribute	**Preferred attribute parameter**		
Height	☐ Short	☐ Medium	☐ Tall
Number of leaves	☐ A few	☐ Moderate	☐ More
Colour of stem	☐ Green	☐ Purple	☐ Any other.
Colour of petiole	☐ Green	☐ Purple	☐ Others…..

10. The information below relates to various accessions/varieties of spider plant. Indicate your level of preference for each accession/variety described below using the five point Likert scale, where;

    1=Least preferred, 2=Moderately preferred, 3=Neutral, 4=highly preferred 5=Most preferred**.**

SPIDER PLANT ACCESSION DESCRIPTION	**PREFERENCE RATING SCALE**				
	1	2	3	4	5
Green stem _Green petiole					
Green stem _ Purple petiole					
Purple stem_ Green petiole					
Purple stem_ Purple petiole					

3 of 3

Appendix VI: Questionnaire for Consumers

The general objective of this research is to determine the consumer preferences towards spider plant in Ruiru Subcounty, Kiambu County. The information gathered from this survey will be treated with highest level of confidentiality. The information from this study will inform other stakeholders and inform the process of policy development concerning spider plant seed selection, production and marketing in Kiambu County.

SECTION A: GENERAL INFORMATION

Questionnaire No………………………..

1. Name of market……………………..

   County………………………………… Subcounty…………………………………..

2. Name of enumerator……………………………………………………………………..
3. Date ……………………………………
4. Gender of the respondent

   Male ☐ Female ☐

SECTION B: HOUSEHOLD CHARACTERISTICS

5. Please fill the table below relating to the respondent.

Age of respondent in years	**Marital status** 1) Married 2) Single 3) Widower/ widow 4) Other (specify)…	**Highest level of education.** 1) No formal education 2) Primary 3) Secondary 4) Diploma 5) Degree 6) Post graduate 7) Others (specify)…..	**Relationship to the household head.** 1) Son 2) Daughter 3) Father 4) Sister 5) Others	**Household size** (indicate the total number of members in the household)	**Monthly income (Ksh)** 1) No income 2) Less than 10,000 3) 10,001 – 20,000 4) 20,001 –30,000 5) 30,001 – 40,000 6) 40,001 – 50,000 7) 50,001 – 60,000 8) above 60,001

1 of 4

6. (a) Do you own land?

☐ Yes ☐ No

(b)Which type of ownership?

Leasehold ☐ Freehold ☐ Communal ☐ Others ☐

(c) What is the land size in acres? …………

SECTION C: SPIDER PLANT ATTRIBUTES

7. (a) When did you last purchase spider plant?

☐ Today ☐ This week ☐ Last week ☐ Last month

☐ Others (specify)………

8. How often do you purchase spider plant?

☐ Daily ☐ Weekly ☐ monthly ☐ yearly ☐ others (specify)……

9. What is the price of spider plant per kg that you have just bought (Ksh)? ....

10. Indicate by a tick your attributes of preference when buying spider plant in the table below and rank them in order of importance using a scale of 1 – 9, where;

1=Dislike extremely, 2=Dislike very much, 3=Dislike moderately, 4=Dislike slightly, 5=Neutral, 6=Like slightly, 7=Like moderately, 8=Like very much, 9=Like extremely.

ATTRIBUTE	Preference (indicate by ticking √)	RANKING SCORE								
		1	2	3	4	5	6	7	8	9
Texture										
Size of leaves										
Colour of leaves										
Freshness										
General appearance										
Aroma										
Taste										

11. Indicate your preferred attribute parameters for the spider plant while purchasing.

Attribute	Preferred attribute parameter		
Leaf texture	☐ Smooth	☐ Rough	
Size of leaves	☐ Small	☐ Medium	☐ Large
Colour of leaves	☐ Green	☐ Purple	☐ Any other.
Freshness	☐ Fresh	☐ Preserved	☐ Others…..

SECTION D: **PREFERENCE FOR RECIPES**

Indicate your level of preference for the following recipes of spider plant using the scale below, where; 1=Dislike extremely, 2=Dislike very much, 3=Dislike moderately, 4=Dislike slightly, 5=Neutral, 6=Like slightly, 7=Like moderately, 8=Like very much, 9=Like extremely.

RECIPE	RANKING SCORE								
	1	2	3	4	5	6	7	8	9
Spider plant plain									
Amaranth + spider plant + ground nut									
Spider plant + milk									

12. Indicate your level of agreement on the following perceptions about spider plant.

Factor	1 Strongly disagree	2 Disagree	3 Neutral	4 Agree	5 Strongly agree
1) Spider plant leads to hunger and poverty alleviation					
2) Spider plant offers employment opportunities to rural communities					
3) Market demand for spider plant has positive impacts on rural economy					
4) Spider plant cultivation leads to food security					
5) Spider plant leaves do not carry any chemical residues					
6) Consumption of spider plant reduces chronic diseases					
7) Spider plant do not contain GMOs					
8) Spider plant is nutritionally rich.					
9) I care about knowing the source of spider plant					

13. Where do you get information concerning spider plant?

☐ Radio ☐ TV ☐ Newspaper ☐ Internet ☐ Farmers/friends ☐ others (specify).

14. (a) Is the consumption of spider plant associated with special occasions in the family?

☐ Yes ☐ No

(b) If yes, specify the occasions……………………………………………

Appendix VII: Consumer Ranking of Spider Plant Attributes in Ruiru

VARIABLE	MIN	MAX	MEAN	STD ERROR	CONFIDENCE INTR	
Leaf texture	4	9	7.0408	0.1094	6.8236	7.2580
Size of leaves	6	9	8.0612	0.0868	7.8889	8.2335
Colour of leaves	6	9	8.2653	0.0840	8.0985	8.4320
Freshness	6	9	8.5816	0.0724	8.4379	8.7253
General appearance	7	9	8.7551	0.0482	8.6593	8.8504
Aroma	5	9	7.4285	0.1085	7.2131	7.6440
Taste	6	9	8.2857	0.0794	8.1280	8.4433

Appendix VIII: Farmer Ranking of Spider Plant Attributes in Ruiru

VARIABLE	MIN	MAX	MEAN	STD ERROR	CONFIDENCE INTR	
Number of leaves	7	9	8.9325	0.0311	8.8706	8.9944
Height	7	9	8.4044	0.0727	8.2599	8.5490
Colour of stem	5	9	6.7415	0.1017	6.5394	6.9437
Colour of petiole	3	9	6.3146	0.1407	6.0348	6.5943
Green stem-Green petiole	3	5	4.5730	0.0595	4.4546	4.6913
Green stem-Purple petiole	2	5	3.3595	0.0802	3.1999	3.5191
Purple stem-Green petiole	2	5	3.2921	0.0817	3.1295	3.4546
Purple stem-Purple petiole	3	5	4.3483	0.0670	4.2132	4.4834

Appendix IX: Cattle Manure Nutritional Composition

Chemical properties	Concentrations
pH (-Log[H$^+$])	6.6 (0.5)
Organic matter (%)	30.3 (0.2)
Total N (g kg^{-1})	9.4 (1.6)
P (mg kg^{-1})	5.0 (0.1)
K (cmol$_c$ kg^{-1})	7.7 (0.5)
Ca (cmol$_c$ kg^{-1})	20.1 (0.1)
Mg (cmol$_c$ kg^{-1})	3.8 (0.1)
Na (cmol$_c$ kg^{-1})	1.4 (0.1)
Mn (mg kg^{-1})	494.1 (24.5)
Fe (g kg^{-1})	1.6 (0.1)
Al (g kg^{-1})	3.5 (0.1)
Zn (mg kg^{-1})	174.3 (8.1)
Cu (mg kg^{-1})	32.9 (0.7)
EC (mS m^{-1})	47.3 (13.1)

Source: Han *et al*., 2016